B. Background on Well Water

Residents in Maine get their drinking water from one of two sources. A slight majority of Maine residents get their drinking and cooking water from Public Water Supplies. Public Water Supplies are tested and regulated by the State of Maine Drinking Water Program and need to follow safety guidelines developed by the Environmental Protection Agency. These safety guidelines are called “Maximum Contaminant Limits” (MCLs) and often include risk management considerations relevant to public water systems so they are not necessarily health based and hence, are not appropriate for private wells. Generally speaking, public water supplies are more common in urban areas, and often (but not always) rely on surface water sources.

In contrast, Maine ranks first in the nation in having the highest percentage of its population (at 44%) dependent on private wells for drinking water (USGS 2004). The percentages vary from a low of 20% in Cumberland County to more than 80% on private wells in Washington County (USGS 2005). Figure X (from Nielsen et al 2010) estimates the percentage of each town population using domestic wells as a drinking water source. It is presumed that these values are under estimated given the growth in population since the last water use survey (1990) and the geographic distribution of that growth (predominantly in rural areas).

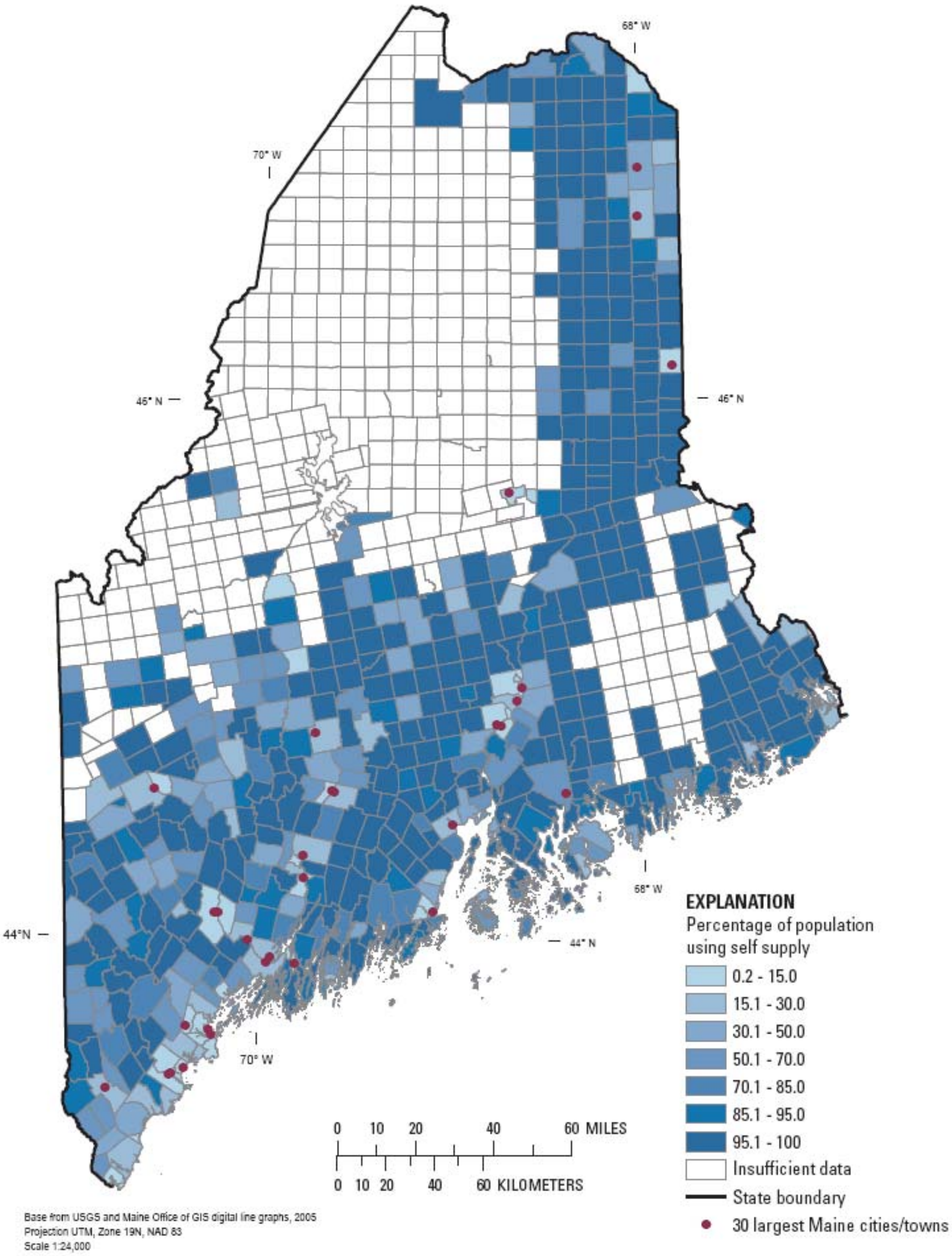


Figure 7. Percentage of town populations using a self-supply water source, generally wells, in Maine, 1990 census. Some towns have insufficient demographic data because of low population density.

