# SUNNYSIDE DRINKING WATER PROJECT:

## EXAMINING CHLORINATED DISINFECTANT BY-PRODUCTS, RESIDENT PERCEPTIONS AND PRACTICES AND MUNICIPAL RESPONSES IN SECURING SAFE DRINKING WATER IN THE TOWN OF SUNNYSIDE, NL

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## List of abbreviations

| | |
|---|---|
| ANSI | American National Standards Institute |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BDCM | Bromodichloromethane |
| BWA | Boil Water Advisory |
| CDC | Centre for Disease Control |
| CDW | Federal-Provincial-Territorial Committee on Drinking Water |
| $CHBr_3$ | Bromoform |
| $CHCl_3$ | Chloroform |
| COT | Committee on the Toxicity (UK) |
| DBCM | Dibromochloromethane |
| DBP | Disinfection By-product |
| DCAA | Dichloracetic Acid |
| DOCHS | Department of Community and Health Services, Government of Newfoundland and Labrador |
| DOEC | Department of Environment and Conservation, Government of Newfoundland and Labrador |
| EPA | United States Environmental Protection Agency |
| GCDWQ | Health Canada Guide for Canadian Drinking Water Quality |
| HAA | Haloacetic Acid |
| IARC | International Agency for Research on Cancer |
| IPCS | International Programme on Chemical Safety |
| MAC | Maximum Acceptable Concentration |
| MBSAP | Multi-Barrier Strategic Action Plan |
| MCL | Maximum Contaminant Level |
| MCLG | Maximum Contaminant Level Goal |
| MIGA | Municipal and Intergovernmental Affairs, Government of Newfoundland and Labrador |
| MNL | Municipalities Newfoundland and Labrador |
| NL | Newfoundland and Labrador |
| NOM | Natural Organic Matter |
| POE | Point-of-Entry |
| POU | Point-of-Use |
| SPSS | Statistical Package for the Social Sciences |
| TCAA | Trichloracetic Acid |
| THM | Trihalomethane |
| TOC | Total Organic Carbon |
| UV | Ultraviolet |
| WHO | World Health Organization |
| WRA | *Water Resources Act* |

# Abstract

The *Sunnyside drinking water project* is a university-community partnership between researchers at the Environmental Policy Institute- Grenfell Campus and municipal leaders of the Town of Sunnyside. This project explores the persistent drinking water-related challenges facing Sunnyside, eastern Newfoundland and Labrador (NL), primarily through the viewpoint of local residents. These challenges include: threats to source water; effective water treatment, disinfection and distribution, including dealing with high levels of disinfectant by-products (DBPs) as a result of their current disinfection system; and developing strategies for addressing these issues. Many rural municipalities in Newfoundland and Labrador face similar issues, which present a challenge to municipalities in ensuring residents access to clean, safe drinking water.

This report is structured through five main parts:

1. <u>Introduction</u>: Community profile, project rationale and methodology;
2. <u>Sunnyside drinking water survey report</u>: Analysis and discussion of the drinking water survey conducted in Sunnyside during the fall of 2014;
3. <u>Chlorinated disinfectant by-products and drinking water in Sunnyside</u>: Literature review and discussion of the potential health impacts posed by DBPs in publically supplied water systems, policy responses and alternative technologies;
4. <u>Community Water Forum</u>: Discussion of the results of the Community Water Forum presentations, which took place in Sunnyside in May 2015, and;
5. <u>Policy recommendations</u>: Concluding thoughts and policy recommendations.

One issue that frequently arose over the course of the project is the lack of regulatory emphasis placed on federal water quality guidelines related to DBPs in NL. Arriving at an enforceable level, however, would require consideration of feasible technological solutions and/or significant increases in provincial investment into the water treatment systems of hundreds of small rural communities with high levels of DBPs. Until such time, increased public health education and support is needed for municipal leaders and the public at large. Thus, our main policy recommendation for the Government of NL is to develop and support a multi-faceted education campaign around the potential health impacts of DBPs, the role of chlorination in publicly supplied drinking water, and solutions and alternatives available in preventing and/or mitigating DBP impacts. Education (and research) is also needed on the environmental and social impacts of bottled water in the province, currently the most common drinking water source for Sunnyside residents. DBPs are a collective responsibility shared by residents, municipal and senior levels of government. Municipal governments share in the responsibility of educating their residents about the impacts of both DBPs and bottled water. Home-treatment technologies also offer an alternative for residents in reducing DBP exposure, particularly in the short-term. We are cautious in recommending this as a long-term solution due to issues of affordability and social equity, the need for proper maintenance, and difficulties finding appropriate systems. In general, we argue that it is the responsibility of public institutions (i.e. the government) to ensure that the appropriate water systems are in place to deliver safe drinking water to residents.

# Part one: Introduction

This project explores the persistent drinking water-related challenges facing the community of Sunnyside, located on the Isthmus of Avalon in eastern Newfoundland and Labrador (NL), primarily through the viewpoint of local residents and the municipal leadership. These challenges include: threats to source water; effective water treatment, disinfection and distribution, particularly dealing with high levels of chlorinated disinfectant by-products (DBPs) as a result of their current disinfection system; and developing strategies for addressing these issues. Many rural municipalities in NL face similar issues in ensuring residents access to clean, safe drinking water. The impetus for this project emerged from interviews and conversations with residents, including municipal representatives, from the Town of Sunnyside, NL, regarding their drinking water system as a part of *The Rural Drinking Water Project.* Through this additional research, it has become clear that the issues surrounding DBPs, the potential health impacts they pose and strategies to resolve them are very real concerns facing municipal leaders, which require greater levels of support from senior governments in a policy area where all levels of government share responsibility and jurisdiction.

*Community profile*

Sunnyside is located on the Isthmus of the Avalon Peninsula, approximately 0.5 km off the Trans-Canada Highway approximately 150 km north of the provincial capital city of St. John's. In 2001 the population was approximately 500 residents, and it remained relatively constant until 2010 (Sunnyside, 2010). In recent years, Sunnyside Town Council members have noticed an increase in resident numbers, which they directly attribute to oil-related employment, as well as the indirect economic benefits associated with this employment (e.g. full time "handymen", hairstylists, and other small business) in the Isthmus region (Daniels 2014). The town is in close proximity to three major oil-related industries: NALCOR's Bull Arm Fabrication Site, North Atlantic Refining Ltd., and the Newfoundland Transshipment Terminal.

The water system in Sunnyside has been developed in various stages, but the major modernization of their system occurred in 2002, when a main line was installed with the capability of delivering water from Centre Cove Brook through the entire eight kilometre length of town (Daniels 2014). The brook flows from Long Pond and the chlorine building is located near the base of Centre Hill wherein the water is gravity-fed through the mainline. The town council has been very active in terms of seeking out the most appropriate chlorination system for their water supply, as they have experienced challenges in ensuring the drinking water has adequate levels of residual chlorine throughout the entire system. Additionally, the community has experienced elevated levels of DBPs, which are the chemical by-products that form when chlorine interacts with natural organic matter (NOM) in the water. Sunnyside's DBP levels have typically registered far above guideline levels recommended by Health Canada (as discussed in further detail below). This has motivated Sunnyside Town Council to explore various potential solutions, but has also created frustration in that it is difficult to understand the nature and full extent of the issue let alone communicate this with residents and choose the appropriate response.

*Project methodology and report layout*

Through a university-community partnership, this project facilitates a community-based approach to drinking water related research that provides the community of Sunnyside with further information regarding resident practices and perceptions relating to drinking water as well as implications and potential recommendations that arise from these practices and perceptions. As researchers, it is our hope that the information provided will be helpful for the municipality in moving towards sustainable solutions with respect to water systems, source water protection, and development in the future. The research objectives identified at the outset of this project were:

1. To determine population perspectives and practices related to drinking water security and potential solutions;
2. To investigate the implications of public perceptions and practices related to drinking water for the operation of drinking water systems and for the well-being of residents and their communities;
3. To provide recommendations for the municipality and the provincial government that address resident concerns related to water security (such as high levels of contaminants, in particular, elevated concentrations of DBPs, or extreme weather events).

The research questions, drinking water survey and Community Water Forum (a knowledge mobilization/public discussion event) were developed in consultation with Sunnyside council members and the town manager. Other project outputs in addition to this report are three DBP fact sheets addressing the potential health impacts and technological solutions to DBPs on the public system level and at the household level. These were developed as information sources with the general public in mind. In addition to discussing these fact sheets with representatives of the Town of Sunnyside, they were also reviewed by several drinking water experts including: two representatives from the provincial government (Department of Health and Community Services (DOHCS) and Department of Environment and Conservation (DOEC)), two representatives from a provincial health authority (Eastern Health) and one representative with Health Canada. We also conducted two semi-structured interviews to obtain information not available from existing published or local Sunnyside sources, one with a representative of the provincial health authority, and the other with the Health Canada representative.

This report is presented through five main sections, including this introduction. In Part two, we report on the drinking water survey, which was conducted in the fall of 2015. In this section, we explore community perspectives and practices related to drinking water, as well as discuss some of the potential implications for the town council in terms of operating their public drinking water system. Given the nature of how this project evolved, examining DBPs, their potential health impacts and mitigating solutions, became the major focus of the literature review portion of the project, which is presented in Part three. This review is important from a municipal leadership perspective because it has been a longstanding issue facing the town council as far as implications and ways of reducing the high levels of DBPs. The survey results indicate that there is limited public awareness around DBPs specifically, suggesting that there is a need for further public education given that these chemical by-products are present in the publicly supplied water. In this section, we not only address those solutions relevant to the entire municipal water system, but also those that are available to residents in their homes. We also developed three project fact sheets on DBPs: Health Impacts, Public Drinking Water Systems and Household Treatment Options, with the assistance of Sarah Minnes. These fact sheets were developed from the information found in the literature review and were presented to Sunnyside residents at the Community Water Froum. In Part four, we discuss the results of a Community Water Forum held in Sunnyside on May 12th, 2015. The forum involved presentations from the mayor, the town manager and the lead project researchers. At this forum we discussed the results of this project and provided opportunities for participating citizens to provide feedback and responses to a series of related questions via interactive polling. In Part five of this report we conclude by providing policy recommendations, primarily targeted towards the provincial government. In terms of policy recommendations, it is appropriate that the focus here is primarily on the provincial government because, at least in the case of the Town of Sunnyside, despite significant efforts municipal governments have demonstrated a need for additional support in attempting to navigate and address the DBP issue. This report and other related resources are available on the NL drinking water project website – nlwater.ruralresilience.ca.

# Part two: Sunnyside drinking water survey report

## Survey introduction

This project emerged through conversations between the municipal council and the town manager of the Town of Sunnyside and members of the *Exploring Solutions for Sustainable Rural Drinking Water Systems* project research team. Sunnyside was one of the case-study communities focused on in the Rural Drinking Water project, and through this investigation it was apparent that Sunnyside was facing numerous drinking water issues. In addition to the municipal drinking water supply contains high levels of DBPs, as a result of the water disinfection process, town council and staff stated they were operating under certain knowledge gaps when it came down to what the broader population of residents thought of the drinking water generally as well as residential drinking water practices. Thus, one purpose of this project was to look further into what residents of Sunnyside think about their municipally supplied drinking water, the extent to which residents are aware of high levels of DBPs in their water and any safety concerns they have related to tap water, and finally what are residents' practices? That is, what kinds of water do community members drink when they are at home (or out at the cabin), and how may their perceptions of the municipally supplied water influence these practices?

To address these questions, the research team developed a drinking water survey in consultation with the Sunnyside council and staff, modifying a previous community drinking water survey conducted by two of the research team members in the Indian Bay area of NL (see Holisko *et al*. 2014). Once finalized the survey was conducted door-to-door throughout Sunnyside during two fieldwork visits over the fall (September and November) of 2014. Data from the 2011 census indicate there 452 people living in Sunnyside, and 233 private dwellings (StatCan 2012). A survey of households conducted in this project estimates the total number of households, including those that are rented and/or occupied on a seasonal basis, at 256. A total of 124 surveys were collected (121 of these were conducted in person, at the resident's household, and the remaining three surveys were filled out independently by the resident and then dropped off at the town office) out of 256 households, providing a 48% response rate. This response rate is conservative however, because close to 10 % of the total households were either seasonally or permanently unoccupied in addition to a large portion of the households being rented out and a limited number of "renter" respondents. Out of the 124 surveys collected, only two respondents indicated that they were renting, and subsequently they do not pay for municipal water services. The surveys were anonymous, and only one survey was conducted for each household. Each survey took approximately 15 to 20 minutes to complete while at the residents' home. Field research instruments, including: resident consent forms, request for participation forms, a researcher survey guide, DBP explanation guide and town maps can be found in Appendix A. Over the course of the two field visits, each house received at least three visits from a project researcher: after the first visit, a "request for participation" form was dropped off at the house if the door was unanswered. To the greatest extent possible, each house was visited at different times of the day (including a late afternoon/evening visit) and on a weekend day in attempt to "catch" residents at home. If the resident indicated he or she was not interested in participating, then their house was marked in our records as a refusal and they were not re-visited. After the third pass through the community we faced a definite diminishing return of surveys successfully completed per field research hour.

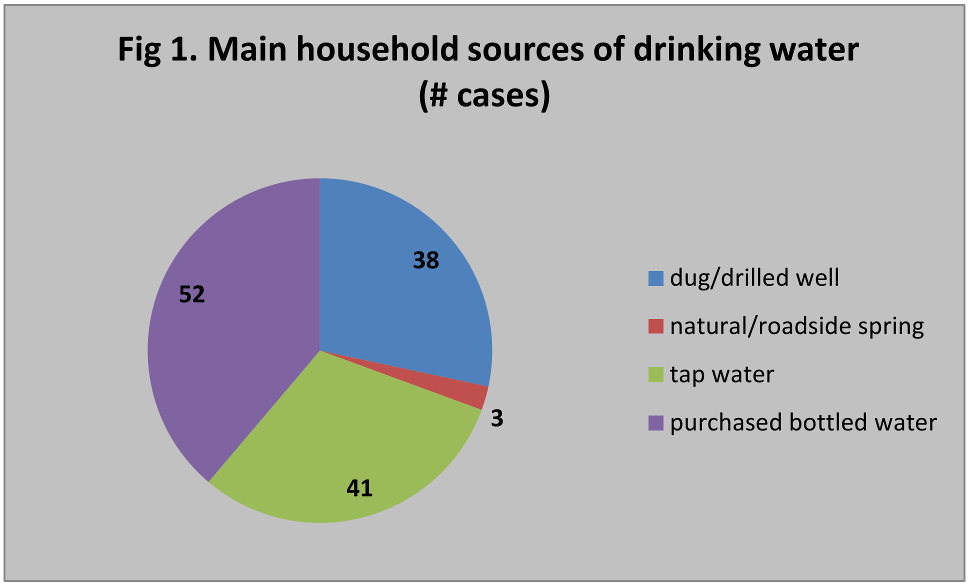
This section of the report provides an analysis of the survey data collected as well as a discussion of the council's efforts towards addressing the issue of DBPs in the community. The subsections below draw on the major themes emerging from the survey, which provide insight on residents' perceptions and drinking water practices in Sunnyside. The survey responses have been analyzed and presented through IBM's Statistical Package for the Social Sciences (SPSS) software and Microsoft Excel. The statistical analysis is described in greater detail below; however, it is important to note here that only those correlations that were statistically significant have been included in this report, and are denoted with * for correlations significant at the 0.05 level (2 tailed) and ** for correlations significant at the 0.01 level (2-tailed) (see Appendix B). Correlations that were not statistically significant have not been included because they indicate relationships between two responses which are based entirely on chance. Additionally, all of the correlations demonstrated below have been run through Spearman's Rank, a non-parametric correlation test, because Spearman's Correlation is more well suited to data which have skewed (non-normal) distributions, as is the case with data emerging from the survey questions (Burt & Barber 1996).

