

# **Potential Human Health Impacts of Water Contaminants in Newfoundland and Labrador**

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## List of Abbreviations

<b>Abbreviation</b>	<b>Definition</b>
ADD	Attention Deficit Disorder
ATSDR	Agency for Toxic Substances and Disease Registry
CDC	Center for Disease Control
DBA	Dibromoacetic acid
DBP	Disinfection by-product
DCA	Dichloroacetic acid
DOEC	Department of Environment and Conservation, Government of Newfoundland and Labrador
EPA	Environmental Protection Agency
GCDWQ	Health Canada Guide for Canadian Drinking Water Quality
HAA	Halogenic acetic acid
IARC	International Agency for Research on Cancer
IQ	Intelligence Quotient
MAC	Maximum Acceptable Concentration
NL	Newfoundland and Labrador
TCA	Trichloroacetic acid
THM	Trihalomethane
WHO	World Health Organization

## Introduction

Clean, safe drinking water is essential to human life. Without drinking water free from harmful contaminants, a host of potential health risks are present. Water can be contaminated by microbiological contaminants, chemical contaminants, and in more recent times, concerns have arisen around disinfection by-products (DBPs). The following is a review of the academic literature, government documents, the Health Canada Guide for Canadian Drinking Water Quality (GCDWQ) the International Agency for Research on Cancer (IARC) and the database of the Agency for Toxic Substances and Disease Registry (ATSDR), examining the health risks from exposure to 15 contaminants that are relevant to drinking water supplies in Newfoundland and Labrador (NL).

Drinking water contains many dissolved chemicals and particles as a matter of course. Some of these dissolved particles are actually essential for good health, while others have negative health impacts. The Health Canada Guide to Drinking Water Quality provides the standard of the Maximum Acceptable Concentration (MAC) for contaminants in NL. These guideline values are the standards where consistent consumption of a contaminant at that concentration poses an acceptable risk to public health. It is noteworthy however, that these tolerance levels are different from individual to individual, and that there is always a risk associated with the consumption of many contaminants through drinking water.

The relevance of the 15 contaminants discussed herein was established through a scan of the available water testing reports publicly available through the Water Portal of the website of the Department of Environment and Conservation (DOEC). These 15 contaminants have been found in concentrations in excess of the Health Canada guideline values at least once within the last 20 years. When evidence is referenced suggesting the presence of contaminants within the province, it is based on these reports.

Where possible, information on the effects of low-level exposure, most comparable to that in NL is presented. Each contaminant is presented in a clear format outlining the major health concerns from exposure, as well as issues of carcinogenicity. Finally, evidence from the academic literature is cited in support of the main health concerns, as well as offering suggestions for further research where applicable.

## Microbiological Contaminants

Microbiological contaminants are the most immediate concern to public health from drinking water supplies (Health Canada, 2012). In NL, microbiological contaminants are of particular concern, as evidenced by the 239 water supplies currently on boil

water advisory (Johnson, 2014). This means that 69,400 people in the province are currently asked to boil water provided by a public distribution system. The following looks at a few key microbiological concerns.

## **E. coli**

*GCDWQ MAC: 0*

### **Main Health Concerns**

*E. coli* is the most immediate health concern in water supplies. The presence of *E. coli* indicates that there is recent fecal contamination of a water supply, and either *E. coli* or another fecal bacteria can cause serious gastrointestinal illness (Health Canada, 2012). The ensuing enteric illness creates a serious risk of dehydration and can be fatal in some cases. Some rare strains of *E. coli* (O157:H7) can also cause kidney failure (Wong, Jelacic, Habeeb, Watkins, & Tarr, 2000).

### **Is *E. coli* a Health Risk in NL?**

*E. coli* is a serious health concern in NL and should be monitored regularly in all water supplies. In NL, total coliforms is used as a first step test as an indicator of bacterial contamination. Over 10% of public water tests in peak months show presence of total coliforms (Johnson, 2014). If total coliforms are present in a water sample, it is further tested for *E. coli* contamination. In peak months, approximately 1% of tests of public water supplies show *E. coli* contamination (Johnson, 2014).

### **What Does the Literature Say About the Health Risks From?**

Studies, including one of Walkerton, Ontario after the gastroenteritis outbreak of 2000 found that those who developed symptoms had an increased risk for hypertension (high blood pressure), kidney problems and some increased risk for cardiovascular disease (Clark et al., 2010; Garg et al., 2005). A 2009 study also found a trend towards hypertension in pregnant women who had contracted gastroenteritis during the Walkerton outbreak (Moist et al., 2009).

