REPORT ON BLACK DUCK BROOK-WINTERHOUSE DRINKING WATER SURVEY

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Introduction

Black Duck Brook-Winterhouse is situated on the Port Au Port Peninsula (on the Gulf of Saint Lawrence, at Port Au Port Bay) on the island of Newfoundland (Black Duck Brook, n.d). The community had a total of 56 households (Statistics Canada, 2016) during census 2011.

This drinking water survey was conducted by Chez les Français/French Centre in the Black Duck Brook-Winterhouse community, in collaboration with RDÉE TNL and Grenfell Campus, Memorial University. There have been concerns concerning drinking water in the community, and this survey is the first step to better understanding the extent and nature of the problem(s) and gaining an overall picture of the community's drinking water. Residents have no access to a public drinking water system; the main sources of drinking water are well water, bought bottled water, and roadside/spring water (RDEE TNL, n.d).

Methodology

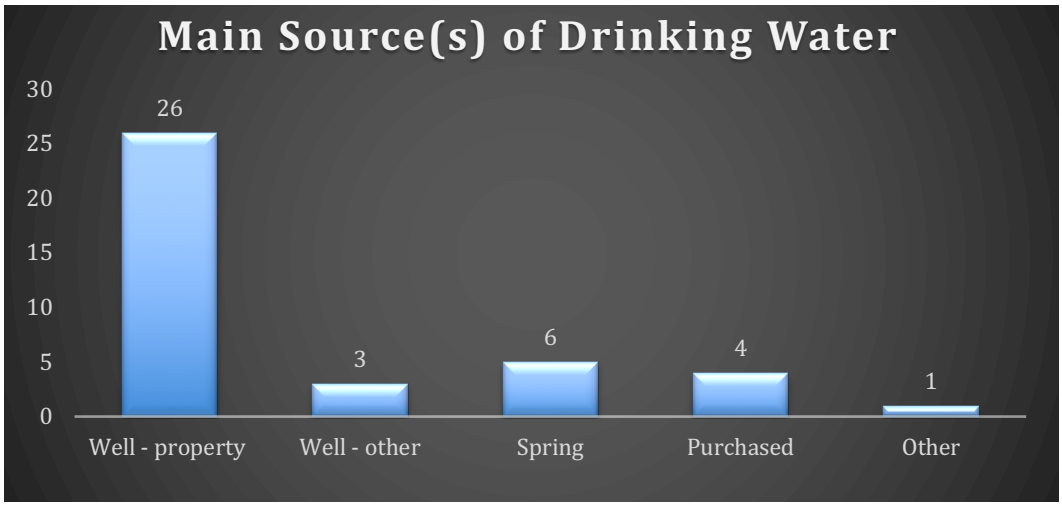
The survey was voluntary and was conducted by door-to-door visits using a structured questionnaire developed collaboratively by RDÉE TNL and Grenfell Campus researchers in consultation with the Department of Environment and Conservation, Water Resources Management Division. The questions were about the water quality, the type of well, well maintenance, and water analysis (see Appendix 1 for a copy of the survey). Residents were pre-informed by mail through a letter sent out by Chez les Français/French Centre. Most residents were open and welcoming to the survey. Out of the total of 55 households, residents from 39 households completed the survey, 2 declined to participate, and 13 surveys were left in mailboxes or with residents but not returned. In total 73% of households completed a survey, whilst 27% were not completed.

Survey Analysis

Main Source(s) of Drinking Water

A total of 39 households indicated their main source of drinking water on the survey. As outlined in Figure 1 below, 67% (26) of households obtain their drinking water from a well on their property, 13% (6) from a spring, 10% (4) purchase water, and 8% (3) obtain water from other well sources.

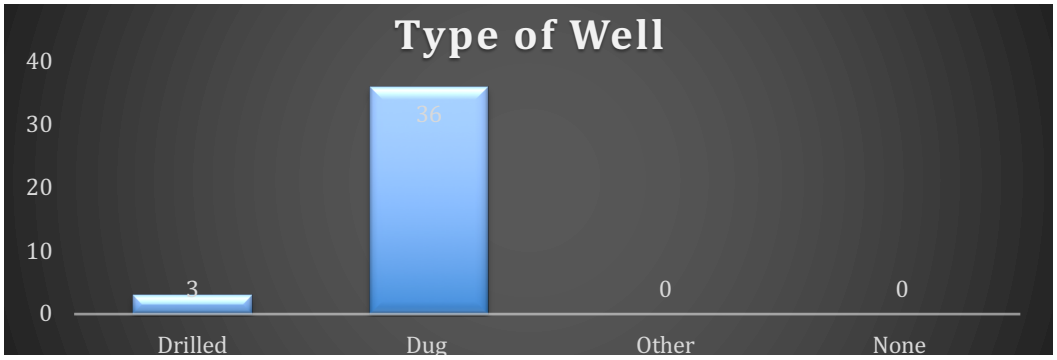
Figure 1. Main sources of drinking water



Well Characteristics

All participating households have wells, with the majority (92%, or 36 of the total of 39 households) having dug wells. Only 8% (3) of households have drilled wells.

Figure 2. Type of well



With regards to questions on drilled wells, all 3 households have wells installed by a licence well driller with depths of 16-30 m (50 to 98 feet), 31-45 m (99 to 148 feet) and

46-60 m (149-197 feet) respectively. Two of these wells are cased with steel extending above the surface at least 0.4 metres (1.5 feet) while one respondent indicated that their well is not cased. Two have steel vented vermin proof cap and the other has a plastic cap.

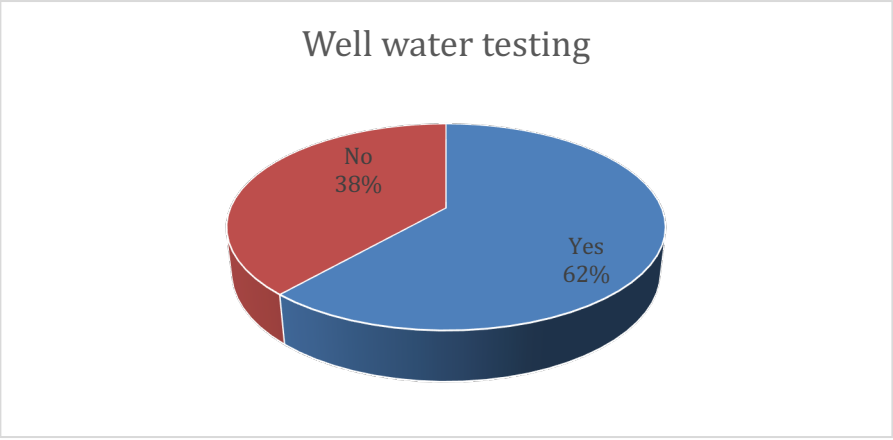
A total of 36 households answered questions regarding dug wells. 42% (15) of these households have wells dug by self/family, 44% (16) households had others (contractors, companies, landlord, hired people) dig their wells, while 14% (5) households don't know/are unsure who dug their well.

Out of 34 households, 32 households have dug wells with a depth of 0-6 m (less than 20 feet) and 2 households had dug wells with depth more than 10 m (more than 33 feet). Most (28) dug wells were lined, with 13 having black plastic liners and 15 other types (Teflon, brick, wood, plastic culvert, metal, wood, steel), whilst 6 households stated that their dug wells were not lined (2 indicated "wooden box"). All dug wells are capped, with the following well caps/covers: 28 wood, 2 steel, and 9 others (handmade steel cap, aluminum, styrofoam with vent, building over well, metal, plastic with the wood, plywood box, "two pieces of plywood for the moment", wood and aluminum).

