Potential Health Risks of Contaminants in Private Groundwater Sources in Newfoundland and Labrador

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Abstract

The Government of Newfoundland and Labrador regularly tests public drinking water supplies to ensure the absence of any microbiological, physical or chemical contaminants. Private water supplies, including wells however, fall outside the mandate of these testing regimes and thus monitoring becomes the sole responsibility of the individual well owner. There are over 40,000 wells in Newfoundland and Labrador servicing approximately one fifth of the total population. Limited information on private well water quality is available, especially of physical and chemical contaminants. A scan of provincial government water quality reports of public wells was performed to create a proxy model of the potential risk of private well contamination. Our results show potential problems with toxic levels of arsenic, barium, cadmium, chromium, lead, mercury and selenium. Lead and arsenic pose the greatest risk with 13% and 10% of public wells having shown contamination at least once. Our model finds 8,544 people at risk for exposure to toxic levels of arsenic, 11,232 people at risk of exposure to toxic levels of lead, and 3,840 people at risk for exposure to the remaining contaminants from drinking water from private wells. In total, this model shows 5% of the province's population at risk of exposure to toxic drinking water contaminants. A review of the literature was conducted to assess the health risks from each of these individual contaminants. Health risks on account of chronic exposure to these seven contaminants include cancer, cardiovascular disease, kidney damage, diabetes, as well as neurological and developmental conditions, among others.

Keywords: private groundwater quality, contaminants, monitoring, health risks

Introduction

Clean, safe drinking water is essential to all life and good health. While the most immediate health concerns in drinking water come from bacterial contaminants like *e.coli* and their potential complications, one cannot ignore the health risks from prolonged exposure to toxic chemical contaminants. While there is a strong body of research surrounding the risks of exposure to high levels of toxic chemicals, there is a growing body of evidence that even low levels of exposure, like those found in Newfoundland and Labrador, can pose a serious health risk.

The Health Canada Guide for Canadian Drinking Water Quality (GCDWQ) has established acceptable limits for levels of potentially toxic chemicals, and these guidelines were adopted by the province of Newfoundland and Labrador in 2001. Currently, public water supplies in the province of Newfoundland and Labrador are subject to regular bacteriological testing, and twice yearly chemical and physical testing. Private water sources however, fall outside of the mandate of this testing regime, and therefore are the responsibility of the private well owners. With over 40,000 private wells in Newfoundland and Labrador, this lack of regular monitoring poses a serious public health risk.

Methods

The Newfoundland and Labrador Water Resources Portal is an online resource providing information on public water supply type, location, source information, and the population serviced by the water supply. In the province of Newfoundland and Labrador, there are 179 public water groundwater wells that supply 88 communities serving a population of approximately 39,339. Source water tests are regularly performed by the Department of Environment and Conservation of the provincial government to monitor this water quality, and these results are published through the Water Resources Portal. Reports on private water supplies, such as wells however, are not published, because these sources are not monitored. Therefore, the public water quality reports present the best data to estimate the risk to private well owners and were used to create a proxy model. Focusing on public water systems supplied by groundwater wells, a scan of available public well source water quality reports was performed to assess the potential risk to private well owners in the province. Tap water test results were not included in this study, because of the potential confounder of contamination within home plumbing systems.

Included in this study were 2,292 public well source water quality reports of tests ranging from September 23, 2001, to July 11, 2013. Through this process, key potential contaminants were identified to be in excess of the Health Canada guideline values (GCDWQ) for toxic chemicals. A review of the literature was conducted to attempt to assess the health risks from each of these individual contaminants.

Results and Discussion

Our results show toxic levels of arsenic, barium, cadmium, chromium, lead, mercury and selenium have been found in past groundwater source tests. Contaminants were found in a wide range above the guideline value. These results are summarized in Table 1.

Table 1. Toxic Chemical Contaminants Found in Excess of Health Canada Guideline Values in Public Supply Ground Water Sources in Newfoundland and Labrador

Contaminant (Health Canada guideline value mg.L^{-1})	Total number of test results in excess of Health Canada guideline value	Exceedance range (mg.L^{-1})
Arsenic (0.01)	43	0.011-0.044
Barium (1.0)	7	1.03-1.66
Cadmium (0.005)	1	0.0056
Chromium (0.05)	1	0.1

Lead (0.01)	41	0.011-0.183
Mercury (0.001)	1	0.0021
Selenium (0.01)	2	0.012-0.023

Of the contaminants found, the data was analyzed to examine the distribution of contamination as a portion of communities (n=88), and water supplies (n=179). These results are summarized in Table 2.