Finally, a comprehensive record of responses to each survey question is presented in Appendix B. Given the analysis of these questions, in conjunction with the overall project objectives, the main themes discussed below include: (I) types of drinking water, (II) municipal taxation, (III) drinking water safety concerns, (IV) DBPs and (V) perceived threats to and use of the watershed.

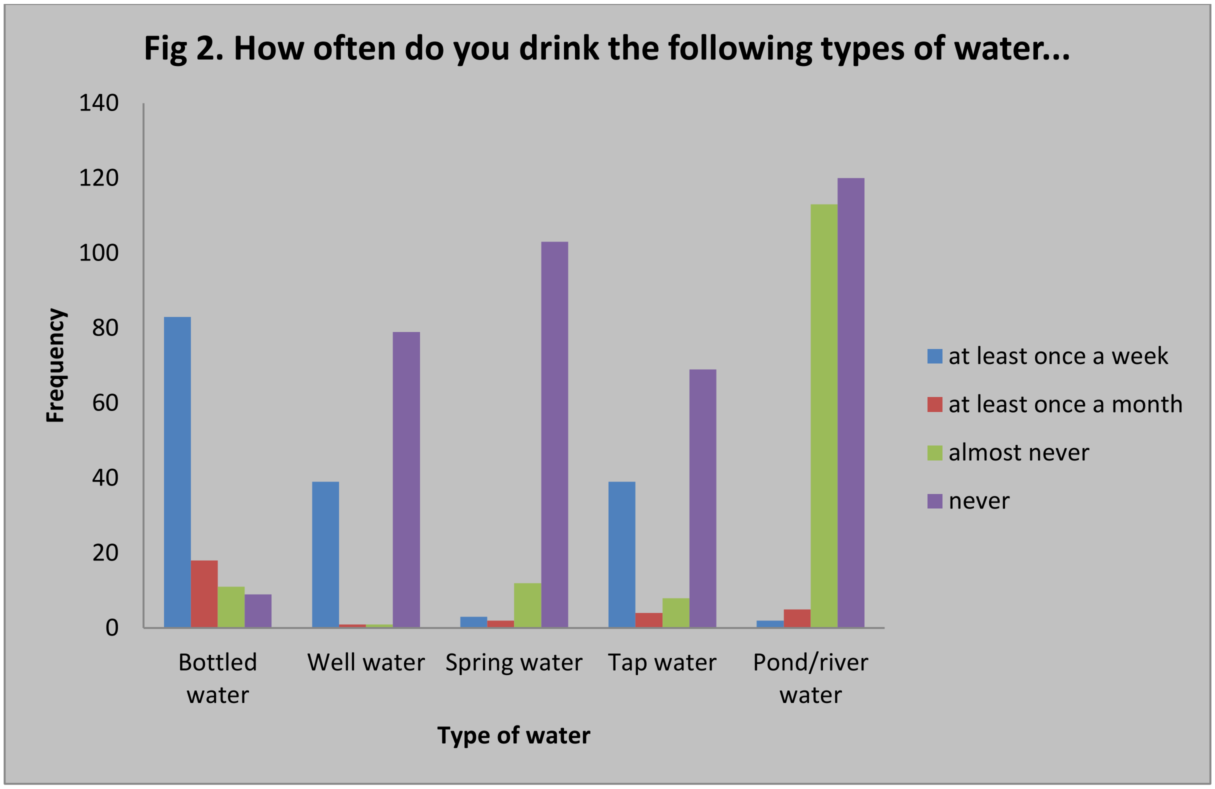
<u>(I) Types of drinking water</u>

One of the key objectives of conducting this survey was to gain a greater understanding of residents' drinking water practices, including the main types of drinking water they consume and the frequency in which they consume different types of drinking water, followed by analysis of why they exhibited these specific preferences. This subsection focuses on residential drinking water sources and the frequency at which they are consumed.

In the survey, we included five main types of drinking water for residents to choose from: dug/drilled well water, natural/roadside springs, "tap water" (municipally supplied), water directly from local ponds or rivers, and purchased bottled water (hereafter referred to as bottled water). The question asked respondents to indicate their main source of household drinking water, which in a few cases included more than one type of water as a main source of household drinking water. In total, there were 52 cases in which respondents indicated their main source of water was purchased bottled water, 41 one cases of tap water, 38 cases of well water and 3 cases of spring water (Fig 1). Thus, approximately 39% of the responses indicate bottled water as a main water source, 31% tap water, 28% well water and 2% spring water. None of the respondents indicated that water from local ponds and rivers was a main source of drinking water. Eleven percent of respondents indicated that they were not connected to the municipal water supply, despite 98% of respondents stating that they were in fact paying for water services. Along with the relatively high percentage of well water users, this indicates that the majority of residents – despite having access to the main water line – either do not have their faucets hooked up to “town water”, or if they do, prefer not to drink it on a regular basis.




The type of water that is drunk with the highest frequency at least once a week is also bottled water, followed by well and tap water (these two sources were consumed “at least once a week” by 39 different respondents each) (Fig 2.). Water from ponds and rivers is consumed least frequently, with 120 respondents indicating that they never drink it.

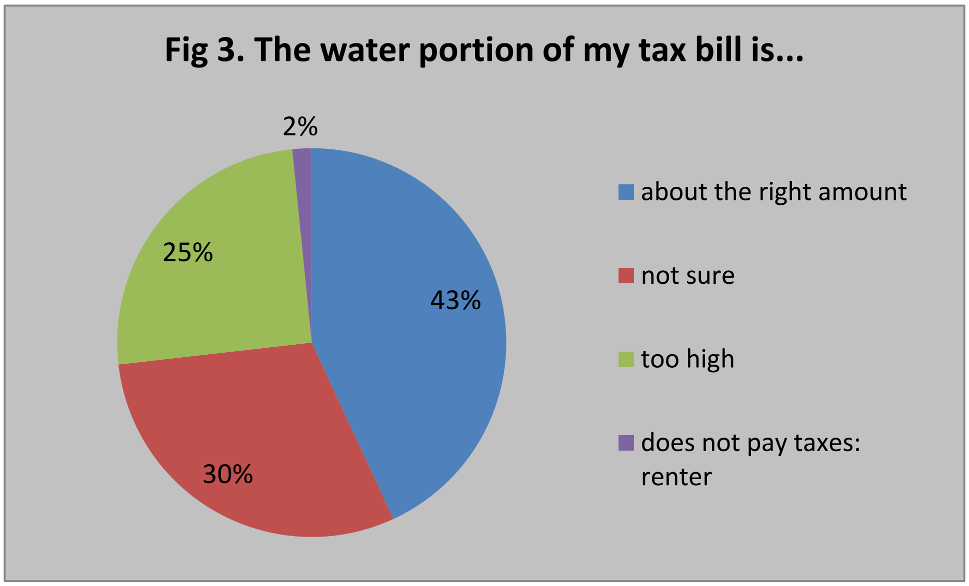


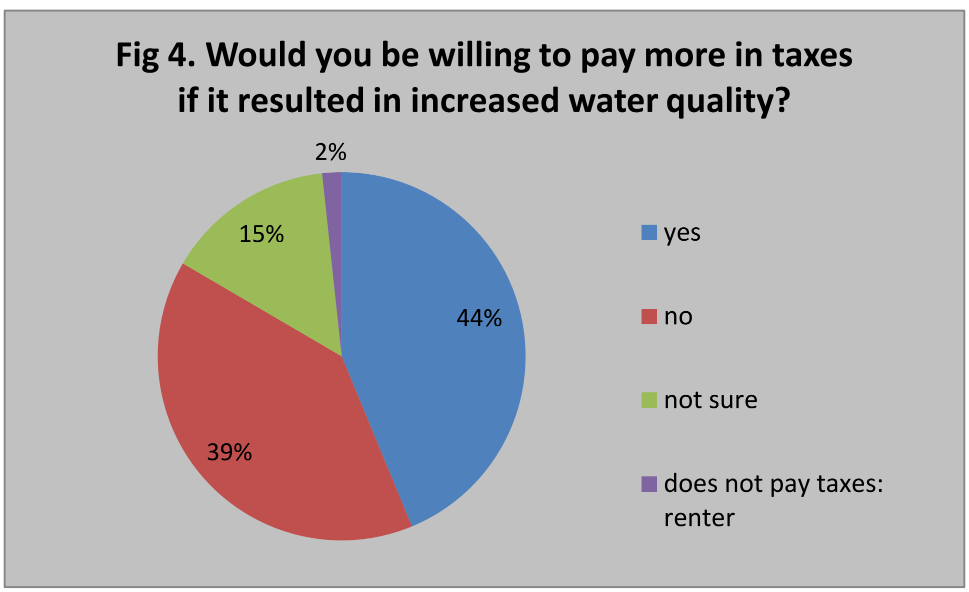

In terms of main sources of drinking water correlations are relatively weak negative relationships between age and the average amount of money spent on bottled water (-0.281**), as well as whether or not respondents use a water filter and the average amount of money spent on bottled water (-0.198*). In other words, older respondents tend to spend less on bottled water and those who use a filtration system, of any variety, tend to spend less on average on bottled water, compared to those who do not.

(II) Municipal taxation and water services

As stated above, 121 respondents (roughly 98%) indicated that they are paying for water services in Sunnyside. Fourteen (11%) of respondents state that they are not connected to the main water line, while 109 respondents (88%) are connected. All of the 14 respondents who said they were not connected to the main line are paying municipal taxes, which implies that they have the ability to be connected to the municipal water supply, but for one reason or another they utilize other sources of water for drinking and general household use. Additionally, of these 14 respondents not connected to the main line, eight of them said they would be unwilling to pay an increased water tax if it would result in increased quality of the municipally supplied water, two said they would, and four said they were not sure.

Overall, 43% of respondents said that the water portion of their tax bill was about the right amount, 30% said they were not sure, 25% said it was too high and the remaining 2% indicated they do not pay taxes because they rent while residing in Sunnyside (Fig 3.). When asked if they would be willing to pay more for water services, if it meant that there would be an improvement in the quality of municipally supplied water, 44% of respondents said yes, 39% no and 15% were not sure (Fig 4.) While a significant portion of the residents who did the survey said they would not support an increase in water taxes, it may be the case that further discussion of water issues emerging in Sunnyside would be useful providing more information to the 15% who indicated they were not sure (as well as those who were not in support of a tax increase).



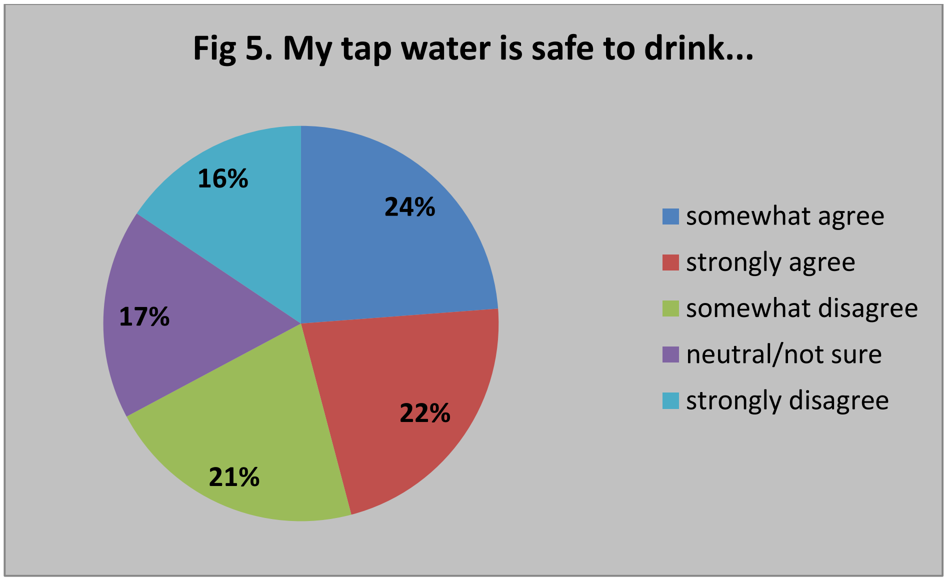

There is a slightly positive relationship between respondents who indicate that their main source of drinking water was purchased bottled water and whether they feel their taxes were too high (or they were unsure) at 0.224*, and a slightly negative relationship between those whose main source of water is from the tap and whether they feel their taxes were too high or were unsure at -0.192*. In other words, those who indicate bottled water as their main source were more likely to consider their water taxes too high or they were unsure, and people drinking mainly tap water were more likely to indicate that their water taxes were about right. There was a strong negative relationship between how much respondents would be willing to increase their water taxes and whether they felt their taxes were too high or were unsure, at – 0.826**, which stands to reason because those who felt that there taxes were too high indicated that they were not willing to pay any increase in taxes.

(III) Drinking water safety concerns

Understanding perceptions of drinking water safety has been a key component of this research – particularly in the context of high DBPs levels in Sunnyside. However, historically and currently, the primary concern of senior and municipal governments in providing safe drinking water is to ensure that the water is properly disinfected. These issues will be discussed in greater depth in Part three of the report. In this section, we explore the degree to which survey respondents feel their tap water is safe and the reasons that they feel this way, all of which we assume have an important impact on their drinking water practices and buy-in for municipal drinking water management strategies (Minnes & Vodden 2014).