The use of private wells as a source of drinking water has a long history, but they are completely unregulated. It is up to the home owner to ensure that their private well water is safe to drink, and until recently, there have not been consistent recommendations from the state on testing private well water. Toxicological guidelines for contaminants in well water have been developed and are called "Maximum Exposure Guidelines" (MEGs). These represent health based voluntary guidelines for private well water quality and can be used as a benchmark for comparing data about a particular contaminant to "acceptable" levels.

Contaminants in well water from private wells can vary geographically (both within state and across the nation) and with construction of the well. Generally speaking, shallow depth dug wells are more likely to have problems with bacterial contamination, while deeper drilled wells are more likely to have contamination from naturally occurring minerals found in the bedrock. Many of these naturally occurring minerals are found at extremely high levels in well water and represent a significant risk to consumers of that water.

There are three types of wells commonly used in Maine, drilled bedrock wells, drilled overburden wells, and dug wells/springs. Of the three types, drilled bedrock wells are by far the most common source of drinking water for Maine homes. A typical drilled bedrock well is six inches in diameter and one hundred to five hundred or more feet deep. Bedrock wells generally have steel casing, driven through the soil, and "set" into bedrock. Drilled overburden wells are shallower, and are not sealed to bedrock. Another term for drilled overburden wells is a well point. Dug wells are an older style of well, originally hand dug to the depth of the water table. They are often lined with concrete or tile to prevent collapse of the well. Hand dug wells often have bacterial contamination problems and can run out of water during portions of the year. Roadside springs are sometimes used as a water source. These springs are not tested or evaluated in anyway and it is up to the consumer to determine if they are safe to drink.

Naturally occurring contaminants of concern typically found in Maine drilled well water that are a priority include arsenic, uranium, fluoride, bacteria, nitrates and nitrites, and radon. Other common contaminants that are aesthetic concerns include iron and manganese. Maine can also have water with high levels of sodium or chloride – this may be from naturally occurring sources or from surface water sources (salt piles, etc). Other parameters that are important include pH and hardness – as these impact the corrosiveness of the water (which can results in copper or lead exposure).

Arsenic

High levels of arsenic in Maine domestic wells have been recognized since the early 1990s (Marvinney 1994). Using statewide random data, Loiselle et al (2001) identified that approximately 10% of Maine private wells have elevated arsenic levels above the MEG of 10 ug/L. The arsenic is fairly clearly related to naturally occurring geologic arsenic deposits. Arsenic levels, however, can vary geographically greatly. Many clusters of elevated arsenic levels in well water have been found in the state of Maine, with some concentrations of arsenic in the thousands of ugs per liter. Examples of clusters include, Buxton/Hollis, Ellsworth/Blue Hill, Surry, Rangeley Lakes, and Danforth.

In 2010, MeCDC and USGS engaged in a pilot project to retrieve, screen, de-duplicate and edit existing arsenic well water data from the State Health and Environmental Testing Laboratory. The data covers the time period of January 2005 to July 2009. Data for 11,116 individual wells were extracted and mapped. Figure XX shows the maximum concentration per town (maximum as opposed to median to address sample size limitations).