## **Giardia and Cryptosporidium**

*GCDWQ Treatment goal: Minimum 3 log reduction and/or inactivation*

### **Main Health Concerns**

Giardia and cryptosporidium are parasites that can be found in water that has recent fecal contamination. These can cause gastrointestinal illness (e.g. nausea, vomiting, diarrhea). Giardia is the cause of giardiasis, which is more commonly known as “Beaver Fever.”

Chlorination may not kill giardia, however, boiling water for at least one minute will (DOEC, 2009b).

### **Are Giardia and Cryptosporidium a Health Risk in NL?**

Yes. Both giardia and cryptosporidium can be found in NL, especially in surface water supplies, or in water from untreated, roadside springs (DOEC, 2009b).

### **What Does the Literature Say About the Health Risks From Giardia and Cryptosporidium?**

In rare cases, health effects can include respiratory symptoms, central nervous system infections, liver infections and muscular syndromes (Health Canada, 2012).

## **Turbidity**

*GCDWQ MAC: 1 NTU*

### **Main Health Concerns**

Turbidity is a measure of the total dissolved solids in water, and manifests as cloudiness. While turbidity itself is not a primary health concern, it serves as a secondary indicator of many possible problems. Turbid water may allow bacteria to essentially hide from disinfection agents. Fluctuating turbidity is also a strong indicator of malfunctions within a disinfection system (Health Canada, 2012).

## **Chemical Contaminants**

Many chemical contaminants are a serious and immediate health risk when consumed in large quantities. In NL however, the main concern is health risks associated from prolonged exposure to low-levels of chemical contaminants that are still considered toxic. For example, the groundwater levels of arsenic are not comparable with those experienced in India or Bangladesh. Where possible, academic literature cited focuses on potential health risks from exposure comparable to the levels experienced in NL.

In addition to the academic literature and available government documents from the province of NL, the following resources were utilized in assembling this information on potential health risks from chemical contaminants in drinking water.

The ToxFAQ's database is a resource established by the ATSDR with the Center for Disease Control (CDC) in the United States. Each document presents the key high-level health risks for a contaminant as established by leading health experts. This database served as an initial focusing point for driving the investigation of evidence into public health risks from the below potential water contaminants.

The Health Canada Guide to Drinking Water Quality provides the standard of the MAC for contaminants in NL. Furthermore, this resource provides high-level information on the health justification for the MAC of each particular contaminant.

One of the major health concerns of many chemical contaminants is cancer. The IARC of the World Health Organization (WHO) has a classification system for the carcinogenic quality of each contaminant. The classification is included with each contaminant where appropriate. These groups are summarized in Table 1.1. Group 1 denotes a contaminant that has sufficient evidence to prove the agent is cancer causing in humans. Group 2A shows there is limited evidence to suggest carcinogenicity in humans, but there has been sufficient evidence to show that an agent is cancer causing in animals with a mechanism that likely operates in humans. Group 2B shows there is limited evidence to suggest an agent causes cancer in humans, and there also is not sufficient evidence to prove carcinogenicity in animals. Group 3 signifies that there is inadequate evidence of carcinogenicity in humans as well as animals. Finally, group 4 is used when there is evidence suggesting that an agent does not cause cancer in humans or animals (IARC, 2006).

Group 1	Carcinogenic to humans
Group 2A	Probably carcinogenic to humans
Group 2B	Possibly carcinogenic to humans
Group 3	Not classifiable as to its carcinogenicity to humans
Group 4	Probably not carcinogenic to humans

## Antimony

*GCDWQ MAC: 0.006 mg/L*

*IARC Classification: Group 2B (possible human carcinogen - antimony trioxide); Group 3 (not able to be classified - antimony trisulfide).*

### Main Health Concerns

The main health concern from ingesting antimony are microscopic changes to organs that have been shown to happen in rats.

### Is Antimony a Health Risk in NL?

Antimony is a naturally occurring element that can be found in the ground, and exposure can also occur from industrial pollution (ATSDR, 1992). Antimony is a minor concern in NL. There is minimal evidence to suggest that there might be antimony in the water of some parts of NL.

### Carcinogenicity

The International Agency for Research on Cancer has classified antimony trioxide as a possible human carcinogen. Antimony trisulfide, another common antimony compound has been deemed not classifiable (IARC, 2006).

### What Does the Literature Say About the Health Risks From Antimony?

Antimony in drinking water has been shown to cause liver damage, blood in the urine, and microscopic changes to the thyroid, liver, pituitary, thymus and spleen of rats (Poon et al., 1998). While antimony is a known human health risk by inhalation (eye and lung irritation, heart and lung problems, stomach pain and ulcers, diarrhea and vomiting) and ingesting large amounts will induce vomiting, little research has been done on the specific human health effects by ingestion (ATSDR, 1992).