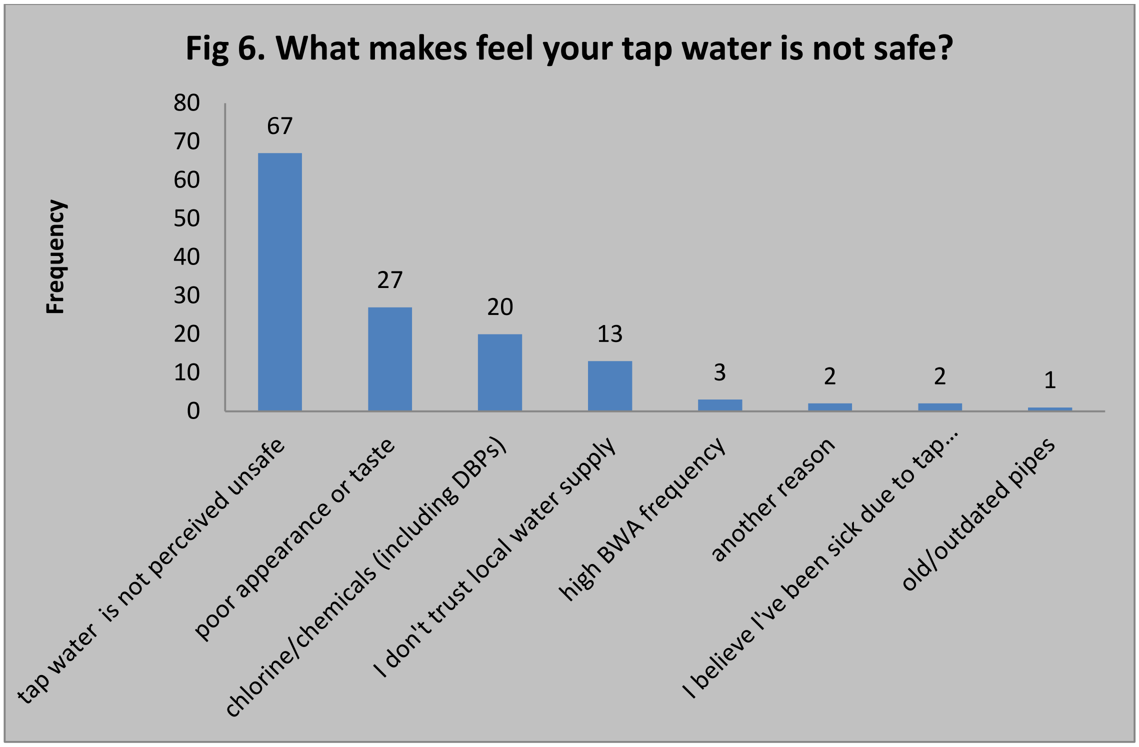
Survey respondents exhibit very diverse opinions on the degree to which their tap water is safe.[1] When asked to assess the following statement "my tap water is safe to drink", 24% of respondents indicate they somewhat agree, 22% strongly agree, 21% somewhat disagree, 17% neutral or not sure and 16% strongly disagree (Fig 5.). In total, slightly less than half (46%) of respondents think the tap water is safe and just over a third (37%) perceive it as unsafe.

[1] In this instance, and throughout this report tap water refers to the municipally supplied drinking water as opposed to well water which some residents have hooked up to all their household taps.



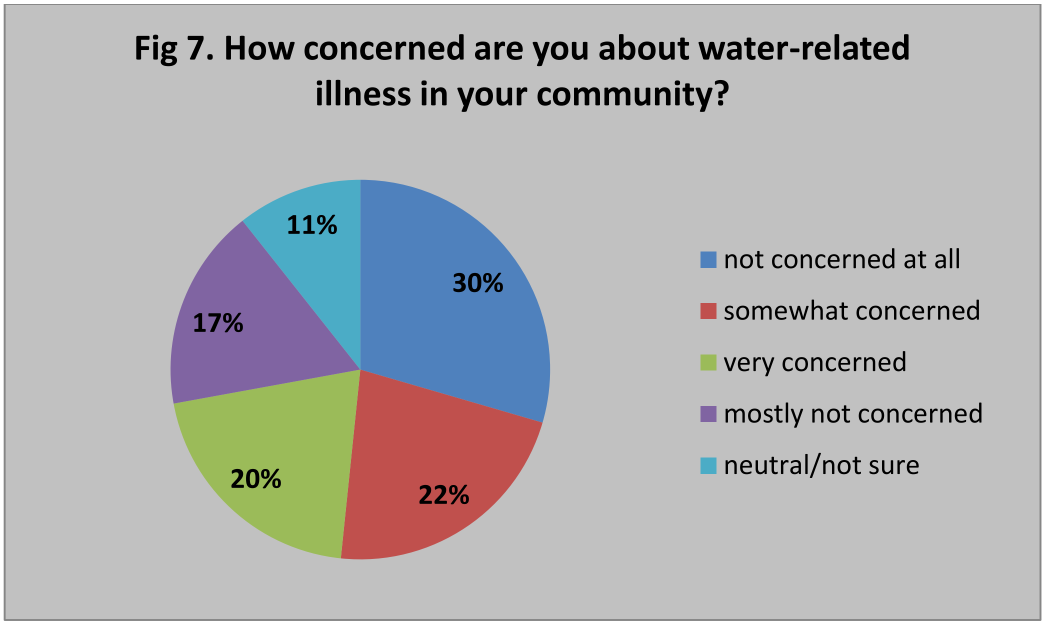

When asked why respondents feel the tap water is unsafe, the reason provided with the highest frequency (27 cases, 22% of respondents) is "…because of the poor appearance and taste". Here respondents described the water as having an unpleasant chlorine taste. This result warrants further exploration because poor water aesthetics, including poor taste, in themselves are not determinants of water safety; in fact they can be very misleading because seemingly 'pure', 'clear' and 'pristine' water can be full of dangerous pathogenic bacteria, if untreated and, likewise, many chemical contaminants do not alter water aesthetics to any great extent (for example, arsenic is tasteless and odourless). However, this demonstrates that, similar to findings from other locales, water aesthetics are highly influential in terms of some individuals' perceptions of drinking water safety in Sunnyside (McGuire 1995, Dietrich 2006, Jones *et al.* 2007, Doria *et al.* 2009).

The second most frequently mentioned reason respondents feel the tap water is unsafe is because of chlorine/chemicals, including DBPs (20 cases, 16% of respondents). The next sub-section will provide a more thorough analysis of DBPs; however, it is worthy to note here that the analysis of survey data did not yield any significant relationships between feelings around tap water safety and either awareness of the term DBP or the level of concern regarding DBPs in the municipal water. In this case, it is very possible that the reason chlorine and chemicals were indicated so highly may have been related to aesthetic concerns; that is, the recognizable chlorine taste in the water, rather than to concerns about DBPs.




Another reason provided that is worth expanding on is the third most frequent, "I do not trust my local supply" (13 cases). Further qualitative analysis would be required to explore the reasons why these respondents feel they do not trust the water supply; in one instance a respondent specified that they did not trust in the town's ability to properly manage the water system. Related to this point is the concern that too many boil water advisories (BWAs) (3 cases) are seen as a sign the water is unsafe. However, in actual fact, the town management is highly vigilant in issuing BWAs should there be a mechanical failure, for instance, which speaks to the commitment the town has towards the precautionary principle. It may also be the case that increasing residents' knowledge about why the tap water needs to be disinfected, the different reasons BWAs are issued, and about municipal water operations in general would be useful in improving feelings towards tap water safety.

Similarly to perceptions of safety, the degree to which respondents said they are concerned about water-related illness is also very diverse (Fig. 7). Thirty percent of respondents said they are not concerned at all, 22% somewhat concerned, 20% very concerned, 17% mostly not concerned and 11% neutral or unsure. Again, slightly less than half of residents (47%) were more or less unconcerned and almost as many respondents stated that they do exhibit concern (42%). It is unclear what specific potential water related health issues these respondents are concerned about, although one respondent indicated that they thought they experienced a gastrointestinal illness after drinking municipal tap water and another thought the water caused them skin irritation (Fig. 6). The relationship between concerns of water-related illness and knowledge of chlorine DBPs will be discussed further in the next sub-section.

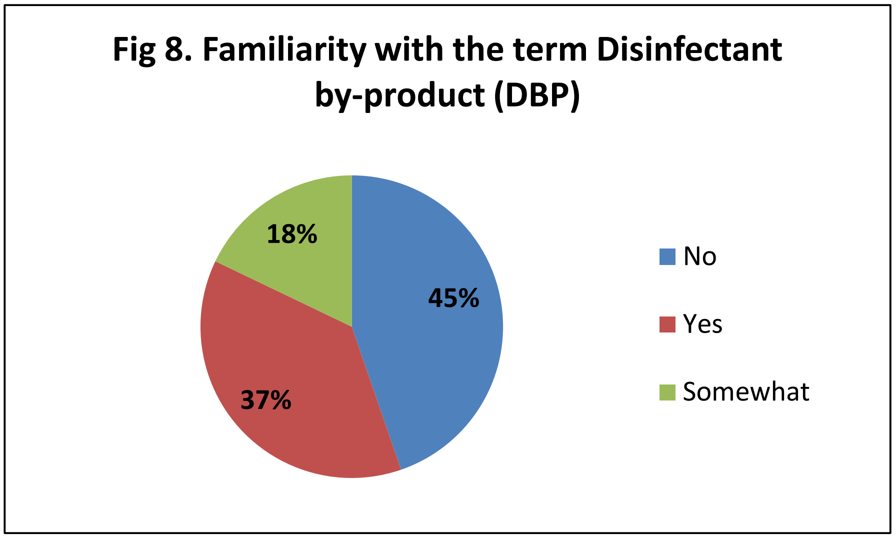



There is slight negative correlation between whether respondents feel their tap water is safe and feelings towards relative levels of municipal water taxes (-0.214*). Those who feel their water is safe are more likely to have responded saying the taxes were the right amount, whereas those that describe the tap water as unsafe are more likely to think that taxes are too high. As stated above, the data indicate that there is a very strong negative relationship between those who think the water taxes are too high and residents' willingness to pay more for water services, if the quality of water improved. That is, those who feel taxes are too high are unwilling to pay more, even if water quality is improved.

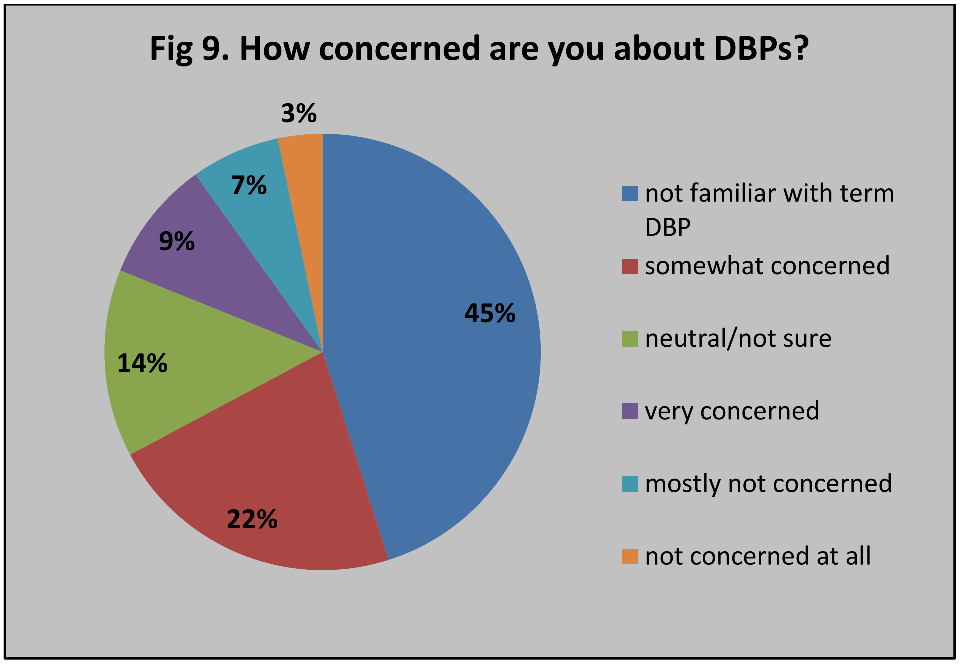
There is a moderate negative relationship between feelings about water safety and average spent on bottled water (-0.457**). Likewise there is a similar relationship (albeit a weaker one) between concerns around water-related illness and average spent on bottled water (-0.319**), those who spend less on bottled water tend to agree that the tap water is safe and demonstrate less concern regarding drinking water-related illness (and conversely those who spend more tend to be more concerned). There is weak positive relationship between perceptions of water safety and concerns regarding water related illness (0.328**), which indicates that those who feel the water is safe exhibit less concern about water related illness.

(IV) Disinfectant by-products (DBPs)

The next section of this report deals exclusively with DBPs, specifically trihalomethanes (THMs) and Haloacetic Acids (HAAs) in the context of potential health risks and impacts they represent, but also various technologies that are being used to eliminate and/or reduce their presence in drinking water supplies. While much of the focus of this entire report is DBPs and the impact they have on rural drinking water systems, and thus, rural residents, the awareness of the term DBP was somewhat mixed in survey respondents (Fig 8.). Forty-five percent of respondents indicate that they are unfamiliar with the term, 37% state they are familiar and the remaining 18% said they are somewhat familiar.




In terms of levels of concern regarding DBPs (Fig 9.), of the 55% of respondents who were either familiar or somewhat familiar with the term, 40% (22% of total) indicated that they are somewhat concerned, 25% (14% of total) neutral or not sure, 16 % (9% of total) very concerned, 13% (7% of total) mostly not concerned and 5% (3% total) not concerned at all about DBPs. There were no correlations between the degree to which residents thought their municipal drinking water was safe with either familiarity with the term DBP or level of concern about DBPs. However, there was a strong positive correlation (.858$^{**}$) between familiarity with the term DBP and the level of concern about DBPs. In other words, at the point when this survey was conducted those who indicated that they were familiar with the term DBP were also concerned about them in the water supply. Thus, the discussion in Part three (and information provided in the fact sheets created through this project) may be of immediate interest to such residents because awareness of what DBPs are is strongly associated with concern about DBPs.




<u>(V) Threats to and use of the watershed</u>

When asked about climate change (with a particular focus on increases in extreme weather events over a longer scale), 60% of survey respondents stated that they noticed the effects of climate change in the environment. Thirty percent of respondents indicated that they perceived climate change had influenced the drinking water quality. The only reason cited for this was the seasonal influx of water in the system related to "spring runoff"; however, this project could not quantify the extent to which that is related to climate change or may be impacting drinking water quality.

When asked which human activities residents thought were a threat to the water system, 82% of respondents indicated that they did not perceive any threats to the water system and the remaining respondents indicated that the top three threats were: the Come by Chance oil refinery, recreational use, followed by hunting and fishing at 5%, 4% and 3% of responses, respectively (Fig. 10). The survey also contained questions directed to individuals who physically spend time in the watershed, which only applied to 11 out of the 124 respondents. When asked if recreational activities, hunting, trapping, wood cutting, or cabin development were a threat to the water the large majority of responses indicated these were not threats, particularly cabin development (Fig. 11). When watershed users were asked if these activities were demonstrated to be a threat seven out of the nine who responded to this question agreed that they would be willing to modify their behaviour in the watershed.