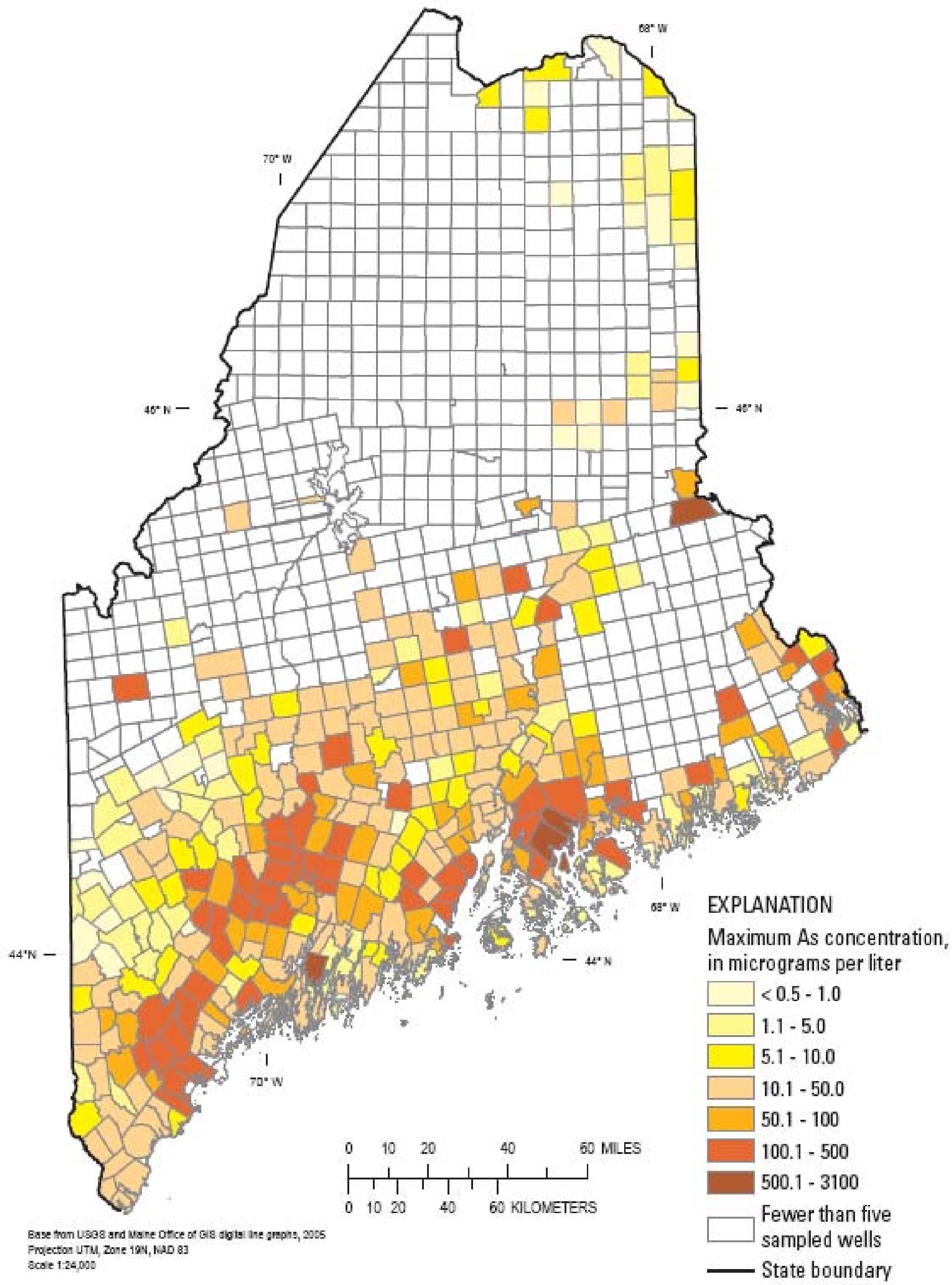


Figure 13. Maximum arsenic concentrations for towns with five or more sampled wells in Maine, 2005-09.

Arsenic is a concern toxicologically and from a public health perspective for three reasons. One is that concentrations in private well water, as stated above, can be quite high. Secondly, the quality of the data showing that arsenic can cause skin, bladder and lung cancer is quite good (studies in human populations). Finally, the cancer risk levels associated with acceptable concentrations in well water are quite high, in the 1 per 1000 cancer risk range (typical acceptable risk levels are in the 1 per 100,000 to 1 per 1,000,000 range). Additional toxicological concerns include possible birthweight and developmental effects. Exposure from drinking water is the dominant concern, although exposure from cooking water becomes significant and higher concentrations. Dermal exposure appears to be negligible although non-compliance or accidental drinking of water (as in a child drinking bath water) may be significant at levels greater than 100 ug/L.

