Targeted Arsenic and Uranium Public Health Study
Summary Report

Biomonitoring New Hampshire

What is biomonitoring?

Biomonitoring is the assessment of chemicals or their breakdown products in human specimens such as urine, blood, or tissue. The biomonitoring sciences are important because they give information on how people come into contact with chemicals from their environment, such as from their work, the foods and beverages they consume, or the products they use. The Targeted Arsenic and Uranium Public Health Study was a biomonitoring project designed to measure the levels of arsenic and uranium in New Hampshire (NH) residents. These metals were selected because NH residents are at risk of coming into contact with these naturally-occurring contaminants if they consume contaminated groundwater.

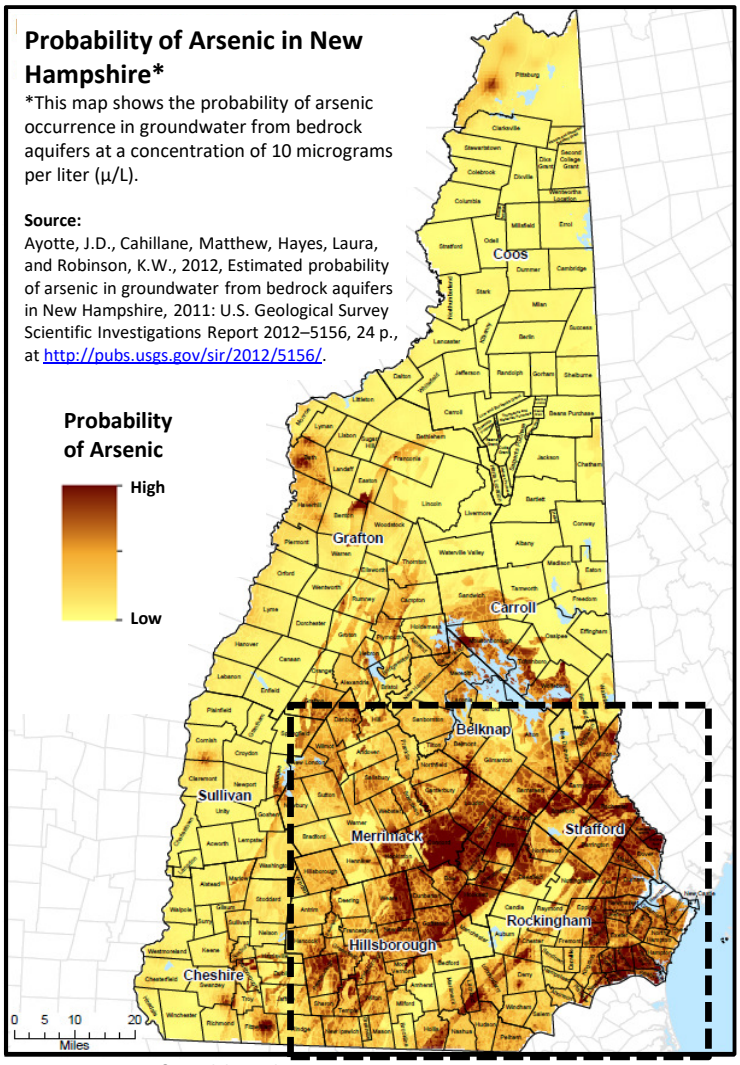
Summary of the Targeted Arsenic and Uranium Public Health Study

Arsenic and uranium occur naturally in the granite that lies deep beneath NH soils. Approximately 46% of NH residents rely on private wells for their home water source and many of these wells are drilled deep into the granite bedrock in order to access the groundwater. Metals like arsenic and uranium can exit the bedrock and enter the groundwater, potentially creating unsafe levels in drinking water. These unsafe levels can cause health effects such as cancer, cardiovascular and respiratory disease, and effect brain development and kidney function. There is no NH law requiring a well user to test their water or to treat their water if unsafe levels of contaminants have been found. Biomonitoring*NewHampshire* conducted this study to see (1) if there are unsafe levels of arsenic and uranium in the well water of NH residents and (2) whether those metals are getting into people's bodies. This was done by testing both well water and urine for these metals.