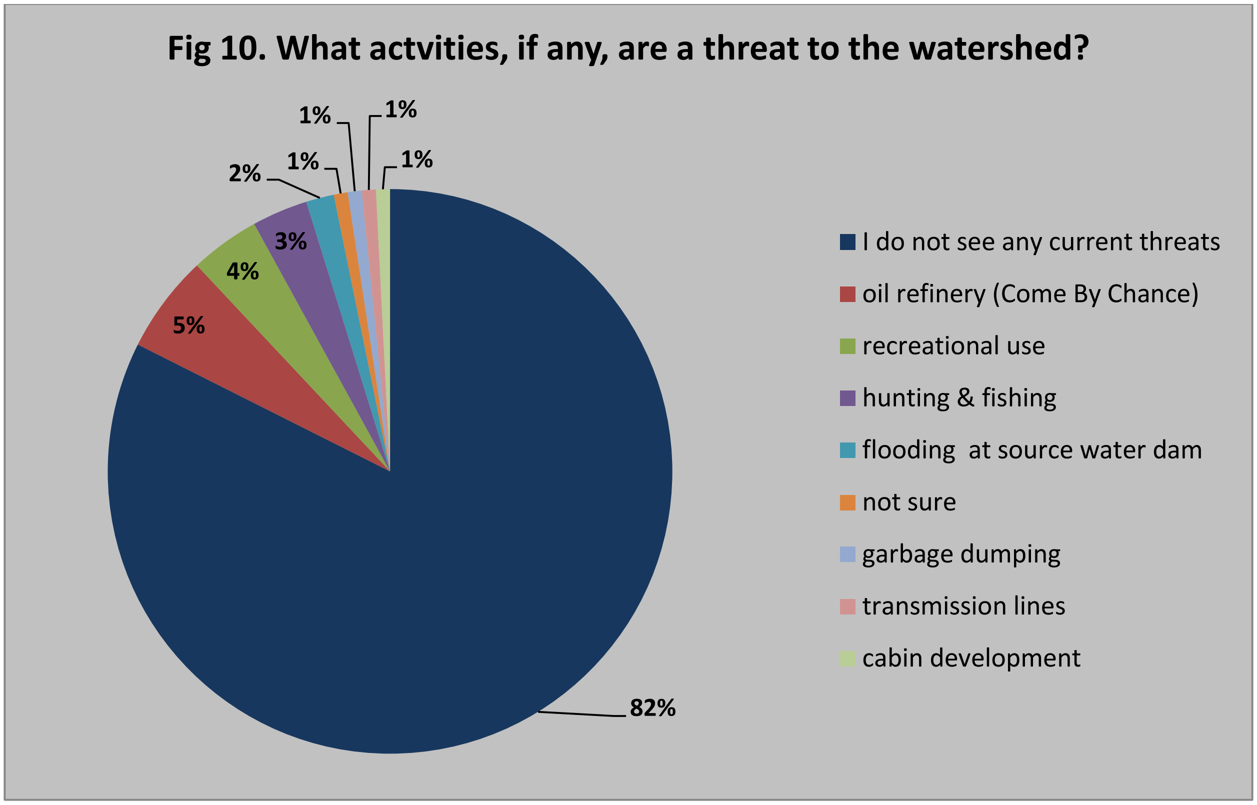


Fig 10. What actvities, if any, are a threat to the watershed?
82%
5%
4%
3%
2%
1%
1%
1%
1%
I do not see any current threats
oil refinery (Come By Chance)
recreational use
hunting & fishing
flooding at source water dam
not sure
garbage dumping
transmission lines
cabin development

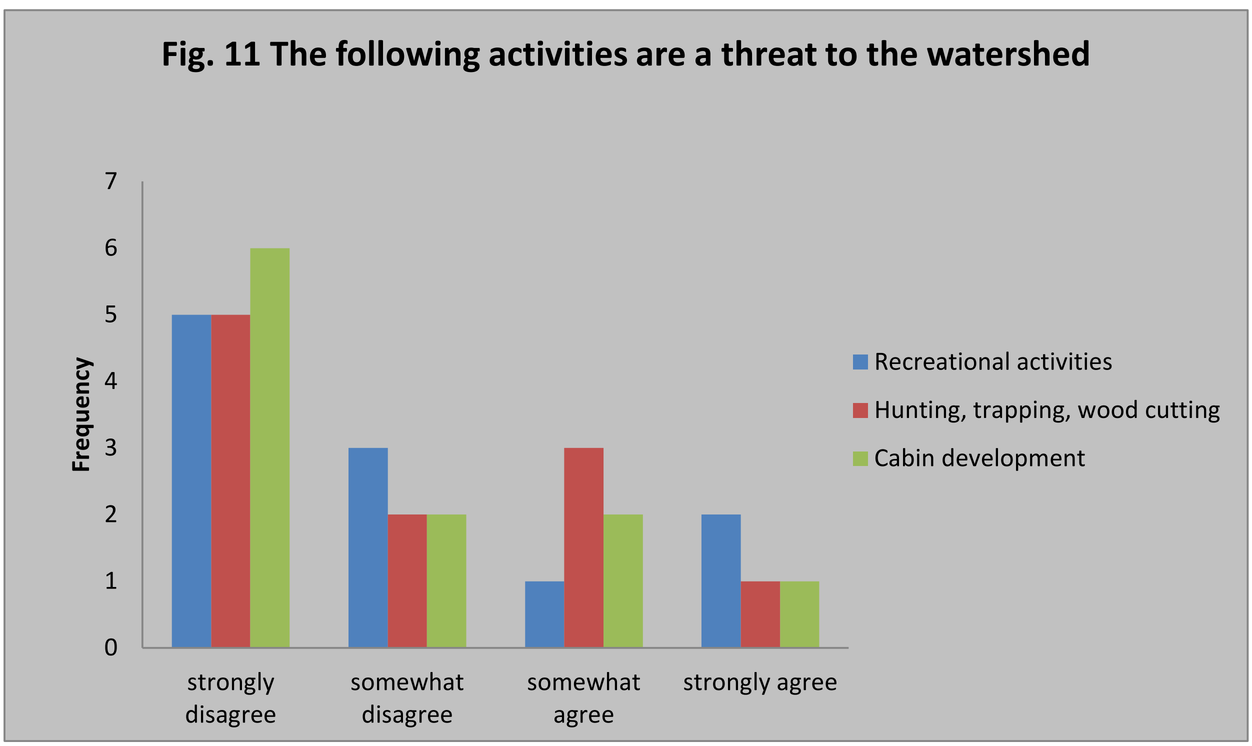


Fig. 11 The following activities are a threat to the watershed
Frequency
0
1
2
3
4
5
6
7
strongly disagree
somewhat disagree
somewhat agree
strongly agree
Recreational activities
Hunting, trapping, wood cutting
Cabin development

**Summary**

Overall, the household survey results indicate that a high proportion of residents are not drinking the municipally supplied drinking water in Sunnyside; 69% of respondents state their main source of drinking water is a source other than municipal tap water. The most popular source of drinking water is bottled water (39% of respondents indicated it was their main source). Given that there is an additional cost associated with this water, above that of municipal taxes, it certainly presents an issue of financial accessibility and social equity (with some better able to afford water alternatives than others). Additionally, there is the need to consider the environmental impacts – and potential health impacts – of drinking high volumes of water from plastic bottles. Influencing the municipality's financial ability to make further investments in drinking water, 43% of respondents indicated that their current level of taxes were "just right", while 25% indicated that they were too high; however, 44% stated they would be willing to pay more if the municipality were to provide a higher quality water.

In terms of water safety and threats to the water system, 46% of respondents feel that the municipally supplied water is safe and 36% feel it is unsafe. The number one reason for why people feel the water is unsafe is the poor appearance/taste (27 cases), followed by apprehension around chlorine or other chemicals (22 cases). Forty-five percent of respondents stated that they were unfamiliar with the DBPs, 37% said they were familiar and 18% somewhat familiar. Of the 55% who were familiar or somewhat familiar with DBPs, 56% of these respondents indicated they were concerned and only 18% stated they were unconcerned. Finally, despite the aforementioned water quality/water safety concerns, the vast majority (82%) of respondents indicated that they do not see any threats to the watershed itself as a drinking water source/supply area.

# Part three: Chlorinated disinfectant by-products and drinking water in Sunnyside

## Introduction

Access to safe and clean drinking water is a concern that has plagued the human population for centuries. Historically, the main threat posed to human health in terms of drinking water quality is contamination by bacterial pathogens and for the vast majority of places this remains the case. Throughout the $19^{th}$ and early $20^{th}$ centuries alone, cholera, a bacteria spread by untreated drinking water caused the death of over 40 million people worldwide and the World Health Organization (WHO) estimates that currently approximately 100 000 to 120 000 people die for contracting cholera each year, globally (WHO 2015). Additionally, the WHO estimates that as much as 80% of all diseases and over one-third of deaths in developing countries are caused by the consumption of contaminated water (WHO 2004). In terms of dysentery caused by the consumption of untreated drinking water, the WHO estimates that 1.8 billion episodes of childhood diarrhea occur annually, mostly in developing countries, which contributes to the death of more than three million children and one million adults annually (WHO 2005). Since the 1920's, with the widespread use of chlorine to disinfect public drinking water systems, drinking water-related mortalities have been substantially reduced in industrialized nations (Galal-Gorchev 1996). In fact, chlorine disinfection of drinking water systems has been widely heralded as one of the greatest and most effective public health measures of the $20^{th}$ century (e.g. Bull *et al.* 1995, Galal-Gorchev 1996, Richardson *et al.* 2007). The WHO states that "infectious diseases caused by pathogenic bacteria, viruses, and protozoa or by parasites [remain] the most common and widespread health risk associated with drinking-water" (WHO 2011, p. 117), and thus, water disinfection must not be compromised as pathogen removal and disinfection is emphasized as the primary health concern when it comes to drinking water safety (Hrudey, 2009).

However, since the discovery of chlorinated DBPs in the early 1970s, it has become obvious there are potential health risks associated with the use of chlorine as a drinking water disinfectant. As stated in the previous section of this report, chlorine DBPs, hereafter DBPs, are formed when chlorine reacts with naturally occurring organic matter in the source water supply. This presents a challenge to many rural communities, particularly in NL where there are predominantly surface water (pond) water supplies, because often these communities have neither the funding nor the tax base to operate the system-wide filtration systems required to remove the organics at the site of chlorination. Over the 2013-2014 period, there were over 117 communities in NL that exceeded Health Canada's maximum acceptable concentration (MAC) for THMs and 153 communities with HAA exceedances (DOEC 2014b).

Sunnyside has faced an ongoing issue of elevated DBPs in their water supply. Research conducted through the University of Laval, along with reports published on the provincial DOEC Water Resource Portal, indicate that over the past number of years, the treated water in Sunnyside has consistently tested over the Health Canada recommended levels for HAA compounds and THMs- as high as 3 and 4 times over for both (Guilherme & Scheili, 2012; DOEC, 2015). For example, in the Laval study in August 2011, Sunnyside tested an average of 249.9 µg/L for HAAs and 357.0 µg/L for THMs, which far exceed the Guidelines for Canadian Drinking Water Quality set at 80 µg/L for HAAs and 100 µg/L for THMs by Health Canada (Health Canada, 2012a). In the fall of 2013, at the highest concentrations over the last five years, the average concentration of HAAs in Sunnyside was 434.05 µg/L and THMs were 326.25 µg/L (DOEC, 2015).

So, the questions emerge: what are the potential health impacts of drinking water with elevated levels of DBPs? What can be done to mitigate exposure, either at the system-wide scale or in residents' homes? These are the major concerns faced by the Sunnyside Town Council, and to some extent residents who completed the survey, and have largely guided our inquiry. The rest of this section will address some of the literature exploring the potential health risks as well as a brief discussion of alternative technologies available to reduce exposure to these contaminant byproducts, with a particular focus on drinking water systems and public health in NL.

**Potential health impacts**

The literature used in constructing this review ranges across scientific and health-related peer reviewed research, with a particular focus on those reports published through Health Canada, the United States Environmental Protection Agency (EPA), the WHO and the International Agency for Research on Cancer (IARC), an agency of the WHO which specializes in cancer research. These organizations provide reports that are international in scope and comprehensive in nature, far more extensive than provided here, given our time and resource constraints for this particular project. However, the importance of highlighting this research here is to provide municipal leaders in particular with information which will assist in their decisions around DBP abatement in their communities. This section is organized in four parts:

(I) Types of DBPs and health guidelines;
(II) Exposure pathways of DBPs;
(III) Carcinogenicity and other health effects and risk assessment; and,
(IV) Summary and policy response in Canada

<u>(I) Types of DBPs and health guidelines</u>

As stated in the introduction, we are focusing on two main groupings of DBPs in this report: HAAs and THMs. The reason for this is two-fold: first, these are well-researched in the scientific literature and second, at this point HAAs and THMs are the only DBPs which are monitored by the provincial DOEC. There are however, over 500 known DBPs, and while efforts have been made to prioritize those that present the greatest potential health concern, further research is required to determine their toxicity and for these DBPs to be adequately regulated (EPA 2002, Richardson *et al.* 2002, Woo *et al*. 2002, Richardson 2003, Richardson *et al*. 2007, Chowdhury *et al*. 2011). In this report we review literature pertaining to four main types of THMs: Chloroform ($CHCl_3$), Dibromochloromethane (DBCM), Bromodichloromethane (BDCM), and

Bromoform($CHBr_3$) and two main types of HAAs: Dichloracetic acid (DCAA) and Trichloracetic acid (TCAA). The potential health concerns and risks of each of these types will be discussed further in the proceeding section.

Internationally, there is fairly consistent rationale for setting health guidelines for DBPs. Here, we present the guidelines set by Health Canada, the USEPA and the WHO (Table 1). In Canada the provincial and territorial governments base their guidelines on those outlined by Health Canada in the *Guidelines for Canadian Drinking Water Quality*. Further discussion of Canadian water policy is in section IV. As described by Health Canada (2009) "the guideline is established at a level at which the increased cancer risk is "*essentially negligible"* when humans are exposed at that level over a lifetime (70 years) (p.4- emphasis added)". This is referred to as *excess lifetime risk*, which in the context of drinking water guidelines, is defined by Health Canada as a range from one new cancer per 100,000 people to one new cancer above background per 1 million people (i.e., $10^{-5}$ to $10^{-6}$) over a lifetime, above background levels (ibid.). In other words, a dose (exposure) above these guidelines would result in a one new cancer per 100,000 people to 1 million people.The WHO guidelines are based on the *tolerable burden of disease* which is defined "as an upper limit of $10^{-6}$ DALY per person per year…[which] is approximately equivalent to a $10^{-5}$ excess lifetime risk of cancer, i.e. one excess case of cancer per 100 000 people ingesting drinking-water at the water quality target daily over a 70-year period" (WHO, 2011, p. 38). This is the risk level used by the WHO when determining guideline values for genotoxic substances, which are those chemical agents that have the ability to damage genetic information within a cell causing mutations, which may, in turn, lead to cancer.