Table 2. Distribution of Toxic Chemical Contaminants Found in Excess of Health Canada Guideline Values in Public Supply, Ground Water Sources in Newfoundland and Labrador

Contaminant	Number of communities with contaminant in excess (percentage of communities)	Number of public wells with contaminant in excess (percentage of wells)	Number of private wells potentially contaminated (proxy model)	Population potentially at risk (proxy model)
Arsenic	11 (12.5)	16 (8.9)	3560	8544
Barium	2 (2.3)	2 (1.1)	440	1056
Cadmium	1 (1.1)	1 (0.6)	240	576
Chromium	1 (1.1)	1 (0.6)	240	576
Lead	18 (20.5)	21 (11.7)	4680	11232
Mercury	1 (1.1)	1 (0.6)	240	576
Selenium	2 (2.3)	2 (1.1)	440	1056

All of the seven chemicals found in excess of the Health Canada guideline values pose serious potential health risks. However, of particular concern is the portion of water supplies having shown arsenic (9%) and lead (12%) contamination. Given that there are 40,000 wells in the province, this proxy model suggests that approximately 3,560 wells could be contaminated with arsenic, and approximately 4,680 wells could be contaminated with lead. The combined public health burden of barium, cadmium, chromium mercury and selenium is also significant, with approximately 1,600 wells potentially contaminated.

According to the 2011 census, the average household size in the province of Newfoundland and Labrador is 2.4 persons (Statistics Canada, 2013a). Assuming that private wells are generally one well per house, based on these numbers, 8,544 people are at risk for exposure to arsenic, 11,232 are at risk of exposure to lead, and the remaining contaminants, barium, cadmium, chromium, mercury and selenium pose a risk to 3,840 residents of Newfoundland and Labrador. This model represents a risk from drinking water contaminants to 23,616 people, or 4.7% of the province’s population (Statistics Canada, 2013a). In Newfoundland and Labrador, 14.5% of the population are children aged 14 or younger (Statistics Canada, 2013b). Therefore, this model also represents a risk of exposure to drinking water contaminants to 3,424 children in the province. This is of particular concern from a health perspective, since children are more susceptible to health impacts from drinking water contaminants, especially lead (ATSDR, 2007c).

These test results represent source water tests for public supplies, before any treatment facility is reached. It can be assumed that publicly administered water receives appropriate treatment at the facility to make this water safe for public consumption, though more research should be done to quantify and further understand the interventions taken. The real concern presented by this data is to residents of the province drinking ground source water from their private well. Since these water supplies are not tested for physical or chemical parameters, it is not known whether this water is safe to drink. Given that most private well owners do not have expensive water treatment systems installed at home, especially for physical and chemical parameters, it is reasonable to assume that these numbers represent a proxy of the potential risk to private well owners in the province.

There are some limitations associated with this model. Public supply source water data is used in place of private supply source water tests because this is the best available information. This emphasizes the need for regular water quality monitoring of private water supplies, so as to ensure an acceptable level of risk to public health. Limitations include well lithology and geologic variation, aquifer characteristics, travel distance and time from source to tap, wellhead protection and population calculations.

Geologic variations contributing to well lithology and aquifer characteristics are extensive and very discrete. This limitation is difficult to adjust for based on the current model, however, as mentioned, there are currently no other mechanisms to look at data from private wells and this limitation illustrates that need. Furthermore, this model is based on public water, where testing is performed to declare water fit for consumption. Another point to consider is that many contaminations occur after use for an extended period. There is actually less risk for public well water, because there are stringent actions for regular monitoring, and the Department of Environment and Conservation exercises vigilance in monitoring the water. However, evidence suggests that private wells are actually more at risk because of a lack of regular monitoring. For example, the town of Cormack was found to have a large issue in terms of arsenic in private well water (Sarkar *et al.*, 2012). Had this community been served by public drilled wells, we assume that the situation would not have gone to this extent. Regular testing of private water will be effective in further articulating the health risks suggested by the current model.

To account for potential issues arising from plumbing and the journey water must take from source to tap, only source water quality data from the public water supply was used.