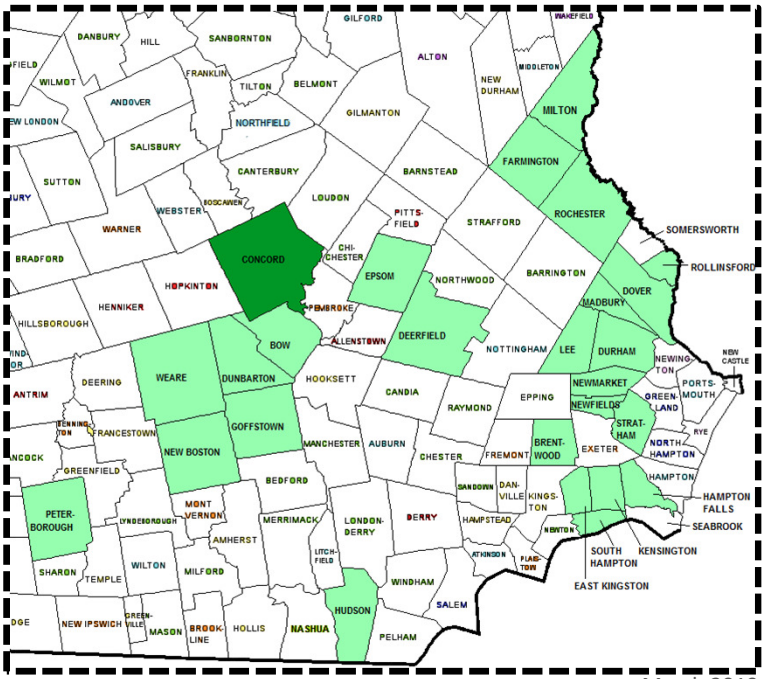
Probability of Arsenic in New Hampshire*

*This map shows the probability of arsenic occurrence in groundwater from bedrock aquifers at a concentration of 10 micrograms per liter (µ/L).

Source:
Ayotte, J.D., Cahillane, Matthew, Hayes, Laura, and Robinson, K.W., 2012, Estimated probability of arsenic in groundwater from bedrock aquifers in New Hampshire, 2011: U.S. Geological Survey Scientific Investigations Report 2012–5156, 24 p., at http://pubs.usgs.gov/sir/2012/5156/.



The left image shows the probability of arsenic contamination in groundwater above the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) in NH groundwater. Previous studies suggest that where arsenic is found in bedrock, uranium may also be found. The image below shows the targeted area (well users) in light green and the comparison area (public water users) in dark green.



Summary of the Targeted Arsenic and Uranium Public Health Study (Continued)

From August 2016 to September 2018, residents with private wells from 27 targeted NH towns were invited to participate in this study. A total of 515 participants from 258 households were recruited from the targeted area (see Key Terms), as well as 51 comparison participants from 35 households in a comparison area (see Key Terms) on a public water supply. All participants completed an exposure survey to see if they had contact with arsenic and uranium in ways other than their drinking water, such as from work history, recreational activities, or consumption of food and beverages. Then they collected a urine sample and water samples from their home.

All urine samples were tested for uranium, total arsenic, and creatinine. Urine samples were tested for the type of arsenic (organic v. inorganic) only if the total arsenic level was above 20 micrograms arsenic per gram creatinine. The type of arsenic detected in urine is important. Organic arsenic, such as the kind found in fish, is not thought to be toxic to humans. Inorganic arsenic, such as the kind that occurs naturally in groundwater, has been found to cause various health effects including cancer, cardiovascular disease, and effects on brain development. Uranium has also been found to cause various health effects such as respiratory disease, poor kidney function, and an increased risk of cancer. Whether a person develops a health effect depends on many factors: how much and for how long they came into contact with inorganic arsenic or uranium as well as personal factors like genetics and overall health (https://tinyurl.com/yxk4omqh). Finding inorganic arsenic or uranium in urine may be a result of drinking contaminated water.