Well Water Testing (both Drilled and Dug Wells)

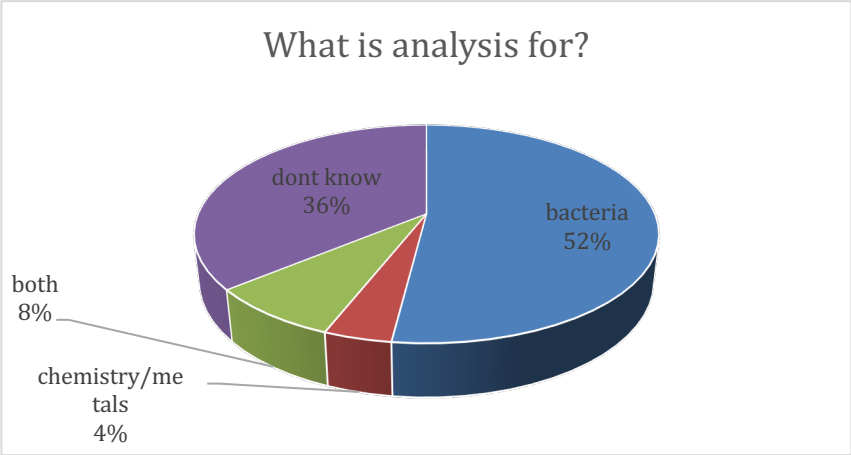
Out of a total of 39 participating households, only 62% (24) of households have ever tested their well water, while 38% (15) households have never tested.

Figure 3. Well water testing



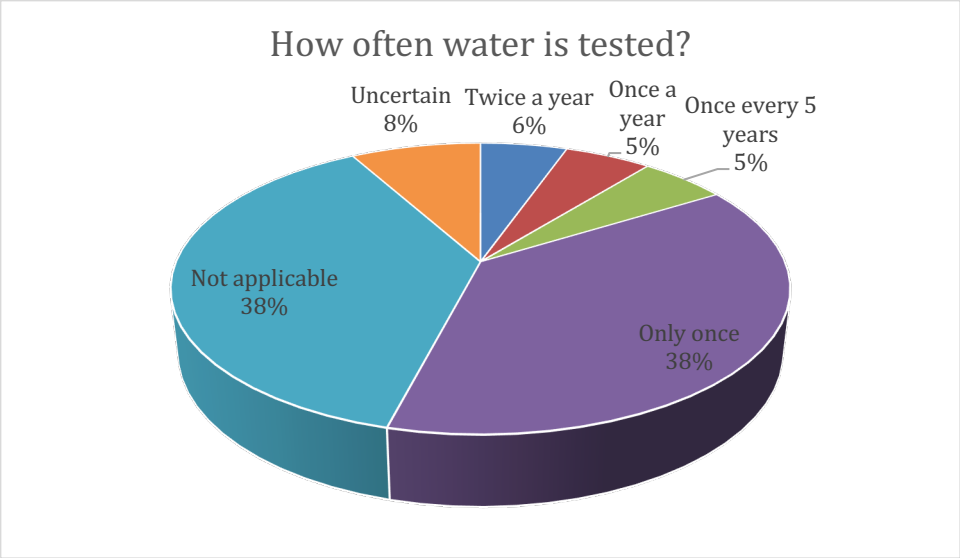
The majority of households who have ever tested their well water have analyzed for bacteria or are unsure what was tested for, while 8% (2) have tested for both bacteria and chemical/metals. Only 1 respondent indicated that they had tested for general chemistry/metals specifically. Households generally have not paid for the testing of their wells. The NL provincial government (Service NL/Public Health Laboratory) tested the well water of 22 households (for bacteria) while one household reported that a water softener company had tested their water for both e-coli and heavy metals.

Figure 4. What is analysed?



Most households who have conducted bacteriological analyses have tested their water only once, while one household tests twice a year, one had "tested twice 3 years ago" and another reported conducting testing "6 times since August." The test results identified issues with the well water of 6 households, while 15 households did not identify any issues. Of the issues identified, 3 refer to e-coli, one "coliforms but acceptable level", two uncertain and "water is safe but lime and something (uncertain)".

Figure 5. How often water is tested for bacteria?

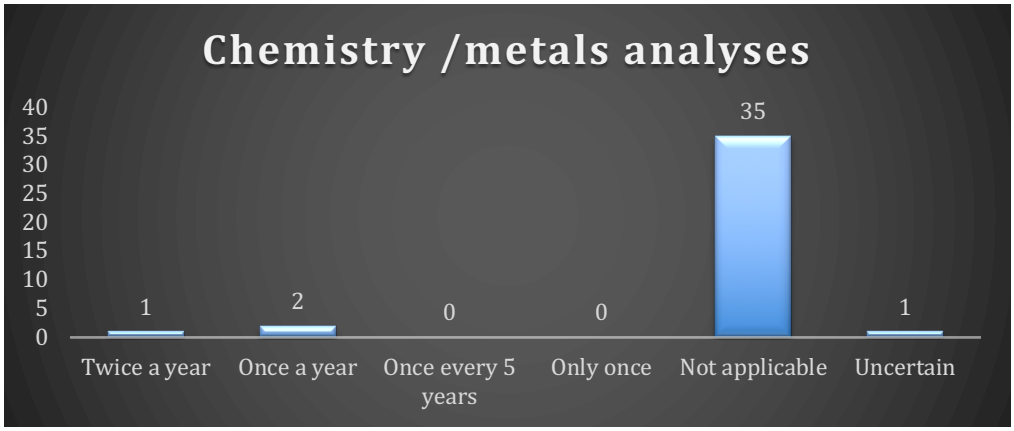


For general chemical/metals analyses, out of a total of 39 households, 35 (90%) of respondent's answered not applicable, implying that they have never had their water tested for chemistry and/or metals. Of the 3 households that indicated they had tested for chemical parameters, 5% (2) households have tested once a year and 1 household has tested twice a year. One household tested for "everything", while 2 were uncertain.

In answering the question about who tested their water, one household said the NL provincial government (Service NL/Public Health Laboratory) analyzed the well water sample, while private water quality laboratories had analyzed the well water samples of another household (one from Halifax and another from Toronto) and a water treatment supply company had analyzed another households' well water samples.

Following the results of the chemical/metals test, two households identified issues of iron and hard water after the analyses, while one household did not identify any issues.

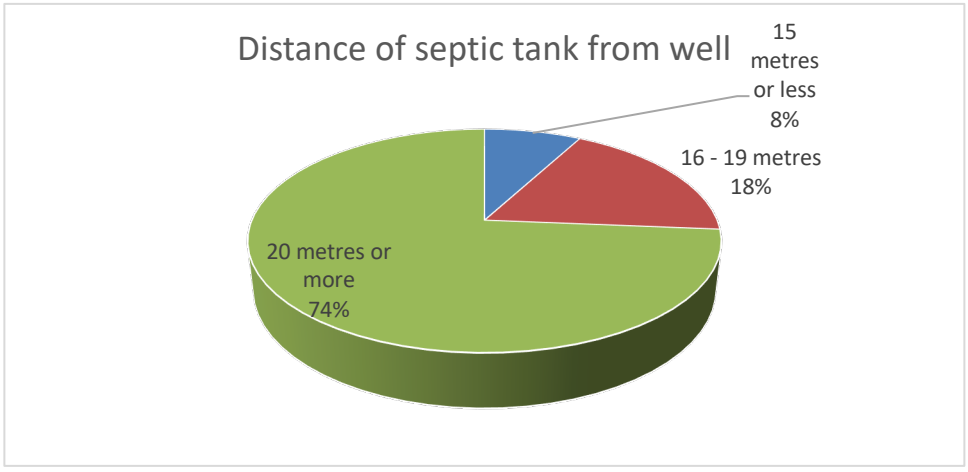
Table 6. Chemistry/metals analyses



Well Maintenance (Drilled and Dug)

The Government of NL (2003) recommends that wells be dug at least 30 metres "from any septic tank disposal areas, privies, cesspools, or any livestock or barnyard areas." The majority of households, 74% (29) in the survey have their septic tanks located 20 metres or more (more than 65 feet) from their wells. However, 18% (7) and 8% (3) of households have their septic tanks located 16-19 metres (50 to 65 feet) and 15 metres or less (less than 50 feet) respectively as shown in the diagram below.