Uranium

Uranium is also naturally occurring in well water in the state of Maine. Uranium is a radioactive metal that actually consists of several different isotopes. Uranium-238 is relatively common in Maine (5.8% of private wells contain levels above the MEG of 20 ug/L). It emits alpha particles weakly and hence its radioactivity is of less concern than its chemical toxicity. Uranium-238 is the dominant isotope from a mass perspective commonly found in water. Hence it is possible to measure on a mass basis (ug/L) as done by HETL. The effects of concern with uranium-238 are relatively mild changes in kidney function. Uranium-234 another isotope of uranium which also emits alpha particles, but much more energetic than U-238. While U-234 is much less important on a mass basis, it is typically of equal importance on a radioactivity basis. Hence, for any measure of U-238 in well water on an activity basis, one can expect on average an equal amount of activity from U-234 that cannot be measured on a mass basis. In other words any measure of U-238 on a mass basis (e.g., 20 ug/L) is roughly equivalent to activity (20 pCi/L) of both U-238 and U-234 (65 FR 236 (12/7/2000): 76709-76753). The concern with long term exposure to U-234 is increased risk of bone cancer. Most concentrations of uranium in private well water in Maine are at levels where the primary concern is chemical effects from the U-238. Occasionally, concentrations do reach levels in the thousands of ug per liter which would likely be a significant cancer risk. 30 ug/L MCL for uranium-238 (and the presumed U-234) is slightly below the 1 in 10,000 lifetime cancer risk (65 FR 236 (12/7/2000): 76709-76753).

Uranium levels also tend to cluster with high levels in the Poland, Gray region and around the Raymond area. Uranium levels have yet to be mapped in the state although they will be mapped with the next iteration of the Unregulated Drinking Water Initiative project (UDWI), a national CDC funded effort through the Environmental and Occupational Health Program.

Fluoride

Fluoride is also a naturally occurring mineral in Maine well water. Like all substances, fluoride can cause unwanted health effects when ingested at concentrations higher than recommended. Fluoride, however, also has beneficial oral health effects at lower levels. The Maximum Exposure Guideline for fluoride identified by the Toxicology Program is 2 mg/L. The current estimate is that approximately 2.5% of Maine wells may have fluoride concentrations greater than 2 mg/L, and occasionally exceed 4 mg/L. Fluoride levels have yet to be mapped in the state although they will be mapped as part of the UDWI project.

Iron and manganese

Iron and manganese are two common minerals found in Maine well water. Both iron and manganese can cause staining of fixtures and clothing (when used for laundry). Manganese can also impart an odor to water at higher concentrations. Iron has been shown to have gastrointestinal effects (pain, nausea, vomiting) and an MEG of 5,000 ug/L was developed in 2010 to protect against this effect. Manganese can result in neurological symptoms with extended exposure and an MEG of 500 ug/L was established to protect against this effect. Manganese and iron levels have yet to be mapped in the state although they will be mapped as part of the UDWI project.

Radon

Radon is a decay product of uranium-238, a naturally occurring radioactive element. Maine is part of a geological region that is relatively high in natural uranium-238. Radon in soil gas and in water is therefore common in Maine, and random sampling of Maine homes suggests that any location could have high radon from either source. Since radon is a radionuclide, concentrations in air and water are reported in units of radioactivity: picoCuries per liter (pCi/l).

Private well water in Maine is thought to have radon concentrations, on average, of around 11,000 pCi/l. This is based on non-random data supplied to the Maine Radon Program. The data may be biased high due to self-selection bias (people who think they have a problem are more likely to test). Soil and water radon concentrations are not strongly related to each other, but it is possible to estimate the contribution of waterborne radon to air in a house. The National Academy of Sciences (NAS) considered estimates of the water-to-air transfer coefficient from several sources, including measurements in Maine homes (NAS 1999). The NAS recommended using a transfer coefficient of 1E-4, midway between the estimates from measurements and modeling. This is equivalent to a water:air ratio of 10,000:1 (10,000 pCi/l in water will result in 1 pCi/l in air). This would be in addition to radon entering the home from the surrounding soil.

Radon is a very well known and understood lung carcinogen. Within the last 10 years many large scale epidemiological studies have shown radon to be a potent lung carcinogen, with cancer risk levels on the order of 1/1000 at 4,000 pCi/L in water (the MEG). However, radon in water is only one source of radon exposure. By far the dominant source of exposure is radon in soil gas entering the home. Radon gas will be discussed in more detail in section XX.

Bacteria

The goal of testing well water for bacteria is not because of concern about the bacteria, per say, as much as that the bacteria are used as an indicator of surface water intrusion. If surface water is leaking into the well, potentially multiple pathogens or contaminants may enter the water. Well construction relies on the surrounding soil to filter water before it enters the well. If surface water flows around the well lining into the well, that filtering action is lost.