Urine testing results were reported after all of the samples had been tested and data analysis could be performed. The purpose of this delay in reporting was to provide participants with average levels of the study population which were expected to be higher compared to the U.S. population (USP) (2015-2016) data. This allowed participants to compare their results to the average of a population with a more similar exposure to arsenic and uranium. All water testing was reported to participants upon completion of testing.

Key Terms

95th, 75th, 50th, and 5th Percentiles: Threshold values where the percent of samples in a group are below the given value. The 95th percentile is the value that 95% of participants tested below and only 5% of participants tested above this value. Likewise, 75% of participants tested below the 75th percentile and 50% of participants tested below the 50th percentile. The 50th percentile is also referred to as the median or the value that half of participants tested below and half tested above. Finally, 5% of participants tested below the 5th percentile value, which means that the majority of participants tested above this value.

Arsenic speciation testing subset, ASTS: Arsenic speciation testing was performed only on a smaller group of individuals in the study that tested at or above a total arsenic level of 20.0 micrograms arsenic per gram creatinine.

Comparison Area: City of Concord, New Hampshire which has a public water system that serves most Concord residents. Residents that use this water supply are not at risk for consuming contaminated water because the City must test the water to ensure that arsenic and uranium levels are below the Maximum Contaminant Level (MCL) set by the U.S. Environmental Protection Agency (EPA). This is different from private well water as there are no laws requiring testing or treatment of private well water; that is up to the discretion of the well water user (homeowner or renter).

Comparison Participants: A smaller group of participants who lived in the comparison area who used municipal or public water.

Creatinine: A naturally-occurring substance in urine that can be measured to see how hydrated someone is.

Geometric Mean: The middle measurement in a group of samples.

Inorganic Arsenic: A form of arsenic that occurs naturally in the ground and is considered to be toxic. It can contaminate groundwater and plants and can be found in industrial and tobacco products.

Limit of Detection, LOD: The lowest level that the laboratory can detect.

Maximum Contaminant Level, MCL: A standard set by the U.S. EPA for drinking water quality. An MCL is the legal threshold limit on the amount of a contaminant that is allowed in public water systems under the Safe Drinking Water Act (SDWA). The limit is usually expressed as a concentration in milligrams per liter (mg/L) or micrograms per liter (µg/L) of water. The MCL for arsenic is 0.010 mg/L and for uranium is 30 µg/L. Based on the recommendation of the New Hampshire Department of Environmental Service (NH DES), NH legislators are currently considering lowering the MCL to 0.005 mg/L for arsenic. Again, the MCL is a standard for public water only.

Key Terms (Continued)

Micrograms per Liter, µg/L: Unit of measurement, sometimes referred to as parts per billion (ppb).

Milligrams per Liter, mg/L: Unit of measurement, sometimes referred to as parts per million (ppm).

N: The number of people or samples in a group.

Organic Arsenic: A form of arsenic that occurs naturally and is not known to be toxic to humans. It is found mainly in fish and shellfish.

Statistically Significant: A "statistically significant" difference between groups (ex. males vs. females) means we are very confident that the difference in levels between groups is real and not due to chance or random variation. A *P* value $\leq$ 0.05 or non-overlapping 95% confidence intervals indicated a statistically significant result.

Targeted Area: NH cities and towns with an increased risk of having arsenic in the groundwater: Bow, Brentwood, Deerfield, Dover, Dunbarton, Durham, East Kingston, Epsom, Farmington, Goffstown, Hampton Falls, Hudson, Kensington, Lee, Madbury, Milton, New Boston, Newfields, Newmarket, Peterborough, Rochester, Rollinsford, South Hampton, Stratham, and Weare. Although solicited, there were no study participants from Seabrook or Somersworth.

Targeted Participants: This refers only to the participants who lived in the targeted area; excludes participants in the comparison area.

Total Arsenic: A measurement of all forms of arsenic, including organic and inorganic forms.