Figure 6. Distance of septic tank from well



Some households, 21% (8), have abandoned wells on their property but the majority (79% or 31 households) do not have any abandoned wells on their property, as shown in

figure 7 below. Regarding households with abandoned wells, 2 households sealed and plugged the abandoned wells themselves, 3 had the wells sealed by a hired contractor and 1 household has not sealed the well. Another replied that they were uncertain.

Figure 7. Existence of abandoned wells

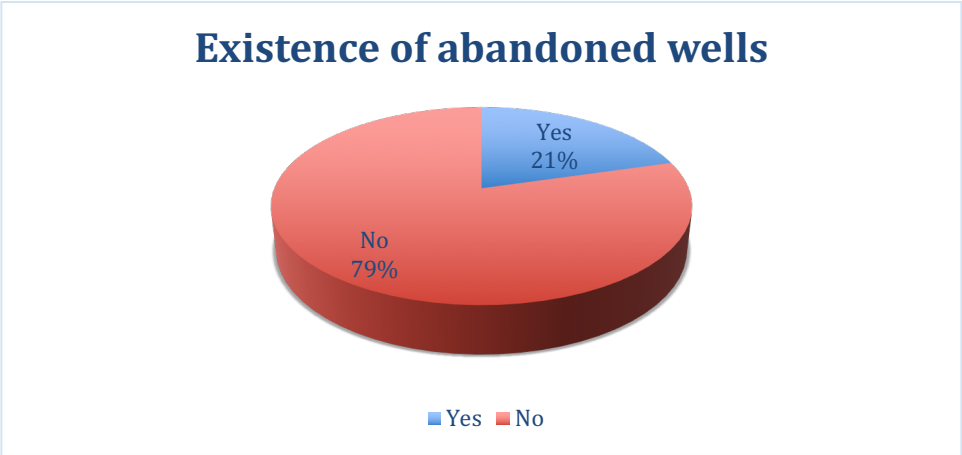


Table 1 below indicates how often households undertake each of the following maintenance activities. The majority of households do keep their wells clear of brush, debris, snow and other obstructions once or more per year (58%), while another 2 (5% of households) do this every few years. Most households (66%) check the well cap for signs of cracking or damage once or more per year while a few households (4 – 10.5%) check every few years.

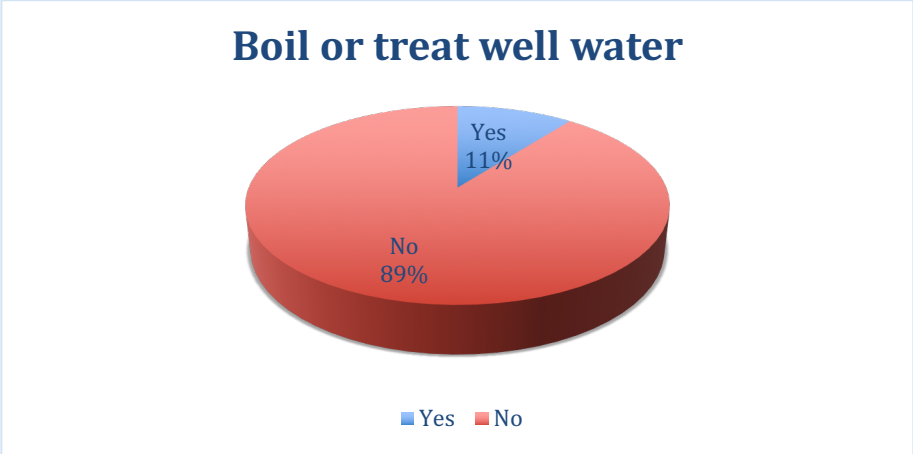
Table 1. Frequency of maintenance activities

	Never	Every few years	Annually	More than once per year
a. Keeping your well clear of brush, debris, snow, and other obstructions (n=38)	14 (36.8%)	2 (5.3%)	14 (36.8%)	8 (21.1%)
b. Checking the well cap for signs of cracking or damage (n=38)	9 (23.7%)	4 (10.5%)	15 (39.5%)	10 (26.3%)
c. Looking for problems with the sealant used to fill the space between the dug or drilled hole and the well casing (n=36)	16 (44.4%)	2 (5.6%)	13 (36.1%)	5 (13.9%)
d. Shock chlorination (disinfection) of your well (n=37)	20 (54.1)	7 (18.9%)	7 (18.9%)	3 (8.1%)
e. Other_____				

Well Water Quality

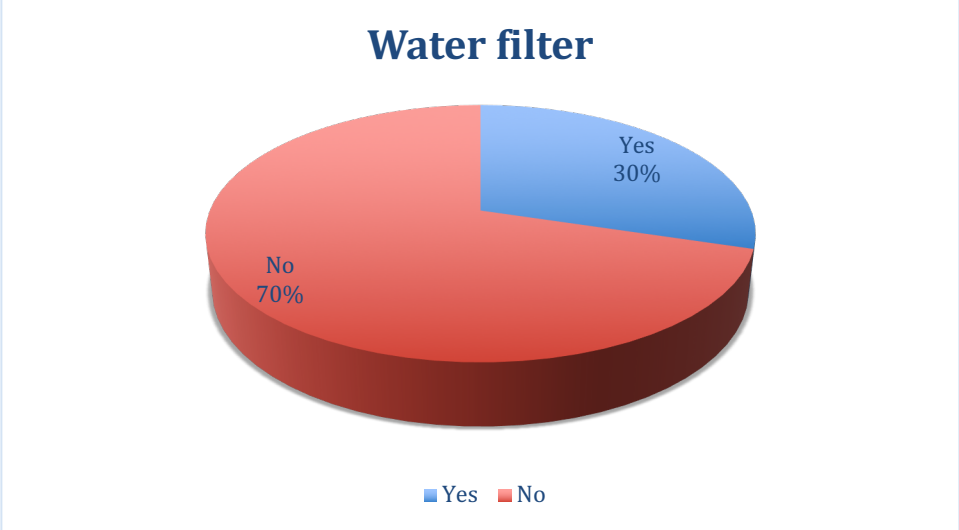
Most households 89% (34) participating in the survey do not boil or treat their well water; only 11% (4) households boil or treat well water, with descriptions such as: “boil water for tea, coffee, dishes, get drinking water from Stephenville spring”, “boil it for dishes but not drinking” and “they don't drink it”.

Figure 8. Boil or treat well water



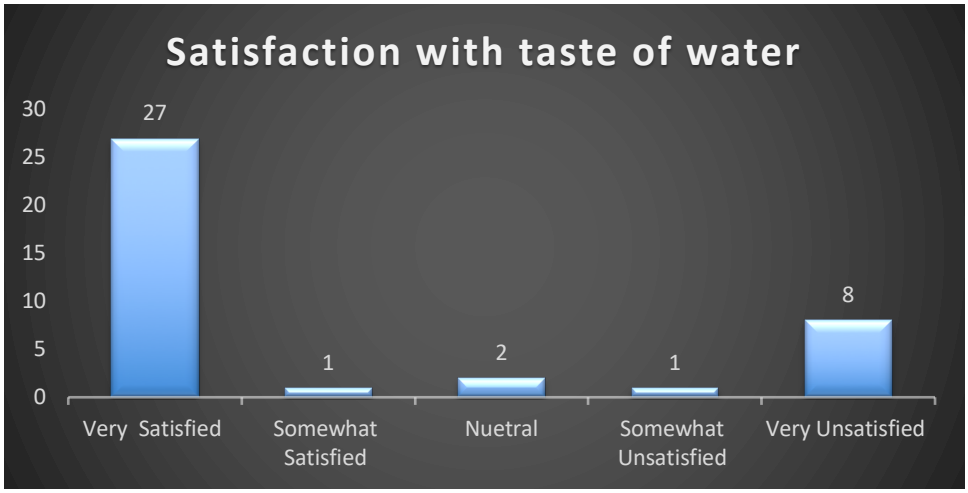
The majority of households, 70% (26), do not use water filters, compared to 30% (11) who use filters such as Brita, fridge filter, UV light filter, ceramic filter, water softener, iron filter and Jet pump.