## Arsenic

*GCDWQ MAC: 0.01 mg/L*

*IARC Classification: Group 1 (known human carcinogen)*

### Main Health Concerns

Arsenic is a particularly toxic chemical that is known to cause cancer (lung, bladder, liver, skin). Arsenic can also cause skin darkening as well as warts, and may be a cause of hypertension, and diabetes. Long-term exposure in children may lower IQ test scores. Arsenic can also cross the placenta and be found in fetal tissues (ATSDR, 2007a).

### Is Arsenic a Health Risk in NL?

Yes. Arsenic is an element appearing naturally in the ground in NL. The DOEC provides a map showing the areas of higher risk (DOEC, 2013a).

### Carcinogenicity

The International Agency for Research on Cancer has classified arsenic as a known human carcinogen (IARC, 2006).

### What Does the Literature Say About the Health Risks From Arsenic?

A new study from 2013 published in the *Annals of Internal Medicine*, shows that exposure to even low levels of arsenic (less than 0.100 mg/L) may increase the risk for cardiovascular disease (Moon et al., 2013). This study builds on previous research which found high levels of arsenic to increase the risk for cardiovascular disease, but required more data on lower level exposure (Balakumar & Kaur, 2009; Moon, Guallar, & Navas-Acien, 2012). A systematic review of 6 studies, as well as new evidence has found a relationship between arsenic exposure and hypertension (Abhyankar, Jones, Guallar, & Navas-Acien, 2012; Kunrath et al., 2013). Furthermore, a recent US study found that lower level exposure to arsenic can cause an increased risk for stroke (Lisabeth et al., 2010)

Research in Bangladesh, Mexico and China has shown exposure to drinking water arsenic to decrease child IQ scores (Calderon et al., 2001; Hamadani et al., 2011; Wang et al., 2007). 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).

Arsenic from drinking water has been shown to cause liver damage (Mazumder, 2005). Furthermore, arsenic is believed to be a cause for skin cancer (Cabrera &



Gomez, 2003). Arsenic is also known to cause lung cancer when inhaled. A systematic review of 17 studies found a relationship between high arsenic exposure from drinking water and lung cancer (Celik et al., 2008). While this study dealt with exposure levels of more than double those found in NL, a 2000 study found increased risk for bladder, liver and lung cancer at levels just about those found in some parts of NL (Morales, Ryan, Kuo, Wu, & Chen, 2000).

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

Even at levels equivalent to the safe guideline value, arsenic exposure in rats has been shown to cause chromosome abnormalities (Kesari, Kumar, & Khan, 2012). An analysis in Michigan found higher mortality rates from cerebrovascular disease, diabetes, and kidney disease in those exposed to low levels of arsenic in drinking water (Meliker, Wahl, Cameron, & Nriagu, 2007).

#### **Contrary Research**

The cancer risk at lower level exposure is still debatable, as new evidence, as well as a review of 8 studies did not find that lower level exposure to arsenic caused an increased risk of bladder cancer (Meliker et al., 2010; Mink, Alexander, Barraja, Kelsh, & Tsuji, 2008). A review of studies from Taiwan, India, Canada and Britain found that arsenic exposure was not linked with an increased risk for childhood cancer (Engel & Lamm, 2008).

Furthermore, a recent study in Denmark found that exposure to low levels of arsenic actually causes a decreased risk for skin cancer (Baastrup et al., 2008).

## **Barium**

*GCDWQ MAC: 1 mg/L*

#### **Main Health Concerns**

Exposure to barium through drinking water has been shown to cause an increase in blood pressure, as well as an increased risk of cardiovascular disease. In addition, ingesting high levels of barium can cause vomiting, abdominal cramps, diarrhea, numbness around the face and muscle weakness. Prolonged high-level exposure can also cause damage to the kidneys (ATSDR, 2007b).

#### **Is Barium a Health Risk in NL?**

Barium is a minor concern in NL. There is some evidence to suggest that there might be barium in the water of some parts of NL. Barium is a naturally occurring element that can be found in the ground, and exposure can also occur from industrial pollution (ATSDR, 2007b).

### Carcinogenicity

The US Environmental Protection Agency (EPA) has determined that barium is not likely to cause cancer by ingestion (ATSDR, 2007b).

### What Does the Literature Say About the Health Risks From Barium?

While there has been little human research into the health effects of barium, both Health Canada, in the Guide to Canadian Drinking Water Quality, and the EPA consider barium a potential health risk when consumed in drinking water in high concentrations.