U.S. Population, USP: A random sample of U.S. adolescents and adults with no known elevated exposure to arsenic or uranium. Data comes from the 2015 - 2016 National Health and Nutrition Examination Survey (NHANES). Information on NHANES can be found at: https://www.cdc.gov/nchs/nhanes/index.htm

Overall Urinary Arsenic and Uranium Concentrations in Study Participants

		Uranium (µg/L)	Total Arsenic (µg/L)
Targeted Participants	Median Concentration	0.006	10.9
	Geometric Mean	0.006	12.5
	5th Percentile	Below the LOD	2.56
	95th Percentile	0.046	83.7
	Number of Participants	515	515
Comparison Participants (Concord, NH)	Geometric Mean	0.004	8.94
	95th Percentile	0.020	32.6
	Number of Participants	51	51
U.S. Population (USP) (2015-2016)	Geometric Mean	0.005	5.96
	50th Percentile	0.005	5.41
	75th Percentile	0.010	11.1
	95th Percentile	0.031	44.6

The Targeted Arsenic and Uranium Study was designed to focus sampling on residents of areas that are more likely to have arsenic and uranium in their groundwater. For this reason, it was expected that the average levels of urinary arsenic and uranium in targeted study participants would be higher than those in comparison participants and the USP. The geometric mean for uranium in targeted participants was 0.006 µg/L, compared to 0.004 µg/L and 0.005 µg/L for comparison participants and the USP, respectively. The geometric mean for total arsenic in targeted participants was 12.5 µg/L, compared to 8.94 µg/L and 5.96 µg/L for comparison participants and the USP, respectively. However, the differences in the concentrations of total arsenic or uranium between these groups are not statistically significant. This means that there may not be any real differences in the concentrations of total arsenic or uranium between the targeted participants, comparison participants, and the USP.

The 95th percentile for uranium in targeted participants was 0.046 µg/L, compared to 0.020 µg/L and 0.031 µg/L for comparison participants and the USP, respectively. The 95th percentile for total arsenic in targeted participants was 83.7 µg/L, compared to 32.6 µg/L and 44.6 µg/L for comparison participants and the USP, respectively.

How Do Arsenic and Uranium Concentrations Vary Across Targeted Participants?

Uranium concentrations in urine varied across targeted participants, ranging from less than the USP 50th percentile of 0.005 µg/L in 213 individuals to greater than or equal to the USP 95th percentile of 0.031 µg/L in 40 individuals. About 8% of the targeted study participants had uranium levels above the USP 95th percentile of 0.031 µg/L, whereas only 5% of the USP were above this value.

Total arsenic concentrations in urine varied across targeted participants, ranging from less than the USP 50th percentile of 5.41 µg/L in 93 individuals to greater than or equal to the USP 95th percentile of 44.6 µg/L in 61 individuals. About 12% of the targeted study participants had total arsenic levels above the USP 95th Percentile of 44.6 µg/L, whereas only 5% of the USP were above this value.

USP (2015-2016) Percentile for Urinary Uranium	Urinary Uranium Concentration (µg/L)	Number of Participants (Percent)
< 50th	< 0.005	213 (41.4%)
50th to < 75th	0.005 to < 0.01	148 (28.7%)
75th to < 95th	0.01 to < 0.031	114 (22.1%)
≥ 95th	≥ 0.031	40 (7.8%)

SYMBOLS: < means "less than" and ≥ means "greater than or equal to"

USP (2015-2016) Percentile for Urinary Total Arsenic	Urinary Total Arsenic Concentration (µg/L)	Number of Participants (Percent)
< 50th	< 5.41	93 (18.1%)
50th to < 75th	5.41 to < 11.1	167 (32.4%)
75th to < 95th	11.1 to < 44.6	194 (37.7%)
≥ 95th	≥ 44.6	61 (11.8%)

SYMBOLS: < means "less than" and ≥ means "greater than or equal to"

How Do Arsenic and Uranium Concentrations of Targeted Participants Vary by Age and Sex?