Public water wells are physically better protected to ensure water quality. These wells are part of an inspection process from the Department of Environment and Conservation. Furthermore, some public wells in the province are contained in protected areas. This kind of protection and inspection procedure is not regular for private wells in the province. This also suggests that the proxy model may be giving a diluted estimation of the risk.

The population calculations of the model are based on census data that is averaged for the entire province, on the assumption that one well serves one household. Given the presence of community wells that often serve multiple families, this estimation might actually present a figure less than the actual number of people at risk.

Ultimately, these limitations of the proxy model suggest that the above model might be underestimating the health risk to private well owners in the province.

Not all communities have shown evidence of just a single contaminant. The health risk to the public is further added to by the presence of multiple contaminants in some communities. Six communities with public wells showed multiple contaminants like arsenic with chromium, or lead with arsenic, barium, cadmium or mercury.

To further articulate the potential risk, it is necessary to understand what the key health risks, especially from low-level exposure to the above chemicals are. While levels of contaminants in Newfoundland and Labrador are less than those found in other parts of the world, for example India or Bangladesh, this is still a serious public health concern. The Health Canada guideline values, adopted by the province in 2001 indicate levels of a contaminant which are considered to pose an acceptable health risk based on chronic consumption. However, individual tolerances and susceptibilities vary. Furthermore, guideline values regularly change as more evidence is presented. For example, the guideline values for safe consumption of selenium is currently under debate (Gore *et al.*, 2010). Should guideline values be lowered, as arsenic was recently, even more of the population would be considered at risk.

Literature Review

The following seeks to identify key health risks, and then outline the evidence of which chemicals increase the specific risk for that contaminant. Information is taken from the Agency for Toxic Substances and Disease Registry (ATSDR) of the US Department of Health and Human Services, the Health Canada Guide for Canadian Drinking Water Quality (GCDWQ), and more recent evidence from the peer-reviewed literature.

Cancer

When examining the health risks from prolonged exposure to low levels of toxic chemicals at or just above the Health Canada guideline value in drinking water, developing cancer is the primary health concern. Specifically, cancers of organs in the digestive tract are particularly vulnerable. The risk for kidney cancer is increased with exposure to lead and cadmium (ATSDR, 2007c; Health Canada, 2012), the risk to stomach cancer is increased with exposure to chromium (ATSDR, 2012b), and exposure to arsenic increases the risk of bladder, liver and skin cancer (Morales *et al.*, 2000; Cabrera & Gomez, 2003). In addition, a systematic review at 17 studies found a relationship between high arsenic exposure from drinking water and lung cancer (Celik *et al.*, 2008).

Cardiovascular Risks

There is growing evidence to suggest that prolonged exposure to chemicals via drinking water increases the risk of hypertension. Specifically, arsenic (Abhyankar *et al.*, 2012; Kunrath *et al.*, 2013), barium, (ATSDR, 2007b), and though still a debated issue, lead (Kopp *et al.*, 1988; Houston & Johnson, 1999; Scinicariello *et al.*, 2011) are all causes for concern. A new study from 2013 published in the Annals of Internal Medicine, shows that exposure to even low levels of arsenic (less than 0.10 $mg.L^{-1}$) may increase the risk for cardiovascular disease (Moon *et al.*, 2013). Furthermore, a recent US study found that lower level exposure to arsenic causes an increased risk for stroke (Lisabeth *et al.*, 2010).

Neurological Risks

The neurological system is particularly vulnerable to lead and mercury exposure. Weakness and difficulty controlling muscles can result from long-term exposure to lead (ATSDR, 2007c). Recent research in the United States and Canada has found that low-level exposure to lead has been found to cause an increased risk for Attention Deficit Disorder (ADD) in children (Eubig *et al.,* 2010; Boucher *et al.*, 2012).

A reduction in child IQ and cognitive function has been associated with fetal lead exposure (Bellinger *et al.*, 1992; Cummins & Goldman, 1992). Research in Bangladesh, Mexico and China has shown exposure to drinking water arsenic to decrease child IQ scores (Calderon *et al.*, 2001; Wang *et al.*, 2007; Hamadani *et al.*, 2011). While these exposures were at levels not comparable to North America, recent evidence out of Maine supports this association even at low levels of arsenic exposure (Wasserman *et al.*, 2014).