A 2012 study was the first to show that prolonged exposure to barium in drinking water causes hearing loss in mice (Ohgami et al., 2012). There has yet to be any human research on the topic.

### Contrary Research

A 1990 study from the journal, Environmental Health Perspectives, found that drinking water contaminated with barium at up to 10 mg/L did not increase risk for cardiovascular disease (Wones, Stadler, & Frohman, 1990), however, this study only followed 11 healthy men for a 10 week period. In addition, a 1981 study found no relationship between elevated levels of barium in drinking water and blood pressure (Brenniman, Kojola, Levy, Carnow, & Namekata, 1981).

## Cadmium

*GCDWQ MAC: 0.005 mg/L*

*IARC Classification: Group 1 (known human carcinogen)*

### Main Health Concerns

Cadmium is a known human carcinogen, and is a component of cigarette smoke. Lung cancer is a serious risk by inhalation, as is kidney cancer when exposed from drinking water (Health Canada, 2012). Long-term exposure to cadmium can also cause the development of fragile bones (ATSDR, 2012a).

### Is Cadmium a Health Risk in NL?

Cadmium is a minor concern in NL. There is some evidence to suggest that there might be cadmium in the water of some parts of NL. Cadmium is a naturally occurring element that can be found in the ground, and exposure can also occur from industrial pollution (ATSDR, 2012a).

### Carcinogenicity

The International Agency for Research on Cancer has determined that cadmium is a known human carcinogen (IARC, 2006). Most evidence deals with cadmium and lung cancer by inhalation, but research suggests that kidney, breast and prostate cancer might also be risks (Hartwig, 2013).

### What Does the Literature Say About the Health Risks From Cadmium?

Research shows that prolonged exposure to low levels of cadmium increases the risk for osteoporosis as well as hip and vertebral fractures (Brzoska & Moniuszko-

Jakoniuk, 2004; Brzoska, 2012; Dahl et al., 2014; S. S. Krishnan, Lui, Jervis, & Harrison, 1990; Youness, Mohammed, & Morsy, 2012).

Research in rats has shown damage to the liver, kidney and testes when exposed to high levels of cadmium (Saygi, Deniz, Kutsal, & Vural, 1991). More importantly though, kidney damage has been seen in mice with chronic exposure to lower levels at or around the safe limit (Thijssen, Maringwa, Faes, Lambrichts, & Van Kerkhove, 2007). Kidney damage has also been found in drinking water exposure in humans (Honda et al., 2010).

Rats exposed to drinking water contaminated with both cadmium and fluoride experienced more kidney and liver damage than rats exposed to only cadmium or fluoride (Zhang et al., 2013).

A 2009 study found a correlation between increased cadmium exposure and decreased sperm concentration and motility in adult males. (Benoff et al., 2009)

## Chromium

*GCDWQ MAC: 0.05 mg/L*

*IARC Classification: Group 1 (known human carcinogen – chromium (VI) compounds); Group 3 (not able to be classified – chromium (III) compounds, and metallic chromium)*

### Main Health Concerns

While chromium is an essential element in small quantities, hexavalent chromium compounds are known to cause stomach cancer. Skin exposure to chromium can also cause ulcers and sores. Evidence in animals shows stomach and small intestine ulcers as well as anemia and sperm damage (ATSDR, 2012b).

### Is Chromium a Health Risk in NL?

Chromium is a minor concern in NL. There is some evidence to suggest that there might be chromium in the water of some parts of NL. Chromium is a naturally occurring element that can be found in the ground, and exposure can also occur from industrial pollution (ATSDR, 2012b).

### Carcinogenicity

The International Agency for Research on Cancer has determined that hexavalent chromium compounds are known to cause lung cancer when inhaled, and are likely to cause stomach cancer when consumed in drinking water. Chromium metal, as well as trivalent chromium compounds are still unclassifiable (IARC, 2006).

### What Does the Literature Say About the Health Risks From Chromium?

There has been considerable debate in the academic literature on whether hexavalent chromium causes cancer when consumed in drinking water (Costa, 1997; Costa, 2003; Costa & Klein, 2006; Paustenbach, Finley, Mowat, & Kerger, 2003; Post & Stern, 2006; Proctor et al., 2002). The most recent consensus from models on exposure in mice and rats, as well as environmental exposure in China is

that hexavalent chromium should be treated as a carcinogen when ingested in drinking water (Smith & Steinmaus, 2009; Stern, 2010; Zhitkovich, 2011).