	Number of Participants	Urinary Uranium Geometric Mean (µg/L)	Urinary Total Arsenic Geometric Mean (µg/L)
Targeted Participants	**515**	**0.006**	**12.5**
Males	254	0.006	12.8
Females	261	0.007	12.2
Ages 0-19	89	0.008	11.5
Ages 20-39	46	0.008	9.63
Ages 40-59	202	0.006	12.8
Ages 60+	178	0.005	13.6

The average urinary uranium and total arsenic concentrations did not vary significantly among male and female targeted participants or between different age groups of targeted participants. This means that there might not be any real difference between concentrations of urinary uranium or total arsenic based on age or sex.

How Do Inorganic Arsenic Concentrations Vary Across Targeted Participants?

Inorganic arsenic is the form of arsenic that may effect brain development or cause cancer, cardiovascular disease, or skin discoloration. A subset of individuals from the study population were tested for arsenic species to determine the amount of inorganic arsenic in their bodies. This subset is considered a distinct population, referred to as the arsenic speciation testing subset or ASTS. Arsenic speciation testing was performed only for individuals that tested at or above a total arsenic level of 20.0 micrograms arsenic per gram creatinine. A minority of participants in this study (152 out of 566 or 27%) tested at or above this level for total arsenic.

Arsenic Speciation Testing Subset (ASTS)

Type of participant	Number of total participants	Number of ASTS participants	Percent (%) of total participants
Targeted	515	141	27%
Comparison	51	11	22%
All	566	152	27%

How Do Inorganic Arsenic Concentrations Vary Across Targeted Participants? (Continued)

The ASTS population is not considered representative of all targeted participants or all comparison participants because only a small portion of each were tested for arsenic species: 141 out of 515 targeted participants (or 27%) and 11 out of 51 comparison participants (or 22%). Additionally, by only sampling individuals with elevated total arsenic levels, the ASTS dataset was expected to trend toward higher concentrations of arsenic species relative to the USP dataset, which includes arsenic speciation results for all individuals who participated in the study (not just those that tested at or above a specific total arsenic level). Because of these differences in sampling, the geometric mean and percentiles for the ASTS and for the USP are not directly comparable. However, these USP measures are included to provide a general picture of the average exposure to inorganic arsenic species.

Overall Urinary Total Arsenic and Inorganic Arsenic Concentrations in ASTS Participants

		Total Arsenic (µg/L)	Inorganic Arsenic (µg/L)
ASTS Targeted Participants	Median Concentration	37.8	9.35
	Geometric Mean	38.9	9.73
	5th Percentile	10.6	2.03
	95th Percentile	284	56.5
	Number of Participants	141	141
ASTS Comparison Participants (Concord, NH)	Geometric Mean	17.3	4.02
	95th Percentile	67.1	25.7
	Number of Participants	11	11
U.S. Population (USP) (2015-2016)	Geometric Mean	5.96	4.41
	50th Percentile	5.41	4.08
	75th Percentile	11.1	6.55
	95th Percentile	44.6	14.5

The geometric mean for inorganic arsenic in targeted participants was 9.73 µg/L, compared to 4.02 µg/L for comparison participants. The 95th percentile for inorganic arsenic in targeted participants was 56.5 µg/L, compared to 25.7 µg/L for comparison participants. The USP geometric mean and 95th percentile for inorganic arsenic are 4.41 µg/L and 14.5 µg/L, respectively. The average urinary inorganic arsenic concentration was higher in ASTS targeted participants compared to ASTS comparison participants. However, the number of people in the comparison data set is limited and it is difficult to evaluate whether these differences are statistically significant. This means that although the average is higher for the ASTS targeted participants, there may not be a real difference between the amount of inorganic arsenic in their urine compared to the ASTS comparison participants or the USP. The NH Department of Health and Human Services (NH DHHS) and the NH Department of Environmental Services (NH DES) may continue to examine these differences in future investigations. It is important to note that these findings show there was a trend toward higher concentrations of urinary inorganic arsenic in people living in areas with a higher probability of arsenic in the groundwater as modeled by the U.S. Geological Survey (see map on page 1).