Table 1. Health guidelines set for THMs and HAAs

| | |
|---|---|
| Health Canada- MAC (2009a, b) | Total THMs: 100µg/L<br>Total HAAs: 80 µg/L |
| United States EPA - MCL (2013) | Total THMs: 80 µg/L<br>Total HAAs: 60 µg/L |
| World Health Organization (2004) | THMs (no total guidelines): Bromodichloromethane 60 µg/L; Chloroform 300 µg/L; Bromoform 100 µg/L; Dibromochloromethane 100 µg/L<br>HAAs (no total guidelines): Dichloracetic acid 50 µg/L; Trichloracetic acid 200 µg/L |

In the US, there are two sets of guidelines: the maximum contaminant level goal (MCLGs) and the maximum contaminant level (MCL). The MCLGs are based on estimates from the best available science that predicts the level of contaminants in drinking water at which no adverse health effects are likely to occur and they are non-enforceable health goals "based solely on possible health risks and exposure over a lifetime, with an adequate margin of safety" (EPA 2013, p. 2). The MCL, on the other hand, sets an enforceable regulation, which is as "close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies" (ibid.). The MCLGs are thus more conservative than the enforceable MCL guidelines presented in Table 1. In Canada there is only one set of guidelines, referred to as the MAC, which are not enforced. The technical derivation of MAC is based on a "daily intake of 1.5 L of drinking water by a 70-kg adult, although intake by the most sensitive subpopulation e.g. pregnant women and children was considered where appropriate" (Mohaptra & Mitchell 2003, p. 11-12).

Despite the MAC guidelines being less conservative than the US MCLs, Mohaptra & Mitchell (2003) argue that the *precautionary principle* is at work in Canadian policy. Canadian policy makers rely strongly on standards established by the EPA, the European Union (EU) and the WHO in terms of carcinogenic chemicals, standards, which are precautionary in that they too are set at a level that protects the most vulnerable over a lifetime of consumption (EPA 2013). Mohaptra & Mitchell (2003) add that "it is beyond argument that when the extent of danger is not accurately established, it is preferable to err on the side of caution rather than err on the side of risk in accordance with the internationally recognized *precautionary principle*…[which states just that]" (p. 12, emphasis original).

In Sunnyside, and many other small, rural communities in NL and the rest Canada, the public drinking water contains THM and HAA levels that frequently exceed the MAC guidelines (Health Canada 2009a, b, Minnes &Vodden 2014). One of the issues we faced from the onset of this project was the concern, from municipal representatives and the larger drinking water project research team that MAC guidelines are difficult to understand from a policy perspective. They do not hold regulatory strength but nevertheless, exceeding these guidelines is considered unacceptable as the name suggests. From a governance perspective, according to one interview respondent from Health Canada, the difference between the Canadian situation and the US being able to enforce their MCL is that the EPA has complete legislative control over the states whereas Health Canada does not have this authority and thus MACs are presented to the provincial/territorial level via the *Guidelines for Canadian Drinking Water Quality* (GCDWQ). The burden to ensure compliance is then placed with the provincial government. Currently the DOEC informs municipalities where they exceed guidelines but there is no provincial mechanism in place to ensure compliance.

Our research suggests that municipal governments are concerned by the implications of exceeding MAC levels, in some cases by close to 10 times (Table 2); however, they are not required to take action and report that they are often uncertain as to what options are available to them while also facing financial and human resources constraints to their ability to act. While a summary of some the literature regarding health concerns and risks associated with DBP will be addressed further in section III, it is important for the reader to keep in mind the guidelines themselves are established based on the precautionary principle as discussed above.

Table 2. Levels of DBPs in high exceeding NL communities (DOEC 2015)

| Community Name | Population (2011) | HAAs Winter 2014 Running Average (µg/L) | THM Winter 2014 Running Average (µg/L) |
|---|---|---|---|
| New Wes Valley | 2265 | 708.4 | 167.50 |
| Keels | 61 | 756.4 | 428.95 |
| Salvage | 136 | 803.63 | 398.25 |
| Cartwright | 516 | 769.17 | 418.75 |
| St. Pauls | 258 | 652.33 | 390.75 |
| Point May | 233 | 512.15 | 298.70 |
| Sunnyside | 452 | 394.17 | 302.00 |

(II) Exposure pathways of DBPs

Individuals can be exposed to DBPs through three ways: ingestion, inhalation and absorption through the skin. Epidemiological and toxicological research has indicated that ingestion, i.e. through drinking chlorinated water, has been the main route of DBP exposure (Hrudley 2009). Further, oral exposure through drinking water, including that used in food preparation, is the main route of focus in previous drinking water research in the province (e.g. Dawe 2009, Minnes & Vodden 2014). However, there is evidence which suggests that up to 40% of total cancer risks can be attributed to both inhalation and dermal contacts (Chowdhury *et al.* 2011), and thus, it is important to consider each exposure route in combination with others.

Inhalation occurs through breathing in DBPs in the air, which are released through showering, bathing and boiling water. Some THMs, such as chloroform, are volatile, meaning they are easily released from the liquid water into a vapour form, particularly when heated. The third route of exposure is absoption through the skin (i.e. dermal contact). This occurs while showering and bathing, and when swimming in chlorinated pools, although, levels of exposure vary depending on the concentration of DBPs in the water system. Again, chloroform, is the main THM that can be absorbed through the skin (WHO 2011). As a general note, HAAs are not volatile and exposure is largely restricted to oral ingestion (Harper 2012).

As suggested, dermal contact and inhalation is a significant route of THM exposure- specifically chloroform. As stated, chloroform is a volatile compound, and as such it presents an elevated concern regarding DBP exposure because it can be ‘taken in’ through multiple routes; on the other hand, this also makes chloroform unique because this is not the case with HAAs and other THMs, which are largely limited to oral exposure via drinking water (Barnes & Dawe, 2011). Bove *et al.* (2007) state that exposure to chloroform via inhalation and dermal absorption during a 10 minute shower or a half hour bath are equivalent to the dose from ingesting 2 litres of tap water. Air circulation is an important consideration as well. In a closed shower stall THM concentrations increase with duration and increase in water temperature; here chloroform still poses the greatest potential risk to human health (Choudbury *et al.* 2011). The rate of exposure to chloroform during bathing and showering is temperature dependent, increasing dramatically with an increase in water temperature, with one study suggesting that absorption through the skin while bathing is 30 times greater in water at 40°C compared with 30°C (Gopal *et al.* 2007). The WHO estimates that the average intake of chloroform during showering is 0.5 µg/kg of body weight per shower (Health Canada 2009)[2]. Ullrich *et al.* 1982, Jo *et al.* 1990a,b conclude that, based on experimental studies on humans, the contribution of dermal exposure to chloroform was approximately equivalent to inhalation exposure during showering. Given the estimates of the average exposure across the various routes, the general population is exposed to chloroform in approximately equal amounts through consumption, absorption and inhalation[3], with the total estimated mean intake is approximately 2-3 µg/kg of body weight per day (WHO 1998, WHO 2011). However, for individuals with drinking water levels with higher levels of chloroform, the mean total exposure is up to 10 µg/kg of body weight per day (ibid.). As stated in a 2011 WHO report, “indoor air exposure to the volatile THMs is particularly important in [regions] with low rates of ventilation in houses and high rates of showering and bathing" (WHO 2011, p.427).

Additionally, swimming in chlorinated pools presents a significant source of exposure, through both absorption and inhalation. Kim *et al.*(2002) suggest that the chlorform levels in swimming pools vary widely because, despite the initial levels of DBPs present in a water system, the enhanced chlorination process used to chlorinate pools may cause the chlorine to react with the organic pollutants originating from swimmers in the pool water such as: skin scales, skin lotions, sweat and urine to form chloroform. Chloroform contributes a significant amount of the THM exposure that swimmers experience (WHO 1998). Levesque *et al.* (1994) estimate that a one hour swim can result in a chloroform dose of 65 µg/kg, which is 141 times greater exposure than during a 10 minute shower and 93 times greater than that for tap-water ingestion. However, as discussed in section III there is little evidence to suggest that swimmers have a greater incidence of adverse health impacts, despite their elevated exposure (Villanueva & Font-Ribera 2012).

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[2] In this estimate, mean intake of chloroform from indoor air was estimated to be 0.3-1.1 µg/kg bw per day (Health Canada 2009).

[3] More recent evidence suggests that inhalation and dermal exposure are likely to play a more significant portion of total exposure of THMs (chloroform in particular) because past research failed to adequately explore factors that increase chloroform concentrations in the air during and after showers (Chowdhury *et al.* 2011).

(III) Carcinogenicity and other health effects and risk assessment

One of the key objectives of this project was to provide a synthesis of some of the available literature on the potential health impacts of DBPs that could be used to clarify the risk associated with exposure to these drinking water by-products. That said, as stated by Hrudey (2008), "the challenge of judging and managing any public health risks "caused by" chlorination disinfection by-products (DBPs) in drinking water is likely the most complex issue that has faced the drinking water industry in the developed world over the past 3 decades" (p. i). There is evidence to suggest that drinking water contaminated with high levels of DBPs is associated with an increased risk of bladder, colon, liver and kidney cancer (Batterman *et al.* 2000, Ashbolt 2004, Bove *et al.* 2007, Gopal *et al.* 2007, Demarini & Lynge 2008, Chowdhury *et al.* 2011, Health Canada 2012a, Guilherme & Rodriguez 2014, Thomson 2014); and potential risks for pregnant women including miscarriage, birth defects, and low birth weight (ATSDR 1989, 1992, 1997). There is also research that finds that the epidemiological research indicates only a weak association between DBPs and cancer (Boorman *et al.* 1999, Batterman *et al.* 2000, Hrudey 2009, Bond *et al*. 2011, WHO 2011).

Here, we provide a general review of the available research as it is presented in the literature. This review is not exhaustive, but rather is pointed in its aim. Care has been taken to review documents from the WHO, Health Canada, the EPA as well as other scientific studies where authors themselves have taken a more comprehensive view of the research on DBP exposure, subsequent health impacts and risk to human health. Two general statements can be made of this body of literature: first, the vast majority of the research investigating the connection between DBP exposure and adverse health impacts has been undertaken through laboratory studies on animals, and comparatively there has been relatively little in the way of epidemiological research on long-term exposure on human populations. Second, authors unequivocally concede that further research is required to adequately understand the full potential impact of DBPs in publicly supplied drinking water. Further, while we hope that this review may be helpful to municipal government officials in navigating the issues, we recognize that a there is a need for greater public policy and resources in dealing with the issue of high DBPs and we address this in Part five of this report.

*i) Summary of health effects in laboratory research*

It is without a doubt that DBPs in drinking water present a concern to human health. The pertinent questions here are: i) what are the health impacts? And ii) is how much of a concern? (a question of risk). When speaking of health impacts, this section will touch on two very broad areas of research: cancer and "other" potential effects, which are primarily reproductive in nature. Table 3 provides an overview of the four main THMs and two HAAs and their respective potential adverse health impacts. This table also provides the IARC rating for each of these compounds, which is based on their extensive review of the available literature on a global scale. These ratings note that three of the THMs (including chloroform) and Dichloracetic acid (an HAA) are *probable human carcinogens*, based on sufficient laboratory evidence, while

Dibromochloromethane (a THM) and Trichloracetic acid (an HAA) are *possible human carcinogens*.

Briefly defined, the *probable human carcinogens* category is used when there is limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals and for a DBP to placed in this category there typically needs to be "strong evidence that the carcinogenesis is mediated by a mechanism that also operates in humans" (WHO 2011 p. 5-6). In other words, there needs to be assurance that physiologically the same result could translate from animals to humans. Agents are categorized as a *possible human carcinogen* when there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals, as defined by IARC (ibid.).

Table 3. DBPs and potential health impacts

| Type of DBP | Compound | Rating | Potential Health Effects |
|---|---|---|---|
| THM | Chloroform | B2 | Cancer, liver, kidney and reproductive effects |
| | Dibromochloromethane | C | Nervous system, liver, kidney and reproductive effects |
| | Bromodichloromethane | B2 | Cancer, liver, kidney and reproductive effects |
| | Bromoform | B2 | Cancer, nervous system, liver and kidney effects |
| HAA | Dichloracetic acid | B2 | Cancer, reproductive, developmental effects |
| | Trichloracetic acid | C | Liver, kidney, spleen, developmental effects |

**A:** Human carcinogen; **B1:** Probable human carcinogen (with some epidemiological evidence); **B2:** Probable human carcinogen (sufficient laboratory evidence); **C:** Possible human carcinogen (Gov NL 2009)

In 1993, a WHO analysis of DBP research, primarily from laboratory settings, found that when absorbed through the intestinal tract: bromoform, DBCM and BDCM caused damage to kidney and liver in high doses in experimental animals and chloroform absorbed following oral, inhalation, and dermal exposure-long term exposure to dose levels in excess of 15 mg/kg of body weight (i.e. very high doses) per day can cause changes in the kidney, liver, and thyroid. They also report that dichloroacetic acid absorbed through gastrointestinal tract was shown to induce neuropathy, decreases in body weight, testicular damage and histopathological effects in the brain in laboratory animals. It also found that trichloroacetic acid exposure in short- and long-term studies, induced tumours on mice livers and resulted in other forms of liver damage (ibid.). More recent analysis, conducted in 2011, reaffirms much earlier research. There is strong evidence that the liver and kidney damage caused by bromoform, BDCM, and chloroform exposure, particularly in short term, acute levels of exposure, is genotoxic in nature, leading to the conclusion that these substances are carcinogenic. However, other studies suggest that the evidence for DBCM in particular is inconclusive (WHO 2011). Further research established a link between BDCM and possible increase in reproductive effects, specifically an increased risk for spontaneous abortion or stillbirth (ibid.). Additionally, Dichloracetic acid became reclassified to *probable human carcinogen* in 2002, based on laboratory evidence that in animal studies (ibid).

*ii) Health risks and research in human populations (i.e. epidemiological research)*

There are vast bodies of research that have sought to define (and refine) risk estimates, quantify human health risk estimates, and communicate the risks of DBPs from toxicological, epidemiological and interdisciplinary modeling approaches (see Richardson *et. al.* 2002, Teuschler *et al*. 2004, Sadiq *et al*. 2007, Simmons *et al.* 2010). In 2008 the Committee on the Toxicity (COT) Chemicals in Food, Consumer Products and the Environment. (in UK) argues that:

> problems remain in the interpretation of published studies. These include the small relative risks recorded, the possibility of residual confounding, and the problems with exposure assessment…the evidence for a causal association between cancer and exposure to chlorination by-products is limited and any such association is unlikely to be strong. (p. 3)

In epidemiological research the burden to prove a causal relationship between DBP exposure and ill-health is high, and has not been met (Monson 1990**,** Hrudey 2008). Because of this there is a significant degree of uncertainty in establishing causality on the basis of laboratory science alone. For example, Hrudey (2008) states that "overall, the consistency of findings on urinary bladder cancer is notable, but the specificity and plausibility, as to causal agent, are weak to negative and the strength of association is generally low enough to be susceptible to even minor confounding (p. ii)". For this reason, accurately measuring risk is a very difficult task.