Figure 9. Use of water filters



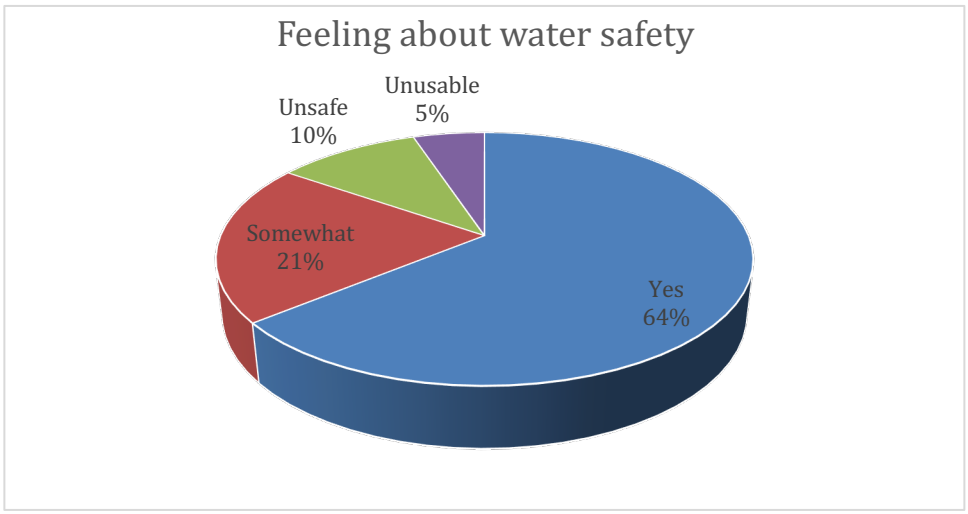
Of a total of 39 households that participated in the survey the majority of households 69% (27) are very satisfied with the taste of their water, while 21% (8) households are very unsatisfied; 2 households are neutral, 1 is somewhat satisfied and another somewhat unsatisfied.

Figure 10. Satisfaction with taste of water



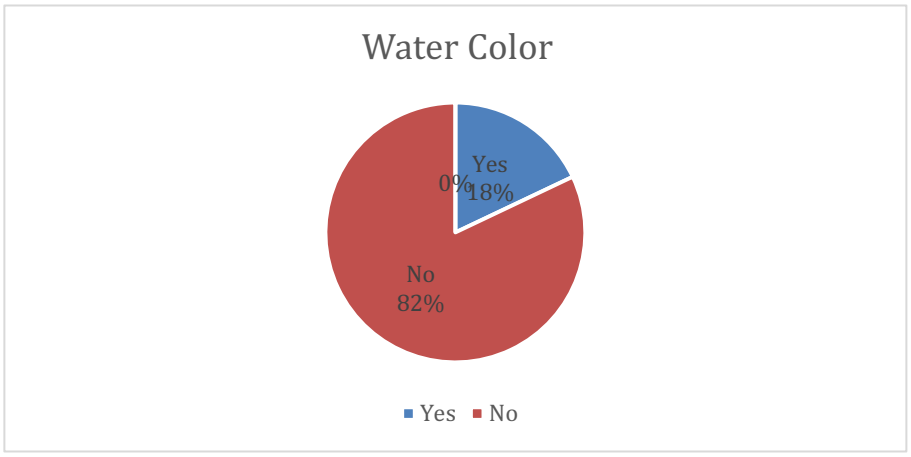
Participating households in the survey chose statements that best reflect how they feel about the safety of their well water. The majority (64%/25) of households feel very safe (believe their well water is safe to drink); 21% (8) of households feel somewhat safe and believe their well water is safe to drink but prefer to drink from another source (e.g. bottled/store bought water); 10% (4) believe it is unsafe to drink and they use it only for doing dishes and laundry; and 2 households believe it is unsuitable for both drinking and household uses.

Figure 11. Feelings about water safety



Many households, 82% (32), in the survey do not have any color in their water, while 18% (7) households report having color in their water. These residents provide descriptions such as “sometimes when it rains yellowish”, black, brown, “yellow - likely iron or soil coloration when comes out of well but once it passes through filters, it is fine”, “yellow-turns the tub yellow”, “in spring color is yellow brown from surface water”, “no color but never very clear”.

Figure 12. Water color



Most households (72%/28) did not have rotten egg smell in their water whilst 28% (11) households have rotten egg smell in their hot water, with descriptions such as: “smells in the summer but during the winter it is perfect”, “strong sulphur smell”, “smells like pug”, “little smell but iron filter takes out smell”, “washer sometimes smells a little”).

Figure 13. Hot water smell

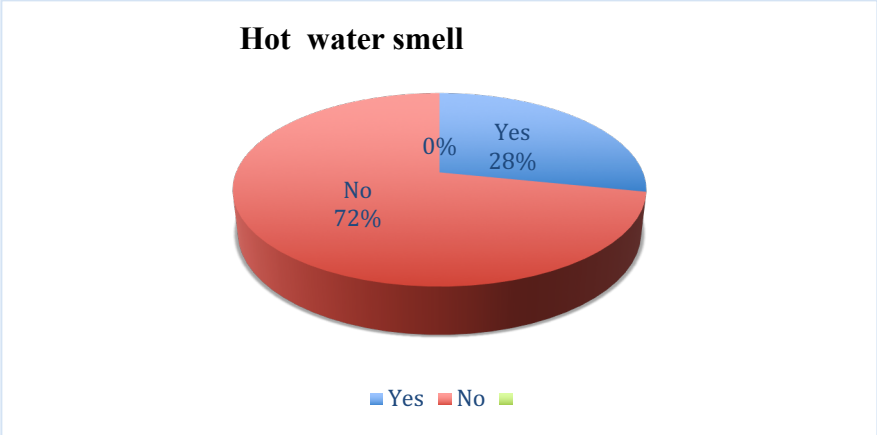


Figure 14 below, shows that majority of households (89%/36) do not have any odor in their cold water while 11% (3) do have odor in their cold water.

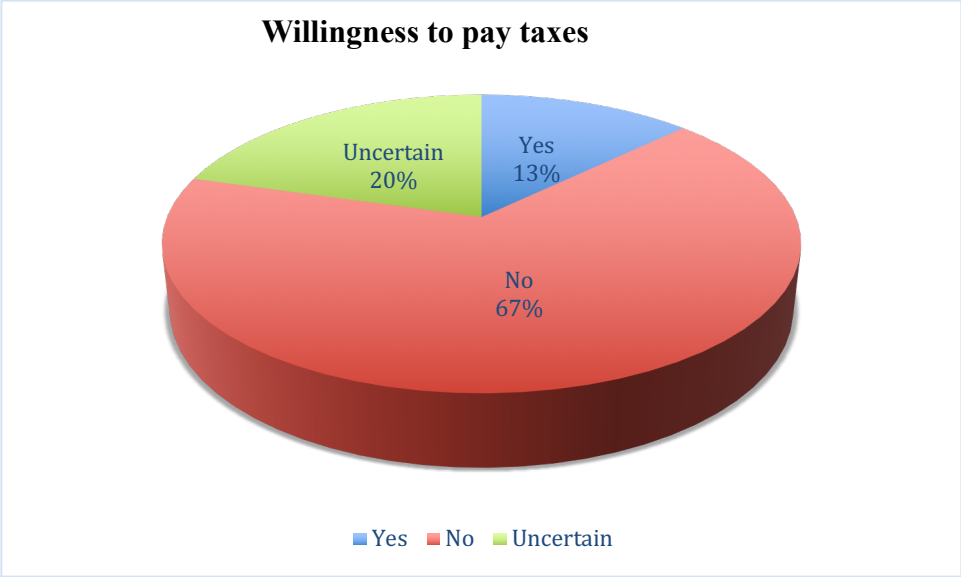
Figure 14. Cold water smell

Only 9 households answered the question on how long they have noticed the issue of smell in their water and all 9 said they have noticed issue for more than one year.

