Toenails, Tap Water and You: The Arsenic Connection[1]

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Introduction

Nova Scotia has the highest mortality rate for all types of cancers combined of any province or territory in Canada, and ranks second only to Prince Edward Island for having the highest incidence rates for cancer (Canadian Cancer Society, 2009). This translates into 6000 new cancer cases every year in Nova Scotia or to put it another way, nine men and eight women are diagnosed every day with cancer. Specifically, the incidence of urinary tract cancer (i.e. cancer of the bladder and/or kidney) is higher in Nova Scotia than anywhere else in the country and is nearly double the incidence rate reported in Ontario, where the rates are lowest (Canadian Cancer Society, 2009).

Why do the residents of Nova Scotia have the highest incidence rates of bladder and kidney cancer and is there a connection between cancer rates and arsenic in drinking water? Studies in other populations have found that people drinking water with high levels of arsenic have a substantially higher risk of developing urinary tract cancer and the World Health Organization identifies arsenic as a carcinogen and a major health hazard worldwide (http://www.who.int/en/). Nonetheless, the health consequences of low to moderately elevated levels of arsenic exposure through drinking water are not well described (Cantor and Lubin, 2007).

One of the largest cancer research studies ever conducted in Atlantic Canada is The Atlantic Partnership for Tomorrow's Health Project (Atlantic PATH). The Atlantic PATH Tap Water Sampling and Analysis sub-study aims to discover to what extent water-borne arsenic is affecting the health of Atlantic Canadians.

Arsenic in Nova Scotia

Arsenic is a very common and naturally occurring element found throughout Nova Scotia and is measureable at varying concentrations in all sample media (soil, rock, water, etc.). Elevated arsenic concentrations in the historical gold mining districts of the province were commonly portrayed to be the result of disturbances caused by human activities associated with former gold mining operations. Arsenopyrite is a very common arsenic-bearing accessory mineral that occurs in every gold district throughout Nova Scotia but also occurs naturally throughout all of Nova Scotia in rocks and soil: even in areas where mining has never occurred. Numerous regional soil and till geochemical surveys (i.e. Stea and Fowler, 1979; Woodman *et al*., 1994) demonstrate that arsenic is very common in these sample media and (mean) concentrations often exceed the Canadian Soil Quality Guidelines (CSQG) of 12 ppm arsenic (for residential, parkland, agriculture, commercial and industrial lands).

A recent province-wide soil sampling program further supports the regional distribution of naturally elevated arsenic in soil throughout Nova Scotia (Goodwin *et al*., 2009). Results of this program found that 56% of the sites sampled exceeded the CSQG of 12 ppm arsenic. The highest concentrations are commonly (but not exclusively) found in the Meguma Terrane of southern mainland Nova Scotia (Goodwin *et al*., 2009). It is important to stress that the soil samples collected represent natural background concentrations and are not

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related to any known mineralized sources of gold, arsenic or any other element (Goodwin *et al*., 2009).

The most common arsenic-bearing mineral found in Nova Scotia is arsenopyrite, an iron-arsenic sulphide. Arsenopyrite is relatively soluble and highly mobile under certain Eh-pH conditions. As a result of its solubility, arsenopyrite will readily break down liberating arsenic (and iron and sulphur) into the surface water or groundwater relatively easily, regardless of whether or not an area has been subjected to mining activities. Locally, other (rare) arsenic-bearing minerals such as scorodite (a hydrated iron arsenate) may occur, particularly within oxidized zones of arsenopyrite-rich tailings associated with former gold mining districts.

Arsenic in Nova Scotia Drinking Water

One of the major exposure pathways for humans to ingest arsenic is through drinking water. Approximately 45% of the residents of the province obtain their household drinking water from either a dug or drilled well. Therefore, the main exposure pathway for the ingestion of arsenic for Nova Scotians is through drinking water from individual wells.