Kidney Risks

As the organ which filters urine, the kidneys are particularly vulnerable to contaminants from drinking water. Kidney disease and decreased kidney function have been shown in adults, adolescents and children from exposure to low-level amounts of lead (Fadrowski *et al.*, 2010; Fels *et al.*, 1998; Kim *et al.*, 1996; Muntner *et al.*, 2003; Sommar *et al.*, 2013). Furthermore, research in mice has shown that chronic exposure to low levels of cadmium at our around the safe limit can cause kidney damage (Thijssen *et al.*, 2007).

Diabetes

Evidence has shown that low-level chronic exposure to arsenic in drinking water may increase risk of Type 2 Diabetes. Though not yet conclusive, an association is supported (Maull *et al.*, 2012; James *et al.*, 2013; Jovanovic *et al.*, 2013; Navas-Acien *et al.*, 2013).

Skeletal Risks

Research shows that prolonged exposure to low levels of cadmium and high levels of selenium causes the development of fragile bones. This increases the risk for osteoporosis as well as hip and vertebral fractures (Krishnan *et al.*, 1990; Brzoska & Moniuszko-Jakoniuk, 2004; Brzoska, 2012; Youness *et al.*, 2012; Dahl *et al.*, 2014).

Reproductive Outcomes

Reproductive outcomes are also a risk from contaminant exposure by drinking water, and women who are pregnant or could become pregnant should be particularly wary. Arsenic is able to cross fetal tissues and be found in unborn babies, posing a developmental risk for unborn children (ATSDR, 2007a). Lead exposure during pregnancy may result in low birth weight, premature births, and learning and growth difficulties (Xie *et al.*, 2013). Also, new research has shown low-level lead exposure associated with an earlier age for menopause (Eum *et al.*, 2014). While the evidence is still limited, there has been some research suggesting an association between low-level lead exposure and decreased semen quality in men (Wirth & Mijal, 2010).

Selenosis

Selenium is an essential element in small quantities. However, long-term exposure to high levels can result in selenosis, a condition characterized by brittle hair, nails, and some numbness or other neurological effects (ATSDR, 2003).

The health risks and their associated chemical causes are summarized in the following table.

Table 3. Drinking Water Contaminants and Associated Health Risks.

Health risk	Contaminant causing increased health risk
Bladder Cancer	arsenic
Liver Cancer	arsenic
Lung Cancer	arsenic, cadmium
Kidney Cancer	lead, cadmium
Skin Cancer	arsenic
Stomach Cancer	chromium
Cardiovascular Disease	arsenic
Hypertension	arsenic, barium, lead
Stroke	arsenic
Neurological Weakness	lead, mercury
Attention Deficit Disorder (ADD)	lead
Decreased Intelligence Quotient (IQ)	arsenic, lead
Kidney Damage	cadmium, lead
Diabetes	arsenic
Skeletal Risks	cadmium, selenium
Reproductive Risks	arsenic, lead
Selenosis	selenium

Conclusion

This preliminary study shows a serious public health risk in the province of Newfoundland and Labrador. Our model finds 3,560 wells and 8,544 people at risk for exposure to toxic levels of arsenic, 4,680 wells and 11,232 people at risk of exposure to toxic levels of lead, and 1,600 wells and 3,840 people at risk for exposure to barium, cadmium, chromium, mercury or selenium. In total, this model shows 5% of the province's population at risk of exposure to toxic drinking water contaminants. While fecal contaminant testing services are available to private well owners, chemical and physical tests are inaccessible to this population due to expense and geographic barriers. This is a hidden risk that is not only a public health burden, but also has financial implications for the cost of treatment and disease. Public water supplies are monitored and have mechanisms in place to ensure public safety. Engineering solutions exist to remove these contaminants from private household water supplies, however, because of a lack of data, these measures are not taken. With increased risk for cancer, cardiovascular disease, kidney damage, diabetes, neurological damage and developmental disorders, quality of life for residents of primarily rural parts of the province is a potential issue. These risks are avoidable. A proper water quality monitoring system for all residents of the province is needed, including those drinking water from private wells. Further research is required to further refine the understanding of the potential health risk to residents in the province. Moving forward, focus group discussions will be conducted in selected communities to assess the concerns of residents, as well as explore solutions that will have greater compliance. A business model for establishing water quality monitoring service will also be created, including financial data as well as a cost benefit analysis.

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