Some animal research has shown developmental issues with chromium (VI) exposure (ATSDR, 2012b). A small case report of two individuals reported a potential link between Hodgkin's disease and exposure to chromium by drinking water (Bick, Girardi, Lack, Costa, & Titelbaum, 1996).

## Fluoride

*GCDWQ MAC: 1.5 mg/L*

*IARC Classification: Group 3 (not able to be classified)*

### Main Health Concerns

In lower amounts, fluoride is effective at hardening bone and preventing dental cavities. However, after prolonged higher-level exposure, dental fluorosis, or very white teeth can result as a cosmetic concern, especially in children under age 8. After prolonged higher-level exposure, bone density can become too high, causing bones to be brittle (ATSDR, 2003a). Fluoride in drinking water is a contentious issue because of dental concerns and concerns of a possible decrease in child IQ scores, though evidence here is not definitive at low-level exposure (Borman & Fyfe, 2013; Choi, Grandjean, Sun, & Zhang, 2013; Sabour & Ghorbani, 2013).

### Is Fluoride a Health Risk in NL?

Yes. Fluoride is an element appearing naturally in the ground in NL. The DOEC provides a map showing the areas of higher risk (DOEC, 2013b).

### Carcinogenicity

The International Agency for Research on Cancer has determined that Fluoride is not yet able to be classified in terms of carcinogenicity (IARC, 2006). Two animal studies have so far been inconclusive on fluoride causing cancer (ATSDR, 2003a).

### What Does the Literature Say About the Health Risks From Fluoride?

Studies have shown that exposure to fluoride in drinking water can cause slight neurodevelopment issues in children that manifest in lower IQ scores (Choi, Sun, Zhang, & Grandjean, 2012; Saxena, Sahay, & Goel, 2012; Seraj et al., 2012). This evidence was at exposure levels much higher than those in North America and has been contested in the academic literature (Borman & Fyfe, 2013; Choi, Grandjean, Sun, & Zhang, 2013; Sabour & Ghorbani, 2013).

Recent evidence shows that there is not a link between fluorinated drinking water and bone cancer (Blakey et al., 2014; Hrudehy, Soskolne, Berkel, & Fincham, 1990; Levy & Leclerc, 2012), however, one study in India involving only 20 participants suggests there may be a link (Kharb, Sandhu, & Kundu, 2012).

While high exposure to fluoride has been shown to increase bone fragility in sheep (Simon et al., 2014), it was not found to be a significant increase in hip fractures in humans (Nasman, Ekstrand, Granath, Ekblom, & Fored, 2013).

Studies looking at fluoride exposure in rats found a significant reduction in fertility (Lu, Wang, Sun, Niu, & Wang, 2014; Zhou et al., 2013).

### Contrary Research

A recent study from Japan found that high Fluoride exposure did not cause hypertension (Ostovar, Dobaradaran, Ravanipour, & Khajeian, 2013).

The question of whether fluoride in drinking water delays tooth eruption has been a contentious issue. Recent evidence shows that fluoride exposure in drinking water was not found to delay tooth eruption in children (Jolaoso, Kumar, & Moss, 2014).

### Further Research

Studies in Iran, Turkey and China have found a significant risk of hypertension from high fluoride exposure (Amini et al., 2011; Sun et al., 2013; Varol & Varol, 2012).

## Lead

*GCDWQ MAC: 0.010 mg/L*

*IARC Classification: Group 2A (probable human carcinogen – inorganic lead compounds); Group 2B (possible human carcinogen – lead metal); Group 3 (not able to be classified – organic lead compounds)*

### Main Health Concerns

Lead is a particularly toxic element that can affect almost every organ and system in the body, but the main concern is the nervous system (ATSDR, 2007c). Long-term exposure can result in weakness. Lead exposure is particularly harmful to children. Even exposure to small amounts of lead in children can interfere with intellectual development and cause anemia (Health Canada, 2012). Lead exposure can also cause hypertension and anemia. Lead exposure to pregnant women can result in premature births, smaller babies, decreased mental ability, as well as learning and growth difficulties (Health Canada, 2012).

### Is Lead a Health Risk in NL?

Yes. Lead is an element appearing naturally in the ground in NL. There is evidence to show lead present in the water in much of the province.

### Carcinogenicity

The International Agency for Research on Cancer has determined that inorganic lead compounds are probable human carcinogens. More research is required into lead metal (possible human carcinogen) and organic lead compounds (not able to be classified) (IARC, 2006). Mice have been shown to develop kidney tumors from exposure to inorganic lead compounds (ATSDR, 2007c).