A major case of chronic arsenic poisoning in Nova Scotia occurred in 1976 when a resident of the town of Waverley became ill after consuming arsenic-"contaminated" drinking water from their dug well, which was lined with arsenopyrite-bearing waste rock obtained from former gold mining operations of the Waverley Gold District (Grantham and Jones, 1977a, b; Hindmarsh *et al*., 1977). As a result of this case, the province initiated an Arsenic Task Force and results of their findings concluded that arsenic exceedences in drinking water can be expected in gold mining districts and in areas underlain by Meguma Group bedrock (effectively a large percentage of southern mainland Nova Scotia) that have no connection to gold mining or show any evidence of mineralization (Grantham and Jones, 1977a, b). In the 1970s, the Guidelines for Canadian Drinking Water Quality (GCDWQ) for arsenic in drinking water was 50 ppb (0.05 mg/L). Grantham and Jones (1977a, b) found that 13% of wells tested within known gold districts exceeded the 1970s guideline of 50 ppb. Drinking water obtained from wells tested outside of known gold districts from various subdivisions such as Collins Park in Wellington and Silversides on the edge of Dartmouth also exceeded the GCDWQ for 12% of the homes tested.

Meranger *et al*. (1984) conducted a similar study of arsenic in drinking water and determined that 70% of the drinking water supplies tested from individual wells from within seven communities in Halifax County exceeded the 1980s GCDWQ for arsenic of 50 ppb. Bottomley (1984) also noted that naturally occurring arsenopyrite occurs in bedrock throughout the Meguma Terrane but can be more abundant in a gold district. Bottomley (1984) also concluded that "the possibility of encountering arseniferous water during drilling is seen as a major deterrent to maximum development of the groundwater potential" of the Meguma Group rocks.

The current 2010 GCDWQ for arsenic is 10 ppb (0.01 mg/L) for total arsenic. Future studies, however, will need to look at arsenic speciation and determine the relative abundances of arsenite (As III) and arsenate (As V) because arsenite is significantly more toxic to humans than arsenate.

In addition to speciation, bioaccessibility (the fraction that is soluble in the gastrointestinal tract) and bioavailability (the fraction crossing the gastrointestinal tract and entering into the blood stream) will also need to be determined (Ruby *et al*., 1999). This is particularly relevant if the exposure pathway for arsenic by humans is through oral ingestion as opposed to inhalation or dermal contact. In this case, bioaccessibility and bioavailability will likely be strongly dependent on the mineral form of the arsenic ingested and its solubility characteristics within the human body.

For additional information on arsenic in Nova Scotia's drinking water, visit the Nova Scotia Environment website at http://www.gov.ns.ca/nse/water/arsenic.asp.

Tap Water Sampling and Analysis

The Atlantic PATH Tap Water Sampling and Analysis sub-study is researching the possibility of a link between arsenic in drinking water and the incidence of urinary tract (bladder and kidney) cancer for residents of Nova Scotia with a five year study; this is the largest cancer research study of its kind in Nova Scotia.

The sub-study commenced in 2009 and is currently in the process of registering approximately 5,000 volunteer residents (aged 35 to 69) of the province who will have their arsenic body burden determined through the analysis of their toenails. Participants' drinking water will also be tested for arsenic concentration (as well as other elements) because exposure to arsenic through the ingestion of drinking water has been linked to adverse health effects, including increased incidences of bladder and kidney cancer.

In the future, results from this study may help support a province-wide health risk assessment through the development of a model of arsenic hazard potential, which will incorporate bedrock and surficial geology with complimentary geochemical arsenic datasets.

NSDNR's Involvement

As previously mentioned, Nova Scotia also has high levels of naturally occurring arsenic concentrations in soil, bedrock and groundwater, as well as other sample media. The Nova Scotia Department of Natural Resources, as custodians of geoscientific data for the province, has a wealth of geologic-based information and knowledge specific to arsenic (and other elements). The department oversees and manages a continually expanding Geographic Information System (GIS) database, which contains all of the province's geoscience knowledge that is currently in digital format. The department has assisted the cancer study by providing digital files with numerous groundwater quality, geological, geochemical and topographic datasets. Besides the digital datasets, department geoscientists also have decades of knowledge and observations gained from field-based mapping and sampling programs throughout the province. Department staff members have also supplied information as requested, as well as rock samples. The department will continue to serve as a geoscientific resource to the study and assist with geology and hydrogeology queries and interpretations.

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