Average urinary total arsenic and inorganic arsenic concentrations did not vary significantly between males and females. The average urinary inorganic arsenic concentrations varied with age. ASTS targeted participants ages 60 and older had lower average urinary inorganic arsenic compared to younger targeted participants. This difference is statistically significant, meaning that there is a real difference in urinary inorganic arsenic between these age groups.

Urinary Total Arsenic and Inorganic Arsenic Concentrations by Age and Sex

	Number of Participants	Urinary Total Arsenic Geometric Mean (µg/L)	Urinary Inorganic Arsenic Geometric Mean (µg/L)
ASTS Targeted Participants	**141**	**38.9**	**9.73**
Males	57	45.7	8.92
Females	84	34.9	10.3
Ages 0-19	14	52.7	17.3
Ages 20-39	8	32.7	8.80
Ages 40-59	47	49.4	14.6
Ages 60+	72	32.0	6.74

How Do Arsenic and Uranium Concentrations Vary by Well Type/Water Source?

Urinary Uranium and Total Arsenic Concentrations by Well Type/Water Source for Overall Study Population

	Number of Participants Using Water Source (N)	Urinary Uranium Geometric Mean (µg/L)	Urinary Total Arsenic Geometric Mean (µg/L)	Water Uranium Average (µg/L)	Water Arsenic Average (mg/L)
All Targeted Participants	**515**	**0.006**	**12.5**	**2.19 (N = 258 households)**	**0.010**
Drilled/ Artesian Well	463	0.006	12.0	2.20 (N = 235 households)	0.010
Other Private Wells*	52	0.007	17.8	2.02 (N = 23 households)	0.005
Public Water Supply (Concord, NH)	51	0.004	8.94	Not Detected (N = 35 households)	Not Detected

*This includes 21 study participants using dug wells, 8 using driven wells, and 23 using wells of which the type was unknown.

Among the overall targeted population, average urinary arsenic and uranium concentrations were higher for people who used private wells for drinking water and lower for people who were on a public water supply. However, the number of people in the data set on a public water supply is limited. The data from this study shows that drinking water from private wells in the targeted area contains higher levels of uranium and arsenic on average compared to drinking water from a public water supply.

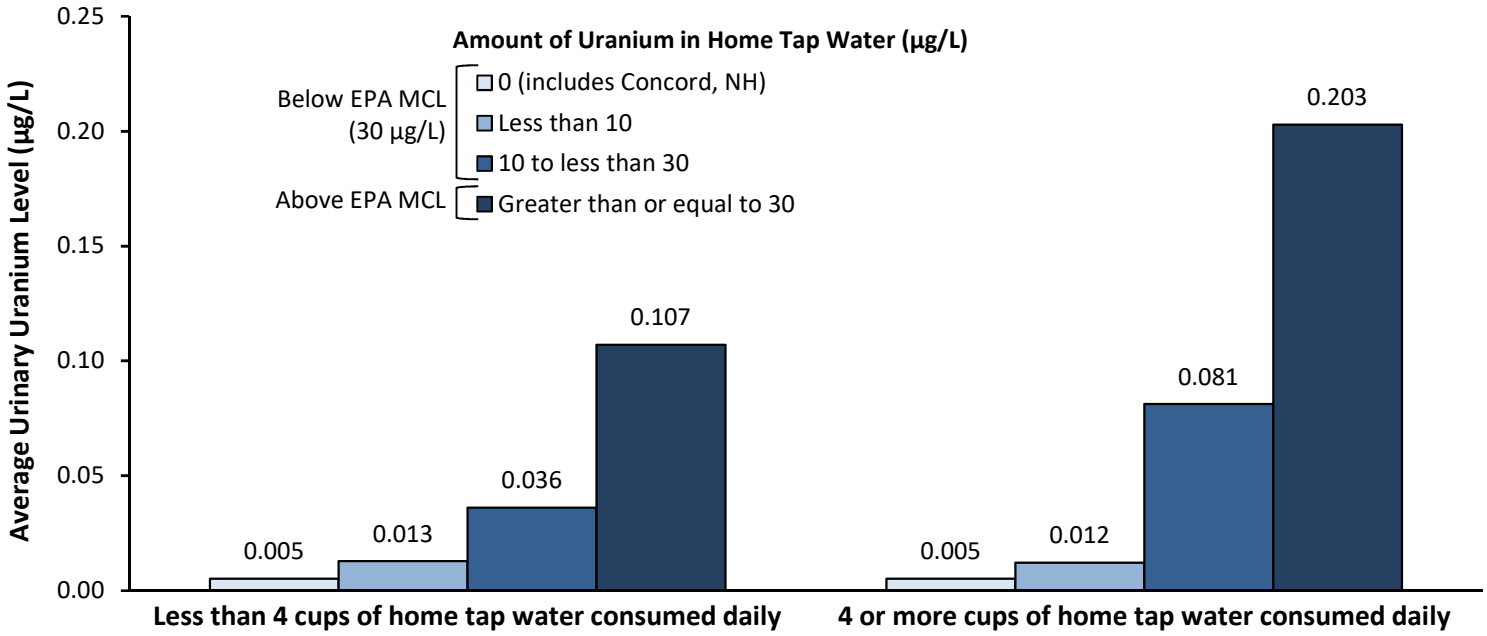
Urinary Total and Inorganic Arsenic Concentrations by Well Type/Water Source for ASTS Population