### What Does the Literature Say About the Health Risks From Lead?

The neurological system is particularly vulnerable to lead exposure. Fetal lead exposure, even at very low levels has been shown to decrease cognitive function (Jedrychowski et al., 2009). 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 (Boucher et al., 2012; Eubig, Aguiar, & Schantz, 2010). Furthermore, exposure to lead in early childhood has been associated with a decrease in IQ in later childhood (Bellinger, Stiles, & Needleman, 1992; Cummins & Goldman, 1992). Evidence does however suggest that cognitive effects due to lead exposure are reversible, at least in adults (Winker et al., 2005). Though experiments in rats have shown memory loss to be persistent (Gilbert, Kelly, Samsam, & Goodman, 2005; Murphy & Regan, 1999).

While a debated issue, evidence also suggests that low-level lead exposure increases the risk for hypertension in humans (Houston & Johnson, 1999; Kopp, Barron, & Tow, 1988; Scinicariello, Abadin, & Murray, 2011) as well as animals (Fiorim et al., 2011; Staessen, Lauwerys et al., 1994). It is important to note that the causal nature of this relationship has been strongly debated (Dolenc, Staessen, Lauwerys, & Amery, 1993; Staessen, Bulpitt et al., 1994).

Lead exposure can cause considerable damage to the kidneys. 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, He, Vupputuri, Coresh, & Batuman, 2003; Sommar et al., 2013)

Lead also poses risks to reproductive outcomes. 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). Lead exposure during pregnancy may result in low birth weight (Xie et al., 2013). Also, new research has shown low-level lead exposure associated with an earlier age for menopause (Eum, Weisskopf, Nie, Hu, & Korrick, 2014).

### **Contrary Research**

A study out of Nepal found that exposure to arsenic and lead in utero did not manifest in neurodevelopment problems at 6 months old (Parajuli et al., 2014).

### **Other Research**

Low-level exposure to lead has been associated with an increase prevalence of gout (E. Krishnan, Lingala, & Bhalla, 2012).

Research also suggests that exposure to high levels of lead in drinking water can increase the risk of hip fracture (Dahl et al., 2014).

## **Mercury**

*GCDWQ MAC: 0.001 mg/L*

*IARC Classification: Group 3 (not able to be classified)*

### **Main Health Concerns**

Exposure to mercury can cause serious nervous system damage, which can result in permanent memory problems, irritability, tremors or changes to vision and hearing.

Higher level exposure can also cause damage to the kidney, or a developing fetus (ATSDR, 1999).

#### **Is Mercury a Health Risk in NL?**

Mercury is a minor concern in NL. There is some evidence to suggest that there might be mercury in the water of some parts of NL. Mercury is a naturally occurring element that can be found in the ground, and exposure can also occur from industrial pollution, as well as some dental work (ATSDR, 1999). There is however, no research into the effects of low-level exposure like those that might be found in NL

#### **Carcinogenicity**

The International Agency for Research on Cancer has determined that mercury is not able to be classified in terms of carcinogenicity (IARC, 2006). The EPA has determined that mercuric chloride and methylmercury are possible human carcinogens (ATSDR, 1999).

#### **What Does the Literature Say About the Health Risks From Mercury?**

While mercury is a known poison, little research has been done on the health impacts in humans of mercury exposure via drinking water.

## **Selenium**

*GCDWQ MAC: 0.01 mg/L*

*IARC Classification: Group 3 (not able to be classified)*

#### **Main Health Concerns**

Selenium is an essential element in small quantities, and has even been shown to decrease symptoms of depression (Johnson et al., 2013). However, long-term exposure to high levels can result in selenosis (brittle hair, nails, and some numbness or other neurological effects). Ingesting high quantities can result in nausea and vomiting (ATSDR, 2003b).

#### **Is Selenium a health risk in NL?**

Selenium is a minor concern in NL. There is some evidence to suggest that there might be selenium in the water of some parts of NL. Selenium is a naturally occurring element that can be found in the ground (ATSDR, 2003b).

#### **Carcinogenicity**

The International Agency for Research on Cancer has determined that selenium is not able to be classified as to its carcinogenicity (IARC, 2006). However, one study suggests that selenium deficiency might actually increase the risk for cancer (ATSDR, 2003b).

#### **What Does the Literature Say About the Health Risks From Selenium?**

A review of available evidence of high selenium exposure in the late 1990's found possible symptoms to include numbness and pain in extremities, nausea, vomiting, bad teeth, diseased nails, arthritis and fatigue and irritability (Valentine, 1997).