Finally, as illustrated in Figure 14, the majority of households (67%/26) are unwilling to pay water taxes to the LSD (or other local authority) for the provision of a clean public drinking water source, while 13% (5) households are willing to pay taxes. However, 20%

(8) are uncertain or will base their decision on tax amount.

Figure 14. Willingness to pay tax



Participant Comments

The following additional comments were expressed by participants during the survey:

1. Not interested in a water system
2. No problem with the water. There is lime in the water everywhere around here. This why we have a water softener (Kenmore). It is a really good investment and we recommend it.
3. A lot of lime in the water.
4. Chlorine water is bad.
5. We do not want public water with chlorine. Good survey to see how is everything. Suggest washing around the well with vinegar twice a year
6. Water quality depends on the area and where the water is good. There is no need to do anything.
7. If there are too many taxes, the people would not be able to afford the taxes and continue to live in the area.
8. Clean the well with high pressure hose annually.

9. Cleaned out the well by scrubbing it down with come Javex cleaner and it seems to be making a difference. Smell maybe coming from the marsh behind my house.
10. Water good during the winter but bad in the summer. Government should provide Black Brook Duck good water.
11. The community has 2 dug wells to make sure the well does not go dry during the festival. Well water is used to clean and do dishes but not to drink. The hot water is shut off in the building normally so it does not stink up the building.
12. Water smell comes from the hot water tank, not the well and there is a rod you can change in the tank to stop the smell or bailing it out helps with the smell.
13. Smell on hot and cold is good in winter - only exists in summer months. Resident said the reason they are having trouble with water is because they are not digging down past the ledge, they are stopping at the ledge. The well is bailed out in the summer and fall.

Administrators Observations

Some observations of the administrators of the survey are as follows:

1. Most residents were open and welcoming to the survey
2. Most dug well depths were 10ft; concerns were raised about the cost of artesian wells
3. The problematic areas seem to be to the French center (Chez les Français) and to the left of the French center, also along the bog on the main road in Maison d'hiver
4. On the main road in Maison d'hiver and it seemed that the rotten egg smell came in the summer and not in the winter
5. Lime seemed to be a problem mentioned in the region left of Ryans Road
6. Comments: no lakes around, we don't have another source of water

Summary

In conclusion, the Black Duck Brook-Winterhouse drinking water survey results show that the majority of households are very satisfied with the taste and safety of their drinking water. In addition, 64% of households feel their drinking water is safe to drink.

The survey results also showed that 89% of participating households do not boil or treat well water, and 70% do not use water filters. This perhaps can be seen as a further demonstration of their satisfaction in their drinking water. In addition, most households do not have issues with their drinking water according to the survey results: 82% do not have color in their water and 72% do not have rotten egg smell in their hot water whilst 89% do not have any smell in their cold water. The results show that 28% of households have rotten egg smell in their hot water and 11% have rotten egg smell in their cold water.

While most households do not report issues with their water it should be noted that testing is limited, with only 62% having done any testing and the vast majority indicating that they have never had their drinking water tested for chemistry and/or metals. Of those that have tested, some have found iron and hard water to be a concern. Most wells are dug rather than drilled wells, with a wooden cover and relatively shallow in depth (0-6 m/less than 20 feet), factors which can leave them vulnerable to contamination. Some are located closer than the recommended distance from a septic tank.

Sources of "Rotten Egg" Smell

Background of hydrogen sulphide (H_2S)

Hydrogen sulphide (H_2S) is a colourless, flammable gas (Wang, 2012). (See Appendix 2 for physical and chemical properties of H_2S). It is one of the main states of sulphur in the natural sulphur cycle (Chang, et al., 2007). H_2S is present in well waters, lakes, springs, oil fields, anaerobic sewage, chemical industries, petroleum refineries, wastewater treatment plants, and textile and paper mills (Chang, et al., 2007 and McFarland & Provin, n.d.).

Formation of H_2S

H_2S in groundwater is formed by the action of naturally-occurring sulphur-reducing bacteria (SRB) on sulphate and sulphur compounds that also occur naturally in groundwater or are produced from the decaying of organic (plant and animal) matter.

Aside from H_2S being produced as a byproduct, this process enables the bacteria to produce their own energy (McFarland & Provin, n.d.).

The characteristic "rotten egg" odor that is sometimes identified in water is an indicator that SRB are present in the water source and that H_2S is indeed being produced and released (Wang, 2012 and Edwards et al., 2011). Optimal conditions for SRB to thrive include anaerobic conditions (whereby oxygen is absent or very limited in its availability e.g., sewers), pH ranges between 5.5 and 8.5, and temperatures between 24°C and 42°C (although some SRB are present at temperatures between 0°C-100°C) (Wang, 2012).

Sources of H_2S

Wells that are shallow, poorly constructed, drilled in shale or sandstone, located near coal or oil fields, or close to sewer lines or septic systems can develop H_2S problems (McFarland & Provin, n.d.). Well water that has not been used or pumped for a long time, and unflushed water tanks may also result in H_2S problems because the water becomes stagnant and different strains of bacteria thrive under such conditions (Saha et al., 2014). Partly blocked drains or deteriorating leftovers present in household sink traps and water treatment devices can also cause the "rotten egg" smell in water (New Brunswick, n.d.).

In some homes, the foul odour caused by H_2S is only detected in hot water. If the water heater used in the home is electric, the problem may be caused by a chemical reaction that occurs with the metal anode. Electric water heaters often contain a magnesium rod that functions to slow down the corrosion of the tank. As the rod releases small amounts of magnesium, some hydrogen gas ($H_{2(g)}$) is also released and it proceeds to react with the sulphur or sulphate that is present in the water to form H_2S (McFarland & Provin, n.d.).

Effects of H_2S

Typical concentrations of H_2S in household water do not pose a serious health risk to consumers, although higher concentrations do affect the taste and odour of water as well as foods cooked with this water (McFarland & Provin, n.d.). (See Appendix 3 for a table of human physiological responses to exposure to H_2S).

H_2S may cause several problems to sewers and water supply systems due to its odour and toxicity (Chang, et al., 2007). H_2S can corrode wells, and plumbing metals such as iron, steel, copper, and brass, thereby exposing the metal components of washing machines and other water-using appliances (Chang, et al., 2007 and McFarland & Provin, n.d.). This can result in the formation of a black precipitate (ferrous sulphide) that can stain laundry and bathroom fixtures, darken silverware, and discolour copper and brass utensils (McFarland & Provin, n.d.).

Solutions to "Rotten Egg" Smell

Testing

The cause of the H_2S problem must be determined before the proper testing and appropriate treatment can be applied. If the problem is caused by H_2S in groundwater, the concentration of the gas in aqueous solution must be measured in order to select and properly size the treatment system. Knowing the concentrations of H_2S will also allow the potential health risks to consumers to be determined. H_2S dissolves readily in water and can easily volatise (escape into the air); thus, water samples, ideally, should be tested on site or immediately stabilised for lab analysis (McFarland & Provin, n.d.).

Disinfection and shock chlorination

In order to control or remove H_2S in wells, shock chlorination is often used. Shock chlorination is a process whereby a single high dose of chlorine is injected in direct contact with the well water and plumbing system (McFarland & Provin, n.d.). This process is an effective way to rid water of irritants and other organisms and bacteria that cause diseases. Shock chlorination is strongly advised immediately after well water tests positive for bacteriological contamination and it also serves as a safeguard against issues arising from iron bacteria and SRB (Department of Environment and Conservation, 2016). Many (7 out of 11) of the participants who reported the "rotten egg" odour in their water have attempted shock chlorination as a solution in the past.

Other commercial disinfectants are generally added to the water to kill bacteria such as SRB. However, H_2S levels recover very rapidly, thereby making the SRB populations

more resistant to disinfectant products. In addition, many commercial disinfectants contain heavy metals and/ or are toxic which can create additional health problems for consumers (Chang, et al., 2007).

Replacing water heater rods

If the rotten egg smell is caused by a water heater, this may be resolved by removing the magnesium rod completely, or replacing it with an aluminum or zinc rod, which will also protect the water tank from corrosion (McFarland & Provin, n.d.). However, in order to determine how this procedure may affect warranties tied to water heaters, residents are encouraged to contact the manufacturers before proceeding with the rod removal and/or exchange.