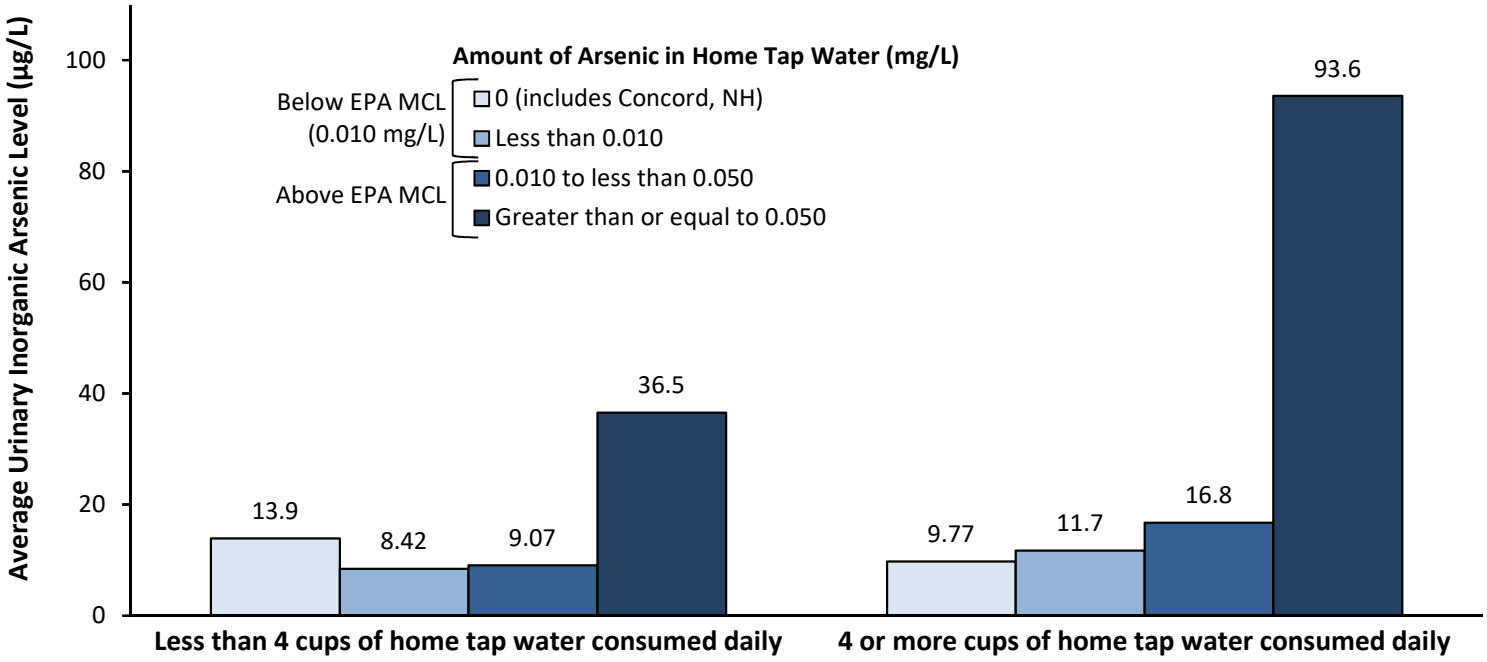
	Number of Participants Using Water Source (N)	Urinary Total Arsenic Geometric Mean (µg/L)	Urinary Inorganic Arsenic Geometric Mean (µg/L)	Water Arsenic Average (mg/L)
ASTS Targeted Participants	**141**	**38.9**	**9.73**	**0.018 (N = 103 households)**
Drilled/ Artesian Well	121	37.9	9.36	0.019 (N = 94 households)
Other Private Wells*	20	46.1	12.3	0.007 (N = 9 households)
Public Water Supply (Concord, NH)	11	17.3	4.02	Not Detected (N = 10 households)