Observation of a population exposed to high levels of selenium found a higher rate of death from some cancers (colorectal cancer, melanoma) and some neurological conditions. The authors however readily admit that there is a lack of information about potential confounders, and the study is quite simple (Vinceti, Nacci et al., 2000). Selenium is not believed to have any significant reproductive effects (Vinceti, Cann et al., 2000).

#### **Contrary Research**

The Valentine review also noted two studies that did not find any notable symptoms from high selenium exposure (Valentine, 1997).

#### **Further Research Required**

New research suggests that 0.01 mg/L is not a safe upper limit for selenium intake, and that 0.001 mg/L should be proposed as the guideline value. Further research is required to investigate (Vinceti et al., 2013).

## **Uranium**

*GCDWQ MAC: 0.02 mg/L*

#### **Main Health Concerns**

The key health concern from exposure to uranium by drinking water is kidney damage (Health Canada, 2012).

#### **Is Uranium a health risk in NL?**

Yes. Uranium is an element appearing naturally in the ground in NL. The DOEC provides a map showing the areas of higher risk (DOEC, 2013c).

#### **Carcinogenicity**

The International Agency for Research on Cancer has not classified uranium in terms of its carcinogenicity (IARC, 2006). There is some research out of Germany suggesting that uranium in the drinking water can cause an increased risk of leukemia in men, and cancer of the kidney and lung in women (Radespiel-Troger & Meyer, 2013). However, a large study out of Finland did not find any link between uranium exposure in drinking water from drilled wells and cases of kidney and bladder cancer (Kurttio, Salonen et al., 2006).

#### **What Does the Literature Say About the Health Risks From Uranium?**

Research on the health impacts of uranium has been predominantly on kidney effects. Several studies have found that Uranium exposure from drinking water effects kidney function, even at low exposure levels around the MAC (Arzuaga, Rieth, Bathija, & Cooper, 2010; Kurttio et al., 2002; Zamora, Tracy, Zielinski, Meyerhof, & Moss, 1998). Studies have also shown that the health effect of uranium is chemical, not radioactive (Zamora et al., 2009).



### Contrary Research

A 2006 study in Finland of 95 men and 98 women who were exposed to an average uranium concentration of 0.025 mg/L did not find any toxic effects to kidney cells (Kurttio, Harmoinen et al., 2006).

## Disinfection By-products (DBP's)

Disinfection by-products (DBP's) can occur when disinfectant chemicals react with other organic material that is in the water supply. Of the potential DBP's, trihalomethanes (THM's) and halogenic acetic acids (HAA's) are the most commonly found in NL. Since the discovery of DBP's in 1974, over 60 epidemiological studies have been done on the potential health risks (Hrudey, 2009). The results of these studies are quite varied, and in many cases offer conflicting evidence in terms of the associated health impacts. It is important to note that the risk from drinking untreated water is greater than any known risk from drinking water contaminated with DBP's, according to the Provincial Government of NL (DOEC, 2009a).

### Trihalomethanes (THM's)

*GCDWQ MAC: 0.1 mg/L*

*Chlorodibromomethane, IARC Classification: Group 3 (not able to be classified)*

*Chloroform, IARC Classification: Group 2B (possible human carcinogen)*

*Bromodichloromethane IARC Classification: Group 2B (possible human carcinogen)*

*Bromoform; IARC Classification: Group 3 (not able to be classified)*

### Main Health Concerns

There is evidence to suggest that drinking water contaminated with high levels of THM's causes an increased risk of bladder, colon, liver and kidney cancer. There are also potential risks for pregnant women including miscarriage, birth defects, and low birth weight (ATSDR, 1992; 1997; 1989).

### Are THM's a Health Risk in NL?

Yes. Currently, 132 water supplies in NL have high THM concentrations (Johnson, 2014). THM's can be ingested from contaminated water, but small amounts can also be inhaled while showering or absorbed through the skin while swimming or showering (ATSDR, 1992; 1997; 1989).

The DOEC is clear to point out that the risk from drinking untreated water is greater than the risk from drinking water contaminated with THM's (DOEC, 2009a).

### Carcinogenicity

The International Agency for Research on Cancer has classified chloroform and bromoform, two of the most common THM's, as possible human carcinogens (IARC, 2006).

## Exposure

The greatest risk from THM exposure comes from ingestion from contaminated drinking water. While it is possible to inhale THM's while showering, a Quebec study found the level the liver would be exposed to by this means from a 10 minute shower is less than one six-thousandth of the safe limit (Levesque et al., 2002)

## What Does the Literature Say About the Health Risks From THM's?

There is good evidence to show an increased risk of bladder and rectal cancer with high THM exposure (Bove, Rogerson, & Vena, 2007; Morris, Audet, Angelillo, Chalmers, & Mosteller, 1992; Nieuwenhuijsen, Grellier et al., 2009).