As stated above, exposure in a controlled laboratory setting is different from long-term, and arguably variable, exposure through drinking affected drinking water. Boorman *et al*. (1999) state that while THMs were found to be carcinogenic in rodents, other DBPs carcinogenic in rodent bioassays, several epidemiology studies "have suggested a weak association (odds ratios of generally less than 2) between drinking chlorinated water and the occurrence of bladder, rectal and colon cancer" (p. 207). In 2000, the WHO reaffrim this sentiment, stating "the epidemiological evidence is insufficient to support a causal relationship between bladder cancer and long-term exposure to chlorinated drinking-water, THMs, chloroform or other THM species" (10). Graves *et al*.'s (2001) review of epidemiological and toxicological studies examining effects of DBP on human reproduction and development found no evidence of association for neonatal death, low birth weight, pre-term delivery, and congenital, cardiac, gastrointestinal, genital, integument, musculoskeletal and chromosomal abnormalities) and a few with suggestive associations (in utero-growth retardation and urinary tract defects). Studies examining the relationship between DBP with still birth/fetal death, spontaneous miscarriage, and congenital abnormalities/birth defects offered mixed or inconsistent results (Graves *et al.* 2001, Davis & Mazumder 2003). These observations regarding studies examining the association between reproductive effects and DBP exposure reaffirmed by Bond *et al*.'s (2011) survey of the literature.

An often quoted study in the provincial literture in NL (Dawe 2009, Ziegler *et al.* 2009is King and Marrett's 1996 piece. Here, King and Marrett (1996) found that 14%-16% of bladder cancers in Ontario can be attributed to long term exposure to high levels of THMs. According to the WHO (1998) the association in King and Marrett's research is only statistically significant after 35 or more years of exposure. While their research indicated that the bladder cancer incidence was about 40% higher among persons exposed to greater than 1956 (µg/litre)/years THMs in water compared with those exposed to less than 584 (µg/litre)-years[4], overall, "it is not possible to conclude on the basis of available data that this association is causal, [and although] observation of associations in well conducted studies where exposures were greatest cannot be easily dismissed…the degree of evidence should be considered to be limited" (WHO 1998, p. 93). Ashbolt (2004) estimates that if a causal link did exist between bladder and rectal cancers and DBP exposure then about 8% of bladder cancers and 18% of rectal cancers in the US could be attributed to drinking chlorinated surface waters, qualifying this estimate with the concern that these analyses may be criticized based their likelihood of being chance associations. Undoubtably, there is a strong need for further research in order to better assess the true impact of these associations as stated by Hrudey (2008):

Until epidemiology studies are completed with substantial numbers of participants residing in larger urban areas who have had low to negligible chlorination DBP exposure because the drinking water supply used alternate disinfection and water treatment practices (ozonation, UV or no disinfection), the possibility will remain of a small systematic bias sufficient to explain the consistent, but comparatively weak association (generally OR<2) of urinary bladder cancer with chlorination DBPs. (p. 88)

It is with this lens in mind, we discuss the literature on discussing the risks posed by consuming drinking water with elevated levels of DBPs. When discussing risk, it is important to return to the concept of the *precautionary principle* in establishing safety guidelines for DBPs in public drinking water supplies. As described by the WHO (2011) because "the genotoxic mechanism theoretically does not have a threshold, there is a probability of harm at any level of exposure (p. 7)". On that basis, in research that models risk – by accounting for the differences in metabolic rates between experimental animals and humans using a surface area to body weight correction, which is applied to quantitative estimates of cancer risk derived from lose-dose expolation models – there tends to be an overestimate of risk in humans (with lower surface area to body weight ratio) (ibid.). And it is this overestimate that informs the *excess lifetime cancer risk* of $10^{-5}$ to $10^{-6}$ guideline value for 70 years (assuming 150 lb adult consuming 2L of water per day) (WHO 2011). While a causal link cannot be established from the existing research, the

[4] King and Marrett use a concept of "THM-years" that represents the cumulative exposure to THM, which incorporates both levels of exposure to THMs and the period of exposure.

consistency in findings across various epidemiological studies suggests that these associations, albeit weak, cannot, or should not be dismissed entirely and that discussion of potential risk (and risk factors) is prudent (Bull 1995,WHO 1998, Hrudey 2009). In 2002, the CDC reported that with DBP exposure of over 70 years (at the MCL), an upper bound estimate of the probability of cancer due to chloroform is 0.24 cancers per 1,000,000 people per year. With the rate of cancer, generally, at approximately 1,930 / 1,000,000 per year US, the extra cancer from chloroform was calculated to be negligible (CDC 2002). Additionally, risks levels do increase for those exposed over longer durations and at higher levels. King and Marrett (1996) state that those exposed to an estimated THM level greater than or equal to 50 µg/L for 35 or more years had 1.63 times the risk of those exposed for less than 10 years. While human studies have suggested a link between reproductive effects and exposure to high levels of THMs, an increase in the concentration of THMs – and other DBPs – could not be linked to an increase in risk in the case of reproductive effects (Hrudey 2008, Health Canada 2009).

As stated in the previous section, there is also increased exposure rates in indoor swimming pools because of the high concentrations of chloroform in the water and released in the surrounding air. Chowdbury (2015) estimates that the cancer risks from THMs in swimming pools were 4.06–6.64 times to the cancer risks from THMs in drinking water, assuming the Canadian MAC guidelines are met. However, this does not take into other factors, particularly, the health benefits that swimming provides. Villanueva and Font-Ribera's (2012) review states that the epidemiological evidence shows that swimming in pools during pregnancy is not associated with an increased risk of reproductive outcomes. They argue, that overall, the available research indicates that the health benefits of swimming outweigh the risks associated with DBP exposure, including cancer.

In the literature, there are also numerous variables cited which impact the risk that DBP exposure poses. For instance, Michaud *et al.* (2007) found that for all THM route of categories, the risk of bladder cancer *decreased* with increasing water intake; however, these results were contrasted by Villanueva *et al*'s (2006) findings, which pooled results from six controlled case studies. According to review by the International Programme on Chemical Safety (IPCS) (WHO 2000) relative risks of DBP exposure vary between smokers and non-smokers and across different geographic areas because the DBP differs and/or other chemical contaminants are present in the drinking water supply. Many published accounts argue that smokers are at a greater risk of bladder cancer when exposed to DBPs, however, King and Marrett (1996) find the opposite result, and overall it is arguable, once again, that the inconsistencies reveal that more research is required (see Hrudey *et al.*, 2012). But as stated by Davis and Mazumder (2003) "regardless of the relationship between exposure to DBPs and human health, one assured approach to mitigate this risk is to reduce organic precursors in raw source water" (p. 278), which will be discussed in detail in the technologies and solutions section.

(IV) Summary and policy response in Canada

There is an adequate public policy basis to maintain a reasonable, precautionary approach to regulating a public exposure as pervasive as drinking water. With that premise in hand,

> I do not believe there is any need, value or justification for overselling inherently uncertain toxicological or epidemiological evidence as being more certain than the evidence warrants in order to scare consumers, drinking water providers or politicians into supporting a particular regulatory standard.
>
> Hrudey 2009, p. 2087

The question that remains for the Town of Sunnyside, and many other rural communities in NL: what should be done to address the issue of high levels of DBPs – levels that exceed the maximum acceptable concentration guidelines set by Health Canada? As stated above, the guidelines themselves are set using a precautionary approach, meaning that when there are periodic, and hypothetically longer term, exceedances the relative risk to human health is still very low. However, it is nevertheless important to discuss this issue for a number of reasons, including: residents' concerns over their publically supplied drinking water, and the growing frustration that municipal officials feel when discussing with residents the implications of having high levels of DBPs in water supply and in determining the best technical solutions moving forward. This section will provide an overview of the "policy response" to DBPs in Canada and NL, particularly in the context of communities exceeding the MAC. This overview is based on interviews and email correspondence with provincial and federal government officials and non-governmental organizations as well as broader public health and policy literature on DBPs.

Monitoring drinking water has been a chief priority of Health Canada for decades, and formalized GCDWQ have published by Health Canada since 1968 (Health Canada 2012b). Since 1984, the Federal-Provincial-Territorial Committee on Drinking Water (CDW) – comprised of 14 voting members (water quality experts and representatives from each of the 10 provinces, three territories, and the federal government) and non-voting members, including representatives from the Canadian College of Health, Environment Canada, and the Canadian Advisory Council on Plumbing – meets on a semi-annual basis (Health Canada 2006). Additionally, provisional experts are invited to each meeting to discuss particular drinking water issues in Canada (ibid). As stated by Mohaptra and Mitchell (2003), "each recommended guideline value and its accompanying health risk assessment has been evaluated for its practicality and impacts and is established through a consensus development process" (p. 4). Given that the guidelines are modified to satisfy the needs of all jurisdictions involved, albeit through consensus, and are not exclusively based-on scientific inputs, Mohaptra and Mitchell (2013) argue that there is a need to adopt a more scientific method for formulations of standards, given the full range of considerations required.

In July 1998, Health Canada established a multi-stakeholder Chlorination Disinfection By-Products (DBP) Task Group to oversee a "comprehensive update of health risk information on THMs and to develop recommendations for controlling the risks" (DOEC 1999 p. 12). In addressing the task group's mandate, Health Canada established three subgroups: i) the Health Effects Subgroup, ii) the Water Quality Subgroup, and iii) the Economics Issues Subgroup. These subgroups were collectively responsible for evaluating: epidemiological and toxicological evidence of health effects posed by DBPs, drinking water quality data, and water treatment facility characteristics for communities across Canada, respectively. In 2000, the subgroups reported to the larger task group, who then presented recommendations to the CDW for managing health risks from chlorination disinfection by-products, which reflect the current MAC (ibid.). According to an interviewee with the federal government, these guidelines are regularly have been re-evaluated by the CDW; however, the process is not necessarily set in stone, as the group operates with a list of national priorities that need revisiting periodically. In other words, DBPs are a part of a broader list of competing priorities when it comes to the assurance of safe drinking water through the GCDWQ. Compared to other federal and provincial water policies in Canada, the GCDWQ stands alone in the sense that it is routinely re-evaluated and modified, where needed, through the work of the CDW (Ramalho *et al.* 2014). The CDW revisits a priority list on an ongoing basis, and updates or develops new guidelines based upon the criteria of risk, prominence, and feasibility as determined by scientific and peer-reviewed research (Ibid, pers. com, HC, May 2015).

The Government of NL and provincial experts from Regional Health Authorities (non-governmental organizations) have collaborated with provincial colleagues in the DBP Task Group and continue to work closely with the provincial representative of the CDW (pers. com. EH, May 2015). These meetings are ongoing, but not regular in nature. The focus tends to remain on analyzing the scientific-evidence emerging on DBPs, and that related to other drinking water issues, in evaluating the current guidelines – as opposed to communicating with local governments about how they should deal with their DBP levels and address this issue with their residents (ibid). This of course, poses a huge challenge for municipal governments because they often do not have the capacity or the resources to assess or communicate the potential health effects of elevated DBPs, and given this, it is difficult to determine what the most appropriate remedial actions and solutions are required to resolve the problem. Additionally, the Government of NL currently has in place a commitment to safe drinking water in this province as expressed through the Multi-Barrier Strategic Action Plan (MBSAP), modeled after a similar design developed by the CDW (Ramalho *et al.* 2014). Through the MBSAP, the province aims to protect the quality and quantity of drinking water at all sections of water systems. Table 4 lists a series of policy highlights present in the MBSAP, which exist in varying stages of implementation.

Table 4. Water policy highlights in NL (Ramalho *et al.* 2014)

| | |
|---|---|
| Expenditure | • Collecting and testing water samples monthly<br>• Treating (generally chlorinating) water<br>• Supporting the introduction of potable water dispensing<br>• Establishing a water portal<br>• Improving access to training and certification for water operators<br>• Providing some funding for new and improved water systems |
| Economic | • Implementing water rates at the local level |
| Institutional | • Watershed management plans<br>• Watershed management committees |
| Regulatory | • Designating and protecting public water supplies and wellheads under the *Water Resources Act* (WRA)<br>• Regulating activities in designated areas using a permitting regime, founded in ministerial discretionary, under the WRA<br>• Establishing water use (rights) restrictions under a licensing regime under the WRA<br>• Prohibiting certain activities in protected public water supplies and wellheads under the WRA |
| Guidance | • Implementing boil water advisories<br>• GCDWQ |

Health Canada (2009a) states that "as with all guidelines, any significant exceedance should be a signal to investigate the situation in order to take remedial action and to consult the authority responsible for public health. For significant exceedances above the guideline value, it is suggested that a plan be developed and implemented to address these situations" (p. 4). However, this is a major challenge to the intra-provincial governance surrounding DBPs, and water quality more generally in NL. The DOHCS and Service NL are the most closely associated with the "public health" role, and while they do provide public informational fact-sheets regarding water chlorination, DBPs and treatment options, they provide little in the way of hands-on council to municipal leaders facing chronically elevated DBPs in their water systems. Likewise, the DOEC offers little guidance beyond providing technical reports to municipalities regarding the chemical/physical contaminants in their water supply. To date, there is no plan within the province to address the chronically high levels of DBPs, those in excess of the MAC guidelines, in municipal water systems.

Minnes and Vodden (2014) illustrate in great length resident and municipal concerns surrounding DBPs in NL, but also indicate that experts during a policy workshop state there is no baseline data for DBP-induced illness in the province (cf. Dolter, 2014). As a result, "it is difficult to quantify the true impacts of DBPs when it is still largely unknown how DBPs have affected NL residents' health, representing an area where future research is needed (Minnes and Vodden 2014, p. 29)". Given that there that a causal link with DBP exposure and the occurrence of cancer has not been established (and likewise for many reproductive effects), it cannot be guaranteed that lowering the MAC levels for DBPs will have an impacts on overall health outcomes. As stated by Hrudey (2008) "only mitigative measures such as reduction of chlorination DBP precursors are likely to assure concurrent reduction of THMs and the unknown chlorination DBPs (p. ii)". With this in mind, we discuss some alternatives and solutions to DBPs in the next section.

**Alternative technologies and solutions**

The Town of Sunnyside has sought out advice from several consultants in order to determine the best course of action to deal with their chronically elevated levels of DBPs. In general, disinfectant alternatives to chlorination and other DBP mitigating treatment options available vary in terms of cost, feasibility and overall "investment" or community buy-in required. In this section of the report, we will outline some of the available options as discussed in the literature, and highlight those processes that have been recommended to the Town of Sunnyside. For a more in-depth review of any particular technology, please see Ling and Husain 2014. This section is organized into four subsections:

(I) Public systems;
(II) Home systems;
(III) Alternative/solutions discussed and/or used in Sunnyside; and,
(IV) Summary of technologies

(I) Public systems

Here, we consider three main components of addressing the issue of DBP prevention and mitigation at the scale of the entire municipal/community/regional water systems: source water factors, operations and maintenance factors, and types of technologies and alternatives to chlorination. Source water considerations include: changing the location of the water intake and/or the source of water, where appropriate; removal of vegetation (as per permit requirements) prior to an area being flooded for the purpose of creating a surface water reservoir; and, conducting chlorine decay rate and THM formation potential tests at an accredited laboratory prior to selecting, developing and commissioning a new source that is intended to be disinfected with chlorine (Government of NL 2009). In general, source control measures refer to those strategies where there is some form of collaboration between municipal and provincial governments. However, as with installing an entirely new system with advanced-filtration or an alternative disinfectant, the applicability and suitability of a particular measure is determined on a case-by-case basis through site-specific assessment and evaluation, and in consultation with appropriate government agencies and municipalities (DOEC 1999).