Filters/ adsorption

Different types of filters can be used to remove sulphates from the water before they enter the heating unit and others can be used to remove H_2S from water.

Activated carbon has been used for many years in the treatment/ purification of drinking water. This compound is used as filter and it has the ability to adsorb certain soluble organic compounds and gases such as H_2S and chlorine. However, this treatment method works to remove small concentrations of H_2S (0.05-0.3 mg/L). Activated carbon filters must be cleaned frequently and in cases where H_2S concentrations are higher, replacement may be necessary. Some filters may improve the taste of water but they may not eliminate the unpleasant odour (McFarland & Provin, n.d.). Copper and zinc oxide are also good adsorbents for H_2S in aqueous solutions (Haimour, et al., 2005).

Iron removal filters that contain manganese greensand work to remove H_2S by oxidising it to sulphate. The iron and manganese then react to form a precipitate that can easily be filtered out. Manganese filters need to be recharged with a solution of potassium permanganate when the oxygen becomes depleted. This method works to remove H_2S concentrations of 2-10 mg/L (McFarland & Provin, n.d.).

Another option is the ion exchange filter. This purifies water by adding salt. One participant from Black Duck Brook-Winterhouse who reported the "rotten egg" odour in their water remarked in the survey that they had "a little smell, but iron filter takes out smell."

Flushing

In cases where well water has not been used or pumped for a long time or water tanks are left unused for extended periods, H_2S can form under these stagnant conditions. Flushing is a process that involves replacing stagnant water with clean fresh water by passing water rapidly through the water system (Hack, 1990).

Monitoring temperature of water heater

*An*other precautionary practice that could help avoid or mitigate the "rotten egg" odour is to avoid long periods of heater inactivity because SRB thrive well in warm, stagnant, anoxic (oxygen depleted) water environments (Jenkins, 2015). In such cases, manufacturers and plumbers recommend increasing and maintaining the temperature of hot water at about 160˚F/ 71˚C for a few hours. By doing this, the heat will kill or reduce the levels of SRB in the tank. However, this is only a temporary solution.

Oxidizing agents and aeration

H_2S is formed from the reduction (addition of a proton (H^+ ion) or the removal of oxygen) of elemental sulphur or sulphates; thus, the reverse reaction, whereby H_2S is oxidized (oxygen added or proton (H^+ ion) removed) will result in the formation of sulphates or sulphur which are less harmful than H_2S. Some common oxidising agents include chlorine/ bleaching powder, ozone, hydrogen peroxide, potassium permanganate, sodium or potassium dichromate (Haimour, et al., 2005).

Aeration is a process in which air is added to the water. This results in oxygen reacting with H_2S to form odourless sulphates. This method works to remove H_2S concentrations of 2mg/L or less (McFarland & Provin, n.d.).

Except in cases where shock chlorination or flushing can be used, residents are encouraged to seek professional/ chemical expertise before using any of the other chemicals or methods listed above.

Recommendations for areas prone to H_2S contamination:

I. Residents are encouraged to purchase water heaters that are produced by Water Heater Innovations (WHI); Rheem Marathon series as these utilize plastic tanks without the anode rods, thereby reducing the chances of the "rotten egg" odour developing. These products also offer a lifetime warranty (Amazon, 2016).
II. Water softeners increase the conductivity of water in tanks, which leads to more rapid corrosion of the metal anode. As previously mentioned, the corrosion of magnesium rods catalyses the formation of H2S. Thus, residents should be cautious when using water softeners.

Recommendations for improved overall water quality

The research team has made the following recommendations regarding water quality testing and treatment that will ensure good quality drinking water for the residents of Black Duck Brook-Winterhouse and Winterhouse

I. Water quality testing

Water quality testing involves analysing water in terms of its chemical, physical and microbiological content. Therefore, "good quality" (potable) drinking water is water free from disease-causing organisms, harmful chemical substances and radioactive matter, tastes good, is aesthetically appealing and is free from objectionable color or odor (Driscoll, 1986).

Residents are encouraged to conduct water quality tests at least once every year for both bacteria and chemical substances to ensure that their water meets established bacterial and chemical standards (EPA, 2015).

The Government of Newfoundland has always made provision for water quality testing. However, this only covers the bacteriological content and its accessibility and effectiveness to smaller, remote communities, such as Black Duck Brook-Winterhouse, cannot be attested (Source….). The local service districts of these communities can attempt to lobby the Government of Newfoundland to provide free, accessible, or even subsidized chemical testing services to residents on a pilot basis in light of the concerns being raised and the community's efforts to address these.

As a collective responsibility to ensure good quality drinking water in the communities, residents can perform water quality testing at home by purchasing and using home test kits or by engaging their senses (Driscoll, 1986).

Water quality testing using a home test kit

There are many convenient, affordable home test kits that are produced by different manufacturers that all perform the same function of testing for nitrate-nitrogen (NO3-N), pH, turbidity, total dissolved solids (TDS), odors, total coliform (the most important test), aerobic and SRB (Driscoll, 1986). An example is the First Alert WT1 Drinking Water Quality Test Kit which has met EPA standards and can be purchased at Walmart for about US$15.00 (First Alert, Walmart #: 001182523). These test kits contain different strips that can determine both bacteriological and chemical contaminations of water. When exposed to water, the strips change color based on their reaction with the minerals and chemicals present in the water. The changed color of the strip is then matched with the color chart provided in the test kit to indicate the compound present (and sometimes an estimate of its concentration). User instructions that are included in the test kits should be used to ensure proper handling and testing. However, it is important to note that home test kits are not always efficient/ effective and that the best way to acquire accurate data about water quality is by submitting water samples to a professional, accredited testing laboratory.

Water quality testing by the use of human senses

According to Driscoll (1986), residents can use their senses, such as smell, taste, and vision, to attain basic characteristics of their water. The reported cases of "rotten egg" odours by some residents of Black Duck Brook-Winterhouse are an excellent example of how the sense of smell can be used to test water for the presence of noxious gases. The smell of bleach may be due to chlorine used in the treatment plant. However, chlorine should dissipate when exposed to air for some time, or a home water filter can be used to remove it. If a musty/ earthy odour is detected, this may indicate the presence of decaying organic matter from either inside the drain or from the water itself (Driscoll, 1986).

Foul tastes identified in water indicate low pH levels, while metallic tastes may be a result of excess minerals (potentially due to rusty pipes), and salty tastes are usually due to elevated concentrations of sulfates.

If a glass of water is held up to the light and brown, orange, or red particles are observed, this may indicate rusty water pipes or fixtures. If black particles are observed, these may be coming from the hoses through which household water runs. Over time, chlorine used to treat waters can deteriorate these hoses. White or tan particles (or general cloudiness) can indicate excess calcium carbonate or magnesium carbonate in water.
If any of these changes in water are observed by the different senses, residents are encouraged to have their water tested immediately.

II. Water treatment options.

The choice for an appropriate method for water treatment will depend largely on the type and sources of water contamination. Residents should also have access to information on what contaminants they are treating as well as the rating standards of the selected treatment method by the National Sanitation Foundation (NSF).

If test results from the aforementioned test methods (See Section I) show hazardous concentrations of nitrate-nitrogen (NO_3-N), pH, turbidity, total dissolved solids (TDS), odours, total coliform, aerobic and SRB, the following measures can be employed at the

household, community, or municipal level to ensure that good quality water is provided to the residents:

A. Shock chlorination is highly recommended to treat waters that test positively for bacteriological contamination or as a routine annual process. However, it is very important to ensure that an adequate amount of chlorine is added to the water system (Jenkins, 2015). Shock chlorination also serves as a safeguard against issues arising from the presence of iron bacteria and SRB in well water (Department of Environment and Conservation, 2016).
B. According to Jenkins (2015), ultra-violet (UV) light filters can be installed to kill bacteria, viruses, and intestinal protozoa in pre-filtered water. An A-class system (NSF 55) is recommended and it is more effective in pre-filtered water. (See Figure 1 below). It is also recommended that the UV light be replaced regularly. Residents are strongly encouraged to refrigerate their drinking water after treatment.