THM's may also pose some reproductive health risks. There is some evidence to suggest that high exposure to THM's may cause low birth weight (Kumar, Forand, Babcock, & Hwang, 2014; Lewis, Suffet, & Ritz, 2006). Also, a small study found drinking THM's at the guideline value may decrease semen quality, though there is evidence to the contrary (Fenster et al., 2003).

Studies in rats have found exposure to high levels of THM's cause the rats to develop liver and kidney damage (ATSDR, 1992; 1997; 1989; Komulainen, 2004).

## Contrary Research

While some studies have shown high THM exposure to pose a risk for low birth weight, there is evidence to the contrary for other reproductive risks, like preterm birth, pregnancy loss, and congenital malformations (Iszatt, Nieuwenhuijsen, Nelson, Elliott, & Toledano, 2011; Nieuwenhuijsen, Martinez et al., 2009; Savitz et al., 2006; Shaw et al., 2003). A large study also did not find exposure to high levels of DBP's to alter sperm quality (Luben et al., 2007).

While consumption of THM contaminated drinking water has been probably linked to bladder cancer, a large 2007 study in Spain has shown that increased consumption of drinking water, even if contaminated with THM's shows a decreased risk for bladder cancer (Michaud et al., 2007). The authors attribute this to the increased flushing of the bladder from more frequent urination.

## Halogenic Acetic Acids (HAA's)

*GCDWQ MAC: 0.08 mg/L*

monochloroacetic acid (MCA),

dichloroacetic acid (DCA), *IARC Classification: Group 2B (possible human carcinogen)*

trichloroacetic acid (TCA), *IARC Classification: Group 2B (possible human carcinogen)*

monobromoacetic acid (MBA)

dibromoacetic acid (DBA) *IARC Classification: Group 2B (possible human carcinogen)*

## Main Health Concerns

The main concern from drinking water contaminated with high levels of HAA's is an increased risk for liver cancer, as well as possible birth defects (Health Canada, 2012).

### Are HAA's a Health Risk in NL?

Yes. Currently in NL, 147 water supplies have high HAA levels (Johnson, 2014). NL had the second highest exposure of any Canadian province (Chowdhury, Rodriguez, & Sadiq, 2011).

### Carcinogenicity

The International Agency for Research on Cancer has classified three common HAA's, dichloroacetic acid (DCA), trichloroacetic acid (TCA), and dibromoacetic acid (DBA) as possible human carcinogens (IARC, 2006).

### What Does the Literature Say About the Health Risks From HAA's?

Laboratory evidence has shown HAA's to pose a cancer risk in animals. A recent review of the available evidence found that DCA and TCA cause liver cancer in mice, and DCA causes liver cancer in male rats (Komulainen, 2004).

### Contrary Research

There is some concern that HAA's pose potential reproductive health risks. Recent research in this regard has been positive. A Canadian study did not find any association between HAA exposure and risk for stillbirth (King et al., 2005). As well, no increased risk was found for pregnancy loss with elevated DBP's, including HAA's (Savitz et al., 2006).

### Further Research Required

While THM's and HAA's are the most prevalent disinfectant by-products, there is still work to be done at discovering and understanding more emerging disinfection by-products (Richardson, Plewa, Wagner, Schoeny, & Demarini, 2007).

Furthermore, there is some evidence to suggest that the interactions between multiple disinfection by-products may have effects on the potential health risks. These interactions are not yet well understood (Komulainen, 2004).

## Conclusion

The above review is assembled as a resource to emphasize the importance of clean, safe drinking water for the good health of residents of Newfoundland and Labrador. Information from the academic literature, government documents, the GCDWQ, the IARC and the database of the ATSDR outlines potential health risks from exposure to the above contaminants. In the case of microbiological contaminants like *E. coli*, the main concern is immediate gastrointestinal upset which can result in dehydration which can be very serious especially in the young, the elderly, or those not in good health. Kidney damage from certain rare strains of *E. coli* is a further complication and critical concern. In the case of Chemical contaminants and DPB's, the principal concern is alterations to health from long term chronic exposure to levels above the guideline value. The main concern here is the development of cancer, especially of the bladder, liver lung, kidney skin or stomach. Other chronic conditions like cardiovascular disease (including high blood pressure), diabetes, neurological conditions, developmental disorders and effects on bone health are also a concern.

Water is our most precious resource, and efforts should be taken to ensure that water is safe through regular monitoring, and appropriate intervention when necessary.

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