*This includes 21 study participants using dug wells, 8 using driven wells, and 23 using wells of which the type was unknown.

Among ASTS population, average urinary inorganic arsenic levels were higher for people who used private wells for drinking water and lower for people who were on a public water supply. However, the number of people in the data set on a public water supply is limited. On average, water arsenic levels were higher for ASTS participants on private wells compared to targeted participants (see previous table) whose urinary total arsenic levels were below 20.0 micrograms arsenic per gram creatinine and did not receive speciation testing. This difference is statistically significant. This means that there is a real difference in arsenic exposure based on the amount of arsenic in household tap water.

How Do Arsenic and Uranium Concentrations Vary Based on Water Consumption?





Average urinary uranium concentrations increased based on the amount of home tap water consumed daily for households that contained significant uranium in tap water. This increase was greatest for residents whose home tap water was above the Environmental Protection Agency (EPA) maximum contaminant level (MCL) for uranium of 30 µg/L, although uranium exposures still occur when tap water contains uranium levels that are below the MCL.

Inorganic arsenic is the form of arsenic usually found in contaminated well water. Average urinary inorganic arsenic concentrations increased based on the amount of home tap water consumed daily for households that contained arsenic in tap water above the EPA MCL of 0.010 mg/L. This may mean that significant exposure to inorganic arsenic can occur when tap water contains arsenic levels that are above the EPA MCL. In households where the water contained no arsenic and/or residents drank minimal amounts of their home tap water, exposures to inorganic arsenic may have occurred through other routes such as diet.

However, the number of people in these data sets is limited. NH DHHS and NH DES are working together to evaluate and understand how urinary uranium and inorganic arsenic relate to water uranium and arsenic.

Where Can I Get More Information?

Data and information will also be presented on the NH Health WISDOM website at: https://wisdom.dhhs.nh.gov

Groundwater changes over time. The NH Department of Environmental Services (NH DES) recommends standard and radiological analysis testing of well water every three to five years. Bacteria and nitrate are the exception; **you should test for them every year**. The NH Public Health Laboratories (PHL) provides water testing for a fee. To have water testing kits mailed to you from NH PHL, visit http://www4.des.state.nh.us/DESOnestop/HOBottles.aspx or call 603-271-4661.

For more information about water testing and water treatment options, please contact a representative of NH DES at: 603-271-2513, dwgbinfo@des.nh.gov, or visit https://www.des.nh.gov/organization/divisions/water/dwgb/index.htm

Additional information about this study and about Biomonitoring*NH* is available at: https://www.dhhs.nh.gov/dphs/lab/biomonitoring.htm.

Biomonitoring New Hampshire

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