Currently two types of bacteria are evaluated – coliform bacteria and E. coli. Both tests are limited in their ability to measure surface water intrusion into the well. Coliform bacteria is bacteria from the gut of any kind of organism. While it is found in virtually all surface water, it is also often found on hands, the faucet, or in recently installed plumbing (when, for example, a spider might have contaminated it while in storage or shipping). Similarly, E. coli comes from the gut of a mammal, is also common in surface water and can be found as a contaminant on surfaces.

Experience based on phone calls within the Toxicology Program suggest that positive bacteria tests are common, that dug wells tend to have a higher chance of positive bacteria tests than drilled wells.

Nitrates/nitrites

Nitrates and nitrites are both nitrogen compounds that are found in soil. They are a primary constituent of fertilizers and manure. Because they are highly mobile in water sources of nitrates near wells can easily contaminate the well water. The concern about nitrates/nitrites focuses on newborn infants and pregnant women drinking water. The distribution of nitrates and nitrites in Maine well water has yet to be mapped or evaluated. Experience from the Toxicology Program (via phone calls) suggests it is relatively uncommon in samples tested by the Health and Environmental Testing Lab but discussions with labs which test more often in Aroostook County suggests nitrate/nitrite contamination is more prevalent there.

Copper and Lead

Lead and copper are combined because they are very rarely found in ground water and typically have a source of the plumbing system. Lead was found in solder used in plumbing prior to 1986. Copper is found in copper pipes. These compounds dissolve into water if the water is corrosive, such as salty, low pH, low hardness, or if an electrical system is grounded to the plumbing or if there is galvanic corrosion (where dissimilar metals in pipes are connected). Occasionally a water treatment system installed to remove another problem (e.g., hardness or arsenic) can change the water chemistry enough to result in a corrosion problem. A visual test of corrosivity is green staining (from copper) where the water drips onto surfaces (such as the bathtub).

There appear to be two ways in which a water sample can test high for lead. One is through lead dissolved in the water. This is most often captured through a “first draw lead test” which samples water that has been sitting in the pipes for an extended period of time (such as overnight). The second scenario is when particulate bits of lead solder or brass (which can contain lead) break loose and, by chance, end up in the sample jar. This can lead to extremely high lead results which cannot be replicated. Occasionally lead solder particles can become trapped in the aerator and break down over time.

With lead and copper in well water there are two concerns. Both lead and copper can have health effects, but additionally, corrosion of the pipes can result in pin hole leaks and resultant water damage. Lead is, of course, well known as a developmental neurotoxin – with children being the most sensitive. Adults, however, appear also to be quite sensitive, with blood pressure effects being the toxicological end point of concern. Exposure to copper above the MEG is associated with gastrointestinal disturbances, such as nausea.

Given lead and copper are often at their highest concentration in the "first draw" or the water that has been sitting in the pipes the longest, the quickest solution to reduce exposure to individuals is to flush the water from the pipes before consuming.

Sodium and Chloride

Sodium and chloride are the constituents of table salt, while chloride is found in many different salts (e.g., potassium chloride). Both contaminants are found in Maine well water. Road salt contamination, contamination from road salt piles, sea water intrusion or trapped ancient seawater aquifers are all possible sources of sodium or chloride contamination. Guidelines for chloride contamination are based on a salty taste to the water, while sodium guidelines are based on concerns for individuals on an ultra low sodium diet. Of greater concern with elevated sodium and chloride concentrations are the increase in corrosiveness of the water – resulting in metals from the pipes (copper) and solder (lead) dissolving into the water and causing exposure. Sodium and chloride levels have not been mapped in the state.

Other water quality parameters: pH, hardness

A standard water test also measures other parameters that are quite useful in diagnosing well water problems. The most obvious, which have already been mentioned are pH and hardness. pH is a measure of acidity or alkalinity of the water – where a pH of 7 is neutral, while levels lower than 7 are acid, higher than 7 alkaline or basic. From a corrosion control perspective, acid water is of most concern and can be modified with a neutralizing water treatment system. Hardness is one measure of the amount of minerals dissolved in the water – where soft water has fewer dissolved minerals while harder water has more. From an aesthetic perspective users typically prefer soft water (in which soap lathers easily) over hard water. However, there is a point where water can be too soft – and in those situations the lack of minerals in the water can result in minerals dissolving from the pipes into the water. Again, a solution can be a "water hardener" – which hardens the water (and is essentially the opposite of the more common water softener).