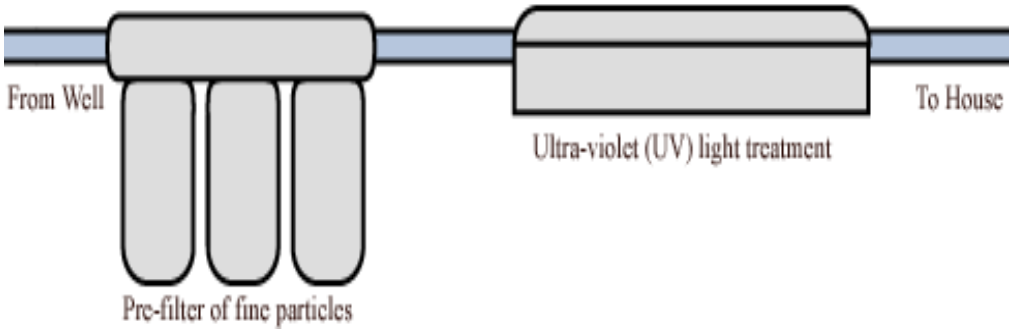


Figure 1 Source:

C. As previously mentioned, activated carbon filters in pitchers (e.g. Brita), or those mounted on to taps, or under sinks can improve the quality of drinking water by a process known as adsorption. Bacteria, organic compounds and gases are adsorbed onto the carbon particles. However, if not regularly cleaned or replaced, the filters can begin to accumulate bacteria, thereby becoming less effective.

III. The importance of regular well maintenance

Monitoring and maintenance of water supplies for quality and microbiological contamination should be highly encouraged, since private well owners are responsible for taking these steps to prevent the occurrence of water-borne diseases (Sarkar and Cooper, 2015). Results from the survey and comments provided suggest that there is room for improvement within some households in terms of good well maintenance practices and monitoring.

IV. Community education

Community education about the importance of water testing and the different types of testing procedures available within the region is highly recommended. Residents should also be encouraged to share information with one another and/or with Chez les Français/French Centre when a solution proves to be effective.

V. Obtaining a Water Quality Report for Your Area

Residents are also able to acquire water quality reports for their communities by contacting their local service district or municipality, or by searching the National Drinking Water Database. Residents can also contact testing facilities/ laboratories if they need help understanding information regarding the quality of water in their area.

VI. Potential for a local, provincial, or federal policy

A recent report by Sarkar and Cooper stated that, "a policy should be introduced requiring the regular testing of private water supplies in the province. Regulations around the maintenance and monitoring of private supplies similar to those required of public supplies should be put in place, even if on a reduced scale" (Sarkar and Cooper, 2015, p.25).

Laboratories for Water Quality Analysis

These labs (all located in Newfoundland) have been accredited by the Standard Council of Canada or Canadian Association for Laboratory Accreditation.

AGAT Laboratories

57 Old Pennywell Road

St. John’s, NL A1E 6A8

Tel: (709) 747-8573 or (888) 468-8718

Fax: (709) 747-2139

Maxxam Analytics

Suite 101A, 49-55 Elizabeth Ave.

St. John's, NL A1A 1W9

Tel: (709) 754-0203 or (888) 492-7227

Fax: (709) 754-8612

Petroforma Laboratories

422 Logy Bay Road and 130 Southside Road

St. John’s, NL A1A 5C6

Tel: (709) 726-9345

water@petroforma.com

References

Chang, Y-J., Chang, Y-T., Chen, H-J. (2007). A method for controlling hydrogen sulphide in water by adding solid phase oxygen. *Bioresource Technology,* 98, 478-483.

Department of Environment and Conservation (2016). Retrieved from http://www.env.gov.nl.ca/env/waterres/cycle/groundwater/well/disinfecting.html

Driscoll, F. (1986). Water Quality Testing. Groundwater and Wells, St. Paul: Johnson Division. Retrieved from http://www.lifewater.ca/drill_manual/Section_16.htm, 14 December 2016

Edwards, S., Alharthi, R., & Ghaly, A. E. (2011). Removal of hydrogen sulphide from water. *American Journal of Environmental Sciences*. Vol. 7 Issue 4.

Government of NL (2003). Retrieved from http://www.servicenl.gov.nl.ca/licenses/env_health/septic/sanitary_dug_well.pdf

Haimour, N., El-Bishtawi, R., Ail-Wahbi, A. (2005). Equilibrium adsorption of hydrogen sulphide onto CuO and ZnO. *Desalination,* 181, 145-152.

Harris, M. (1995). Rotten egg smell fouls cottage water. *Edmonton Journal*. Retrieved from http://search.proquest.com/docview/252140437?accountid=12378

Jenkins, S. (2015). How to Fix Rotten Egg Smell in your Water. Retrieved from www.stevejenkins.com.

McFarland, M.L., & Provin, T.L. (n.d.). Hydrogen sulphide in drinking water: causes and treatment alternatives. *Texas A&M AgriLife Extension.* Accessed as PDF on December 19, 2016.

Madabhushi, B. S. Does your water smell like rotten eggs? Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.501.5922&rep=rep1&type=pdf

New Brunswick (n.d.). Fact Sheet-Why does My Well Water Smell Like Rotten Eggs? Retrieved from http://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Water-Eau/RottenEggs.pdf

Office of Water (4606) www.epa.gov/safewater EPA 816-F-05-013 May 2005

Reiffenstein, R.J., Hulbert, W.C., Roth, S.H. (1992). Toxicology of hydrogen

sulphide. *Annual Review of Pharmacology and Toxicology,* 109-134.

Sarkar A, Cooper TJ, Thomson KK, Rahman MA. (2015). Exploring appropriate business models for establishment of water quality monitoring service in Newfoundland and Labrador. Memorial University of Newfoundland, St. John's, NL, Canada.

Statistics Canada (2011). http://www12.statcan.gc.ca/census-recensement/2011/ (accessed September 23, 2016)

Wang, R. (2012). Physiological implications of hydrogen sulphide: a whiff exploration that blossomed. *Physiological Review,* 92, 791-896.

http://www.home-water-heater.com/rotten-egg-smell.html

https://www.walmart.com/ip/First-Alert-Drinking-Water-Quality-Test-Kit/10099171#about-item

http://waterheatertimer.org/Review-Rheem-Marathon-water-heater.html

http://www.rdeetnl.ca/on-the-west-coast-drinking-water-survey-in-black-duck-brook-maisons-dhiver/ (accessed September 23, 2016)

http://roadsidethoughts.com/nl/black-duck-brook-profile.htm (accessed September 23, 2016)

Appendix 1. Copy of the Survey

Black Duck Brook-Winterhouse Well Water Survey

Main Source(s) of Drinking Water

1a. What is your household's main source of drinking water? (please check one of the following options)

- ☐ Well water (from my property or the property where I live)
- ☐ Well water from someone else's property
- ☐ Natural/roadside spring
- ☐ Tap water
- ☐ Purchased bottled water
- ☐ Other (please specify) _____

1b. What is your main source of water for cooking?

- Same as drinking
- Other, please specify

Well Characteristics

2. What type of well do you have?

- Drilled
- Dug
- Other (please specify) _____
- None – I do not have a well on my property/on the property where I live

Thank You!

If you have a Drilled well, please answer questions 3-7 below.

If you have a Dug well, please go to question 8.

If you do not have a well please proceed to the end of the survey to provide any comments on drinking water in Black Duck Brook-Winterhouse.

Drilled Well Questions

3. Was your well installed by a licensed well driller?

- Yes
- No
- Don't know/unsure

4. How deep is your well?

- 0-15 m (less than 50 feet)
- 16-30 m (50 to 98 feet)
- 31-45 m (99 to 148 feet)
- 46-60 m (149-197 feet)
- 61-75 m (198-246 feet)
- 76-90 m (247-295 feet)
- 91-105 (296-345 feet)
- 106-120 (346-394 feet)
- More than 120 m (more than 394 feet)

5a. Is your well cased?