In their 1999 report on THMs in NL, Government of NL recommended that the following options be assessed on "a case-by-case basis using a cautious, progressive and sequential approach: 1) watershed protection; 2) chlorine demand management; 3) removal of THM precursors; 4) use of alternative disinfectants; 5) conventional water treatment and; 6) assessment of alternative water supply sources" (p. 5-1 – 5-2). Here, the conventional water treatment option refers to an extensive 'overhaul' of a given water system, and the replacement with a new system that includes: disinfection, coagulation/filtration, ion exchange and demineralization, organics removal, and lime softening/corrosion control (ibid.). While a completely new system is the most effective way of preventing and mitigating DBPs, it is by far the most expensive option, and given the substantial investment it entails, it is unattainable for many rural municipalities. As such, it is left to municipal leaders to determine, with guidance from consultants or from research forums like Municipalities Newfoundland and Labrador Symposia, the best combinations of piece-meal options to prevent and/or reduce DBPs in their water system that are both effective and financially feasible.

The operations and maintenance of public drinking water system is the responsibility of the municipality – the provincial government, via Municipal and Intergovernmental Affairs (MIGA), may only provide financial support associated with the startup costs of a system. Best practices in addressing the issue of DBPs in the operation and maintenance of a system include: 1) ensuring that a) the specific design requirements (i.e., filtration, redundancy, continuous monitoring, log reduction using prescribed treatment processes) and b) water quality goals (turbidity, coliforms, DBPs) are written clearly in the design guidelines; 2) regularly system flushing and the use of automatic flushing systems; 3) having a plan that addresses retention time management, such as limiting water time in storage tanks and chlorine management (e.g. via the use of booster stations and; 4) operator training and certification such that the municipal/community operator is aware of these issues (Pers Comm, May 2015, Eastern Health representative).

When discussing specific technologies that prevent and/or mitigate DBPs in public water systems it important to described how these different technologies achieve this goal. Broadly speaking, there are two primary strategies used, one is the removal of the organics and total carbon from the water prior to being treated (e.g. filtration and 'removal' technologies), which prevents DBP formation. The other is the use of alternatives to chlorine disinfection, either as the primary disinfectant or in the case of combined disinfectants, wherein a secondary disinfectant is also used.[5] The former tend to be categorized as filtration systems and the latter as disinfectant systems. Additionally, both of these systems are components of "conventional water treatment"

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[5] Primary disinfectants are those used before the water enters the mainline, where it is subsequently delivered to individual water users. As an example, chlorine can be used as a primary disinfectant, and if the residual levels are maintained throughout the entire mainline, no further disinfectant is required. Secondary disinfectants are used within the mainline, and are required with some disinfectants (such as Ozone), where residual disinfection does not occur in the event that there are breaks in the line, wherein pathogens could be introduced to the water supply (see Table 5). In NL, and elsewhere, only certain disinfectants can function as primary disinfectants and others need to be paired with a secondary disinfectant in order to ensure complete pathogen control (DOEC 1999).

as described above, even if the disinfectant is an alternative to chorine (DOEC1999). There is an extensive list of technologies in the literature (Table 5). Here we note the typology for each of these, and some of the relative costs (Table 6). Authors state that when either an alternative primary disinfectant or combined disinfectants are used DBP levels can be lowered significantly; however, not every alternative disinfectant is by-product free (EPA 1999, DOEC 1999, WHO 2011, Ling & Husain 2014). Additionally, researchers in NL state that given the reliance on the surface water sources in this province, which tend to have relatively high levels NOM, filtration and removal techniques are a key part of the DBP equation (Ziegler *et al.* 2009); however, as demonstrated in Table 6, filtration technologies are highly expensive. Given this extensive list of technologies and the nature of this report, we cannot describe each of these technological alternatives in detail, nor do we provide a thorough analysis of the benefits and drawbacks of each. Please see DOEC 1999, Gov NL 2009, CBCL 2011, and EPA 2012 for a more in depth discussion of the pros and cons of each of these technologies.

Table 5. Technologies that prevent or mitigate DBPs (EPA 1999, Gov NL 1999, Gov NL 2009, Merényi *et al*. 2010, Ling and Husain 2014)

| **Disinfectant techniques** | | | **Requires secondary disinfectant?** | **By-product(s) formed?** |
|---|---|---|---|---|
| | Primary Disinfectants | Chloramine | No | Less volatile than chlorine, reduced by-products |
| | | Ozone | Yes | DBPs are formed in the presence of bromides, aldehydes and ketones |
| | | Chlorine dioxide | No | Under proper generation conditions (i.e. no excess chlorine), halogen-substituted DBPs are not formed. |
| | | Ultraviolet (UV) radiation | Yes | No known by-products |
| | | Potassium permanganate* | No, although long contact time require | Not when in system, but by-product from preparation extremely dangerous for water operator |
| | | Mixed oxidants (e.g. MIOX) | No | Less than that of traditional chlorine gas |
| | | Peroxine (Ozone + hydrogen peroxide)* | Combined disinfectant | Peroxide radicals formed during peroxine process |
| | Secondary disinfectants | Monochloramine | - | Less volatile than chlorine, reduced by-products |
| | | Stabilized hydrogen peroxide | - | No known by-products |

Table 5. continued

| | | |
|---|---|---|
| Filtration/removal techniques | Dissolved air floatation<br>Zirconium coagulation<br>Regenerative magnetic TiO2<br>Granular activated carbon<br>Nano membrane filtration<br>Microfiltration/ultrafiltration<br>Ultrasound and quartz sand<br>Aluminum sulphate or PAC dosing (flocculent)<br>Aeration (air stripping) | These filtration/removal technologies increase the removal of total organic carbon (TOC), thus preventing the formation of DBPs through removing the TOC via the natural organic matter (NOM) precursors. |
| Other processes | Reverse osmosis | Reverse osmosis is a method of ion exchange/demineralization. If a unit is properly is properly installed it can remove upwards of 96% of all inorganic contaminants from water |

*not approved in NL

Table 6. Water system cost based on treatment of 1 million gallons/day (Ling & Husain 2014, cf Roy 2009)

| | | *Capital costs* | *Operation and maintenance costs* | *Annual cost (Based on 10 Year Life Cycle)* |
|---|---|---|---|---|
| Disinfection systems | Chloramine | $ 62,608 | $ 4,861 | $ 11,122 |
| | Chlorine Dioxide | $ 47,531 | $ 21,217 | $ 25,970 |
| | UV Disinfection | $ 359,359 | $ 10,855 | $ 46,791 |
| | Ozone | $ 974,973 | $ 91,862 | $ 189,359 |
| Filtration systems | Granular Activated Carbon | $ 863,696 | $ 61,531 | $ 147,900 |
| | Nano filtration | $ 1,057,344 | $ 133,392 | $ 239,126 |
| | Microfiltration/Ultrafiltration | $ 1,786,445 | $ 78,573 | $ 257,218 |

(II) Home water systems

There are two basic types of home water systems: point-of-entry (POE) systems, which refer to those that can be utilized by residents at the main water line into the house, and point-of-use (POU) types which are options that can be utilized by consumers at individual water taps in the house (DOEC 1999). During this project, there has been a great deal of uncertainty as to which consumer products do in fact remove DBPs from residents' drinking water (as well as the water flowing from their shower faucets). For example, there was a lack of clarity at the level of our expert interview informants as to the degree of protection offered by common filtered jugs (such as Brita) in reducing DBP exposure for residents. While Health Canada cannot make commercial product recommendations, it was pointed out by a Health Canada representative and a representative from the provincial DOEC that the NSF International Standards, conducted through the American National Standards Institute (ANSI), provide objective and auditable THM removal stardards. Certification organizations ensure the treatment filters and equipment meet these standards. In order for consumers to ensure they are getting the correct product, they need to find those filters marked NSF Standard 53 certfied for THM removal. One option to find products that meet the standards for THM removal (Table 7) go to the NSF website and select NSF 53 for "product standard" and total THM reduction under the "Reduction Claims for Drinking Water Treatment Units- Health Effects". Additionally, when using a home water treatment filter, it is important to follow the manufacturer's instructions regarding the product' specified use and maintainance.

Table 7. NSF 53-THM removal claim approved products

| Type | Brand and availability (cost in CAD) | More information |
|---|---|---|
| Point of Entry Systems (i.e. for the entire house) and shower head faucet | There are no systems listed on the NSF site for point of entry systems that are NSF Standard certified shich claim to reduce total THM levels | http://www.env.gov.nl.ca/env/waterres/training/adww/treatmentalternatives/pres11_willard_deon_point_of_use.pdf |
| Undersink unit | Rainfresh Twist Undersink System, ~$135<br>Replacement filters, ~$33<br>Available through Canadian Tire | http://www.rainfresh.ca/qs1.php |
| Tap faucet | Brita Faucet Filtration System, ~$26<br>Replacement filters, ~$18<br>Available through Walmart, Canadian Tire<br>~$26<br>PUR MineralClear Advanced Plus Horizontal Faucet Mount, ~$30<br>Available through Walmart, Home Depot, Canadian Tire | http://www.hindawi.com/journals/jeph/2013/959480/<br>http://www.health.gov.nl.ca/health/publichealth/envhealth/chlorineandthms2009.pdf<br>http://hbg.psu.edu/etc/research/DBPPOU_Fact%20Sheet.pdf |

Additionally, there has been some suggestion in the literature that boiling water is an effective method of reducing DBPs. One study suggests that boiling can help to remove the THMs from drinking water because of those compounds' volatility (especially, chloroform); however, boiling water is not effective in removing HAAs (Ahmad 2013 cf. Ling and Husain). Further, although boiling water will remove volatile THMs, this method alone has not been shown to significantly reduce exposure, and thus it not recommended by Health Canada as method for mitigating DBPs in drinking water (DOEC 2014a). As stated in a previous section, boiling water may also increase exposure via inhalation.

(III) Alternative solutions discussed and/or used in Sunnyside

As discussed in the introduction, the current water system in Sunnyside was only recently completed in 2012; however, the town has a history of chlorination-related issues, in part due to the length of their mainline, which extends over eight kilometers. In 2009, the town installed a MIOX system, which was pilot project for the MIOX Corporation and partially funded through Capital Works (Daniels, 2014). The main issue facing the town council at this time was that they could not maintain a sufficient chorine residual throughout their mainline and the MIOX system sought to correct this issue. Rather than using chlorine gas or liquid chlorine (i.e. sodium hypochlorite), the MIOX system creates a liquid chlorine oxidant on site. In Sunnyside, this mixed chlorine oxidant is stored in two holding tanks and injected into the water with small pumps, which can be run on a generator during a power outage, while the rest of the system is operates through gravity-driven flow (ibid). Initially, the MIOX system had major issues in Sunnyside, but once these issues were resolved, it addressed the larger issue of maintaining chlorine residuals throughout the entire line, which the town was unable to achieve with their previous chlorination system. CBCL (2014) suggests that the current operating practice used by the town to maintain chlorine residuals and reduce DBP concentrations throughout the system is to continuously flush a hydrant located at the furthest end of the system.

Despite the claims that MIOX reduced DBPs in drinking water, the municipal water in Sunnyside still had elevated levels of DBPs, long after the MIOX installation (Daniels 2014, Ling and Husain). In response to this issue, in 2014 the town council put out a request for proposals aimed at provincial engineers- to further the research on appropriate options to resolve Sunnyside's high levels of DBPs (Daniels 2014). Additionally, municipal officials and employees have been active in researching options, particularly through municipal forums such as the Municipalities Newfoundland and Labrador (MNL) events. To date, the town has received three formal proposals from: CBCL Limited Engineering Consultants, WaterSkrubr, and SanEcoTec. The multi-million dollar CBCL proposal involves the development of a completely new water treatment plant, requiring a new WTP building, process equipment, storage tank, and all associated components (CBCL, 2014). This system proposed using one of three basic filtration options: i) enhanced coagulation, dissolved air flotation clarification, and multimedia filtration; ultrafiltration followed by nanofiltration; or, direct nanofiltration (ibid). The WaterSkrubr process specifically involves ultrafiltration. The town has also looked into technologies proposed by King Processes, which involves carbon filtration. Sunnyside is also participating in a 2015-2016 Harris Centre-funded project led by Dr. Tahir Husain, Affordable Water Filtration Technology for Small Rural Communities. The US EPA identifies enhanced coagulation and activated carbon as the best available technologies to reduce NOM. While some commercially available activated carbons show a high potential for removing DBPs and their precursors, they are not affordable for small communities (Streat et al., 1995). Dr. Husain is exploring the potential to extract readily available unburned carbon from oil fly ash (OFA) as a low-cost adsorbent. The current project will assess the performance of OFA activated carbon in NOM removal and DBP formation under different conditions after chlorination in several communities, including Sunnyside.

In September 2015, SanEcoTec's ALIVE™ Water Treatment system was installed in Sunnyside, as part of a four-month pilot project (SanEcoTec, 2015). This system involves the use of stabilized hydrogen peroxide as a secondary disinfectant, which means that there will be less MIOX solution required and the reduction of DBPs (SanEcoTec representative pers. comm. October 2015). This pilot process has garnered support from the DOHCS and Service NL, and in just one month of operation there was a notable difference in terms of water quality, including softer, less 'chlorinated' taste and smell as well as lowered DBP levels (ibid). Improvement of water aesthetics, particularly the reduction of the chlorine taste and smell, could prove to be a very important in influencing residents' drinking water practices. In the residential survey (Part two), poor appearance and taste were noted as the top reason people felt the water was unsafe, followed by concerns around chlorinated DBPs. Additionally, residents were largely unfamiliar with the term DBP prior to answering the survey in the fall of 2014 (63% indicated they were either not familiar or only somewhat familiar with the term) suggesting that safety concerns are largely influenced by the taste and smell of chlorine as opposed to the presence of DBPs themselves. If the pilot is successful, then Sunnyside will continue to use the ALIVE™ Water Treatment with funding support provided through the MIGA (SanEcoTec, 2015).

(IV) Summary of technologies

In emphasizing "chlorination of drinking water has been one of the most effective public health measures ever undertaken" (p. 155), Bull *et al.*(1995) further urge policy makers, municipal leaders and water operators to consider that "alternatives [to chlorination] vary in their effectiveness and some require greater sophistication in their application. This can mean less protection to public health as a result of inappropriate application and control (ibid)". Conversations, and indeed policies, around the best solutions to mitigate DBPs should be framed with this in mind, along with the previous discussion of health risks posed by DBPs. Deciding on the correct solution(s) for any given community depends on various factors, such as the reasons contributing to the formation of DBPs in system in the first place. Numerous authors suggest that given the surfaces waters in NL have high amounts of NOM, that removal of these precursors is a critical piece of the puzzle (Hrudey 2008, Ziegler *et* al. 2009, Ling & Hussain 2014). Seeking inspiration from other jurisdictions across North America and elsewhere where advanced filtration is more widely applied in rural regions is critical. At the same time, it is essential that public system solutions take into account local operational factors, such as the financial and human capacity of NL communities, as well as regulatory requirements. In terms of point-of-use solutions, Minnes and Vodden (2014) recommend that there is a need to look at more household treatment options as well as increased efforts toward communicating with residents about what they can do at home if they are concerned about DBPs, including the promotion of NSF certified products. In Part four we will discuss the results from the Community Water Forum in Sunnyside and provide a series of policy recommendations in moving forward.