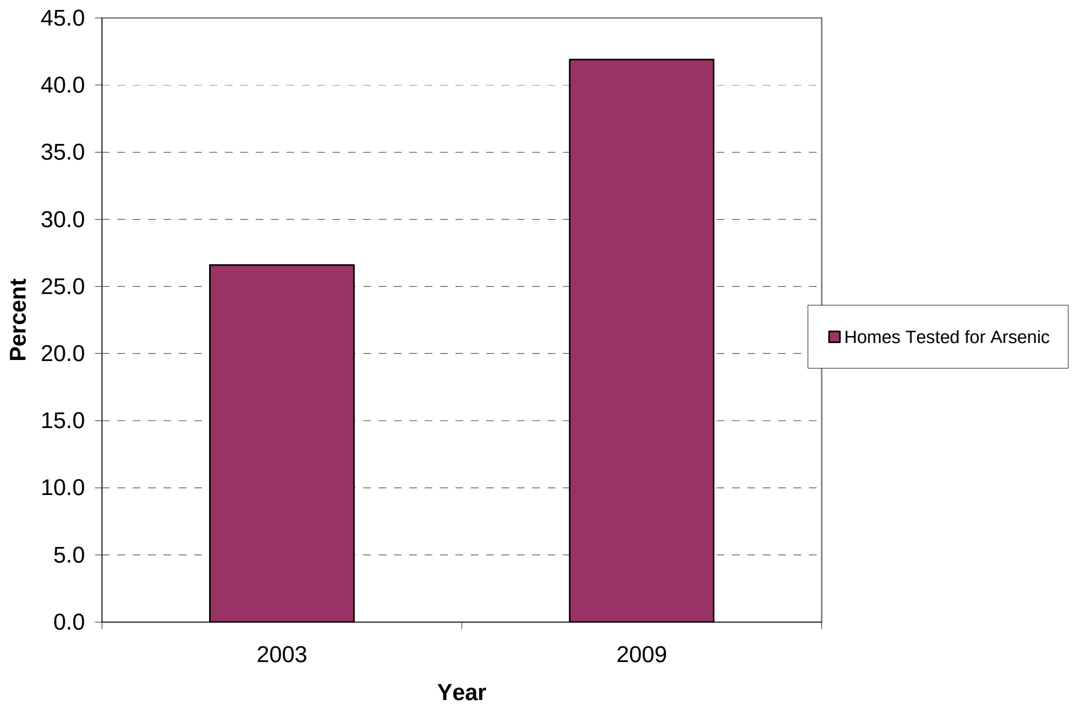
Formative Research on Well Owners

While geographic distribution of contaminants across the state of Maine is reasonably well understood for some contaminants, and not for others, information about well owners, is very poorly understood or studied. Knowledge about what owners think about their well water, what prompts them to test, what barriers prevent them from testing, and what actions they take after a test are critical in improving the ultimate public health outcome – which is homeowners ensuring their water is safe to drink. Sources of information on perceptions of well water, testing of well water and behavior change can be gleaned from published studies in other states, experience through focus group testing and interacting with the public and through studies conducted instate.

Public perceptions about well water are relatively poorly understood. Liukkonen (2007) surveyed private well owners in Wisconsin, Michigan and Minnesota. In that study, she found the presumption was that private well water is safe as it comes out of the ground (67% believed water was safe without testing or treating, 55% of respondents in Minnesota were not worried about health effects from drinking well water, 53% said they did not test their water because they had been drinking it for years). Among those who had not tested their well water 41% responded that they had never thought about the need to test their well water.

Liukkonen (2007) also suggests that reasons to test were driven by finding a neighbor whose well was contaminated (86%) if they noticed a change in taste (86%), and if they had unexplained health problems (63%). Surprisingly, only 28% responded they would test if a new baby was living in the home or visiting. Experience within the state of Maine gathered through focus group testing in 2004, suggests that barriers to testing include knowledge of the need to test, awareness of what to test for, and perceived complexity of testing. The need to protect family members was identified as a positive motivator for testing well water.

The Maine Environmental and Occupational Health Program has been doing outreach encouraging individuals to test their well water. Currently approximately 20,000 brochures encouraging private well owners to test their well are being distributed to town offices with high proportion of homes on private wells or towns with known areas of well water contamination. Evaluation of this effort through the Behavioral Risk Factors Surveillance Study (BRFSS) suggests an increase in testing for arsenic during this time period. This data will also be analyzed comparing those towns surveyed that received the brochure vs. those which have not.



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