- Yes
- No

5b. If yes, what material is your casing made of:

- Steel
- Plastic
- Other (please specify)_____

6. Does your well casing extend above the surface at least 0.4 metres (1.5 feet)?

- Yes
- No

7a. Is your well capped?

- Yes
- No

7b. If yes, what type of cap?

- Steel vented vermin-proof
- Plastic
- Sanitary seal
- Other_____

Thank You! Please continue the survey at question 12 below.

Dug Well Questions

8. Who dug your well?

- Self/Family member
- Other (please specify) _____
- Don't know/unsure

9. How deep is your well?

- 0-6 m (less than 20 feet)
- 6-10 m (20 to 33 feet)
- More than 10 m (more than 33 feet)

10a. Is your dug well lined?

- Yes
- No

10b. If yes, what type of liner?

- Black plastic
- Concrete
- Other_____
- No liner

If no, please proceed to the next question (question 11).

11a. Is your dug well capped?

- Yes
- No

11b. If yes, please describe your well cap/cover

- Steel
- Plastic
- Wood
- Other _____
- No cover

If no, please proceed to the next question (question 12).

Thank You! Please continue the survey at question 12 below.

Well Water Testing (both Drilled and Dug Wells)

12. Have you ever tested your well water?

- ☐ Yes
- ☐ No

If your well water has never been tested please proceed to question 23. If you have tested your well water, please answer questions 13-22 below.

13. How much did it cost to conduct the testing? _____

14. If you answered yes in question 12, was the sample(s) analyzed for bacteria, general chemistry/metals, or both?

- ☐ Bacteria
- ☐ General chemistry/metals
- ☐ Both
- ☐ Don't Know

15. For bacteriological analyses, how often have you tested your water?

- ☐ Twice a year
- ☐ Once a year
- ☐ Once every five years
- ☐ Only once
- ☐ Not applicable - I have never had my water tested for bacteria

If you have never had my water tested for bacteria please proceed to question 19.

16. For bacteriological analyses, what did you test for (check all that apply)?

- ☐ E-coli/total coliforms
- ☐ Cryptosporidium
- ☐ Campylobacter
- ☐ Enterovirus
- ☐ Giardia
- ☐ Hepatitis
- ☐ Norovirus
- ☐ Rotavirus
- ☐ Salmonella
- ☐ Shigella
- ☐ Other: _____

17. For bacteriological analyses, who analyzed your well water sample (check all that apply)?

- ☐ NL provincial government (Service NL/Public Health Laboratory)
- ☐ Private water quality laboratory
- ☐ Water treatment supply company
- ☐ Other (*please specify):* _____

18a. For bacteriological analyses, did the test results identify any issues with your well water?

- ☐ Yes
- ☐ No

18b. If yes, please explain what issues were identified: _____
_____

19. For <u>general chemical/metals analyses</u>, how often have you tested your water?

- ☐ Twice a year
- ☐ Once a year
- ☐ Once every five years
- ☐ Only once
- ☐ Not applicable - I have never had my water tested for chemistry and/or metals

If you have never had my water tested for general chemical/metals analyses please proceed to question 23.

20. For general chemistry/metals analyses, what did you test for (check all that apply)?

- ☐ Arsenic
- ☐ Iron
- ☐ Manganese
- ☐ Lead
- ☐ Sulphur
- ☐ Uranium
- ☐ Fluoride
- ☐ Copper
- ☐ Radon
- ☐ Other: _____

21. For general chemistry/metals analyses, who analyzed your well water sample (check

all that apply)?

- ☐ NL provincial government (Service NL/Public Health Laboratory)
- ☐ Private water quality laboratory
- ☐ Water treatment supply company
- ☐ Other (*please specify):* _____

22a. For general chemistry/metals analyses, did the test results identify any issues with your well water?

- ☐ Yes
- ☐ No

22b. If yes, please explain what issues were identified: _____
_____

Well Maintenance (Drilled and Dug)

23. How far is your septic tank located from your well?

- ☐ 15 metres or less (less than 50 feet)
- ☐ 16-19 metres (50 to 65 feet)
- ☐ 20 metres or more (more than 65 feet)
- ☐ Not applicable. I do not have a septic system.

24. Do you have any abandoned wells on your property?

- ☐ Yes
- ☐ No

24a. If yes, which of the following applies?

- we sealed and plugged it ourselves
- Sealed and plugged by a hired contractor
- Well has not been sealed

25. Please check the most appropriate box indicating how often you have undertaken each of the following maintenance activities (please check for each item):

	Never	Every few years	Annually	More than once per year
a. Keeping your well clear of brush, debris, snow, and other obstructions				

b. Checking the well cap for signs of cracking or damage				
c. Looking for problems with the sealant used to fill the space between the dug or drilled hole and the well casing				
d. Shock chlorination (disinfection) of your well				
e. Other_____				

Well Water Quality

26. Do you boil or treat your well water?

- ☐ Yes (*please describe the treatment used*_____*)*
- ☐ No

27. Do you use a water filter, and if so, what type?

- ☐ Yes (*please describe what type, e.g. brand, style*_____*)*
- ☐ No

28. How satisfied are you with the taste of your water?

- ☐ Very satisfied
- ☐ Somewhat satisfied
- ☐ Neutral - neither satisfied or unsatisfied
- ☐ Somewhat unsatisfied
- ☐ Very unsatisfied

29. Do you feel that your water is safe to drink (choose the statement that best reflects how you feel about the safety of your well water)?

- ☐ Yes, very safe- I believe my well water is safe to drink
- ☐ Somewhat safe – I believe my well water is safe to drink but I prefer to drink bottled or store bought water
- ☐ No, not safe- I believe my well water is unsafe to drink and I use it only for doing the dishes and laundry
- ☐ Not usable- I believe my well water is not usable for drinking or household purposes

30. Does your water have any colour?

- ☐ Yes (*please describe*_____)
- ☐ No

31. Does your hot water have a rotten egg smell?

- Yes (*please describe*_____)
- No

32. Does your cold water have any odor?

- Yes (*please describe*_____*)*
- No

If you answered yes to questions 31 or 32, please answer questions 33. If your water does not have a smell/odor, please proceed to question 34.

33. How long have you noticed this issue?
    - More than one year
    - 61 days to one year
    - 60 days or less

34. Would you be willing to pay water taxes to the LSD (or other local authority) for the provision of a clean public drinking water source?

- Yes
- No
- Uncertain/depends on the tax amount

35. Are there any other comments that you would like to share?

_____

_____

Appendix 2: Table of physical and chemical properties of H_2S (Wang, 2012).

Molecular weight	34.08
Vapour density	1.19
Melting point	-82.3
Boiling point	-60.3
Freezing point	-86
Oxidation products	SO2, H2SO4, S2

Appendix 3: Table of human physiological responses to exposure to H_2S (Reiffenstein, et al., 1992).

Concentration of H_2S (ppm)	Concentration of H_2S (mg/m3)	Physiological Responses

0.003-0.02	0.0042-0.028	Odour threshold
2		Bronchial constriction in asthmatic individuals, spontaneous abortion
3-10	4-14	Obvious unpleasant odour, irritation of eyes, nose, and throat, increased blood lactate concentration, decreased skeletal muscle citrate synthase activity
20-30	28-42	Strong offensive odour (rotten eggs)
30	42	Sickening sweet odour, fatigue, loss of appetite, irritability, poor memory, dizziness
50	70	Conjunctival irritation
50-100	70-140	Irritation of respiratory tract
100-200	140-280	Loss of smell (olfactory fatigue)
150-200	210-280	Olfactory paralysis
250-500	350-700	Pulmonary edema
500	700	Anxiety, headache, ataxia, dizziness, stimulation of respiration, amnesia, unconsciousness
500-1000	700-1400	Respiratory paralysis leading to death, immediate collapse, neural paralysis, cardiac arrhythmias, death

Thank you for your time!