## Part four: Community water forum in Sunnyside

One of the key aspects of this project involved reporting back to the Town of Sunnyside the results of both the residential survey and the literature review regarding the potential health impacts posed by DBPs and technological solutions to this issue. On May 12, 2015, in collaboration with town council, we presented our research findings to approximately 40 people in Sunnyside. The audience predominantly consisted of residents of Sunnyside, including members of town council, but there were also a few residents from outside of the community, a representative from MIGA, and the facilitator from the Office of Public Engagement. The format and content of the forum were developed through a series of meetings in Sunnyside involving: the mayor, another counselor and the town manager, the facilitator, and ourselves (the two lead researchers). There were a number of presentations at the event: Mayor Robert Snook presented about why he felt concerned by the current state of DBPs in Sunnyside. Philip Smith, the town manager, discussed water operations in Sunnyside, particularly the mechanisms in place to ensure that clean, safe drinking water is delivered to residents' homes. Kelly Vodden (Principal Investigator) presented an overview of the results from the larger rural drinking water project, to help contextual the impetus of this research in rural NL and Jen Daniels (Co-investigator) presented on the work discussed in sections one and two of this report. Finally, we felt it important to ask attendees at this event their take on the water in Sunnyside, as well as the larger DBP problematic, to help the research team, and council, more adequately address future research and policy directions.

The questions posed to attendees at the water forum served two main purposes: first, we wanted to have a comparison of whether these responses were at all similar to those from the survey conducted six months earlier. Second, the research team and town council were interested in knowing that if after the presentations of the issues facing the community, including DBPs and the town's water operations, whether they would be willing to increase what they pay into this service and whom they thought were responsible for solving water system issues (Table 8). It should be stated here, that we do not want to make direct comparisons between the two different sets of data, as each were obtained under different circumstances. The first set were obtained by knocking on residents' doors, and while residents certainly had the option of not completing a survey, this represents an entirely different method of data collection from asking questions of an audience of residents committed to showing up to an evening of presentations about their town's water. In light of this, we will only provide broad observations about the two sets of responses. In both instances there seems to be a high portion of residents who are not drinking the town water in Sunnyside. The vast majority (93%) of respondents at the forum said they were concerned or very concerned about the town's water quality and treatment, while relative levels of concern over water safety was not as unanimous in the survey. Sixty percent of the respondents at the forum said they agreed that they have a good understanding of pathogens in the water and chlorination processes, while only 37% of the survey respondents stated that they were familiar with the term DBP.

Table 8. Community water forum responses

| Question (multiple choice) | Response | | | | | |
|---|---|---|---|---|---|---|
| 1. Do you have access to the Town's water supply? (29 responses)* | Yes- 100% | | | | | |
| 2. Is your home connected to the Town's water supply system? (29 responses) | Yes- 93% | No- 7% | | | | |
| 3. How concerned are you about the Town's Water Quality and Treatment? (29 responses) | Very Concerned- 55% | Concerned- 42% | Not concerned at all- 3% | | | |
| 4. "I have a good understanding about water based bacteria and chlorination processes." (29 responses) | Strongly agree- 27% | Agree- 33% | Neutral- 23% | Disagree- 17% | | |
| 5. Do you drink water from the Town's supply system? (29 responses) | Yes- 35% | No- 65% | | | | |
| 6. How much water do you drink each day (per 8-ounce glass- including tea and coffee)? (30 responses) | I don't drink water- 6% | 1-2 glasses- 16% | 3-4 glasses- 16% | 5-6 glasses- 35% | 7-8 glasses- 13% | More than 9 – 13% |
| 7. Do you filter your drinking water? (31 responses) | Yes- 38% | No- 59% | I don't know- 3% | | | |
| 8. "If filtered water costs $550.00 per year in St. John's, it is worth $550.00 per year in Sunnyside". (31 responses) | Strongly agree- 22% | Agree- 26% | Neutral- 26% | Disagree- 15% | Strongly disagree- 11% | |
| 9. "Since coming to tonight's Water Forum, my knowledge and understanding about water born bacteria and chlorination issues has changed". (31 responses) | Strongly agree- 11% | Agree- 57% | Neutral- 18% | Disagree- 7% | Strongly disagree- 7% | |
| 10. Who has the responsibility to solve water system issues? (27 responses) | Residents- 0% | Town Council- 4% | Provincial Government- 11% | Combination of the three- 82% | I don't know- 4% | |
| 11. How much more water taxes would you be willing to pay to have a new water treatment process? (28 responses) | 20% more- 42% | 40% more- 8% | 60% more- 4% | 80% more- 8% | I'm not willing to pay more taxes- 38% | |

* Only residents of Sunnyside responded to questions, attendees living outside the community did not have a clicker/responding device.

Overall, attendees at the forum responded positively (68% agreed) that their knowledge about chlorination issues had changed after attending the presentations. Unfortunately, given the constraints of the event, we did not have the capacity to conduct a series of round tables to explore what this meant for residents; however, when subsequently asked "how much more water taxes would you be willing to pay to have a new water treatment process?" 80% of residents stated that they were only willing to pay 20% more for better water services (and roughly half of these residents said they were not willing to pay any more). When asked who they felt was responsible for solving issues related to their drinking water, 82% of attendees indicated they believe the responsibility resides collectively with residents, town council and (senior levels) of government. It is with this in mind, we will conclude this report with a series of policy recommendations and future directions for research.

## Part five: Policy recommendations

In this review, we build upon the policy recommendations presented in the *Exploring Solutions for Sustainable Rural Drinking Water Systems* project report. One issue frequently addressed over the course of the Sunnyside project is the lack of regulatory emphasis placed on the GCDWQ, particularly that MAC for DBPs, as the provincial level. As stated earlier, the federal government has established the GCDWQ guidelines, and it is in turn the province's responsibility to enforce these guidelines as they see fit. This is a complicated issue, because as demonstrated in the literature, the MAC is based on the available scientific literature and is highly protective in nature. Arriving at an enforceable level would have to take into account the feasibility of technological solutions, in terms of available financial and human-resources available to small rural communities, in addition to any technological expertise required. Alternatively, there would have to be a significant change in terms of provincial investment into the water treatment systems for small rural communities, specifically, in NL, in order for the hundreds of communities affected to reduce their levels of DBPs below the federal MAC guidelines. However, until such time, there is a need for increased levels of public health education and support provided to municipal leaders and the public at large on the part of the provincial government.

Thus, our main policy recommendation for the Government of Newfoundland and Labrador is for the province to develop and support a multi-faceted education campaign around the potential health impacts of DBPs, the role of chlorination in publically supplied drinking water, and solutions and alternatives available in preventing and/or mitigating the impacts of DBPs. This will require specific expertise in health risk assessment and communication. An additional education-related need for the province is one that provides more information (and research) on the environmental and social impacts of bottled water in this province.

Accessible information about DBPs is currently severely lacking, both in terms of the potential health impacts and available technological and operational alternatives. This leaves municipal leaders, such as those in the Town of Sunnyside, to take on the bulk of the research independently without a systematic network of support. Given the number of communities impacted in this province, there is a need for greater support from the province in both interpreting this information, communicating it to their residents, and in identifying those technological solutions that can fit their individual needs. As researchers in geography and planning, we had trouble in developing accessible fact sheets on these subjects without slipping into overly technical language, but that could still address those questions and concerns voiced by municipal leadership and some residents in Sunnyside. There is a public desire to understand this information, which is not being met by the current available "public-friendly" literature on DBPs provided by the provincial government. Communicating risk to the public is not straightforward, which was acknowledged by several of the government and non-governmental health experts consulted in this project; however, the public dissemination of risk analysis related to DBPs is necessary in order for municipal and provincial governments to be able to appropriately respond to this issue. There is, after all, a significant amount of municipal capital and energy directed towards the provision of safe, clean drinking water, which is clearly demonstrated by the actions taken by the town council in Sunnyside. Furthermore, as stated by Minnes and Vodden (2014), in the absence of system-wide solutions, there is a need to promote household treatment options, with NSF 53 specifications. This information could be distributed through pamphlets and other public outreach mechanisms, particularly in those communities most affected.

As described in Part two, given there is an additional cost associated with drinking bottled water, above and beyond public-service fees, dependence on bottled water – especially if it is deemed the "safest" option by the public at large – presents an issue in terms of economic accessibility. Not all residents can afford to purchase bottled water – on top of their municipal taxes. Moreover, there has been significant attention on university and college campuses across North America towards banning bottled water (such as Ban the Bottle), which give rise to the social and environmental concerns posed by consuming bottled water. Conducting research and educating the public-at-large about the impact on relying on bottled water, including the various options of bottled water (e.g. 5-gallon reusable bottles versus individual 333mL bottles) is an important policy endeavor given the rates of bottled water consumption presented in Sunnyside.

At the Community Water Forum (Part four), 82 % of residential attendees stated that they felt solutions for the issue of DBPs are the collective responsibility of residents, municipal and senior levels of government. Municipal governments share in the responsibility of educating their residents about impacts of both DBPs and bottled water and about available alternatives. As discussed in Part three, some filtration technologies that prevent the formation of DBPs are likely to be too expensive for a municipality to install and operate. While these technologies may be highly effective in reducing the formation of DBPs, they are financially out of reach for many rural municipalities. Home-treatment technologies (POE and POU systems), may prove to be effective in reducing DBP exposure in a very short time and with relatively little cost to residents. However, we are cautious in recommending this as a long-term solution, in part because of issues of social equity as not all residents are in a situation where they can afford home filtration systems. Additionally, home treatment systems need to be properly maintained to remain effective and – despite the existence of the NSF search engine tool – finding appropriate systems is still challenging because this tool contains out of date information and difficult to obtain products. In closing, it is the responsibility of public institutions (i.e. government agencies) to ensure that the appropriate water systems are in place to deliver safe drinking water to residents of Sunnyside and other NL communities.

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# Appendices

## Appendix A- Research field guide materials

<u>(I) Survey guide</u>

Sunnyside Survey Guide

23 Sept 2014

Materials to bring: raincoat and water-proof /resistant backpack if you have one. I will bring other stuff, but an extra pen or two wouldn't hurt either.
When approaching house, note the map # and location of house on the map. Houses should be coded using the map # and by assigning a different number to each house on that map (moving from right to left on the map, or top to bottom—based on the alignment of the houses). E.g. on Map 2, the 10$^{th}$ house from the far right-hand side of the map should be coded 2.10. <u>All</u> houses should be coded, whether or not someone is living there, and these codes should be placed directly on the map by their respective houses. Sheds, garages and public buildings do not need to be coded.
If no one answers the door, on a separate sheet of paper indicate that 2.10 was a "no answer" and place a recruitment letter (form A) in their mailbox or somewhere on their door. Also indicate whether this is the 1$^{st}$ or 2$^{nd}$ visit to the house.
Additionally, if we find out that a house is not occupied, please code the house and make a note that it is unoccupied (seasonally or on a more permanent basis)
If some answers the door, briefly introduce yourself and the project (using survey participant consent form- form B). If they are interested in participating, indicate that they are giving oral consent to participate in the project and give them the consent form.
An important thing to remind residents is that their responses will remain confidential, and no one but the research team will know individual person's responses, including Town Council and those working for Sunnyside.
See the script for DBPs, try to avoid elaborate discussions of potential health impacts and focus more on information sources where people can get more information. We are not medical researchers/public health professionals after all and we need to be clear of our position(s) and where this research is coming from.
Once completed the survey, write the house code on the first page of the survey.
If a resident answers the door, but is not interested in participating, please code the house and make a note that the resident is not interested.

(II) DBP script

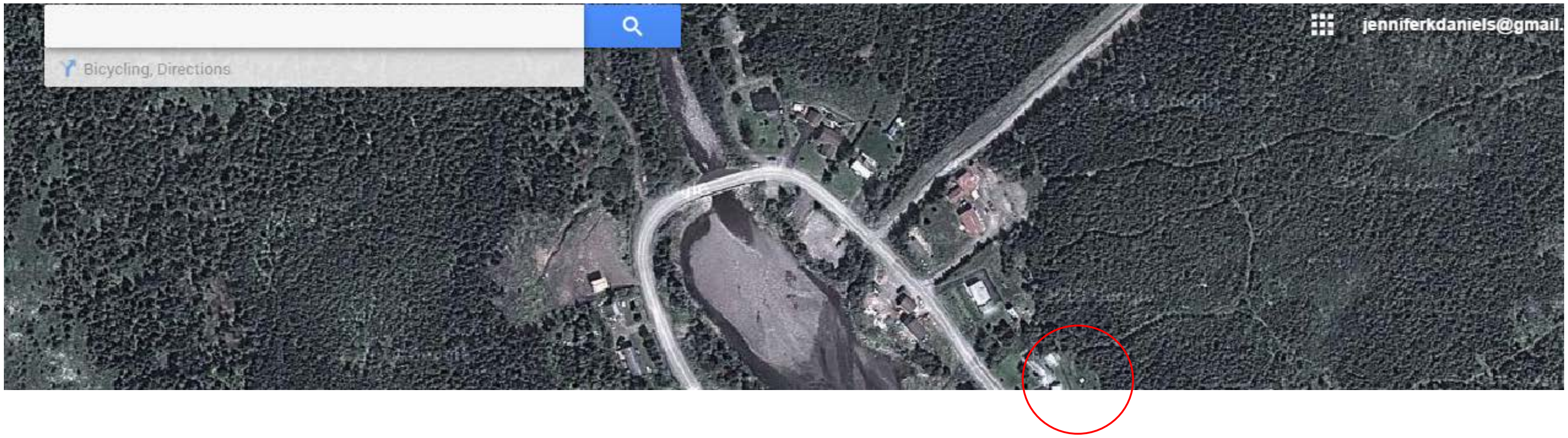
Disinfectant By-product Script (for question 26)

Disinfection by-products (DBPs) can occur when disinfectant chemicals (chlorine in particular) react with organic material present in the water supply. The most well known DBPs in NL are trihalomethanes (THMs) and halogenic acetic acids (HAAs). DBPs are largely consumed through drinking water that has been treated with chlorine, particularly where the high levels of naturally occurring organics in the source water.

Since the discovery of DBPs in 1964, numerous studies [over 60] have been done on the potential health risks (Hrudey, 2009).While some of the research suggests that DBPs are associated with increased rates of cancers, generally the results of these studies are quite varied, and in many cases offer conflicting evidence in terms of the associated health impacts. Recent research suggests that there are high levels of DBPs in Sunnyside, based on Health Canada's federal recommendations; however, it is important to note that the risk from drinking untreated water is greater than any known risk from drinking water contaminated with DBPs, according to the provincial government (DOEC, 2009a) and a larger body of research, including that of the World Health Organization.

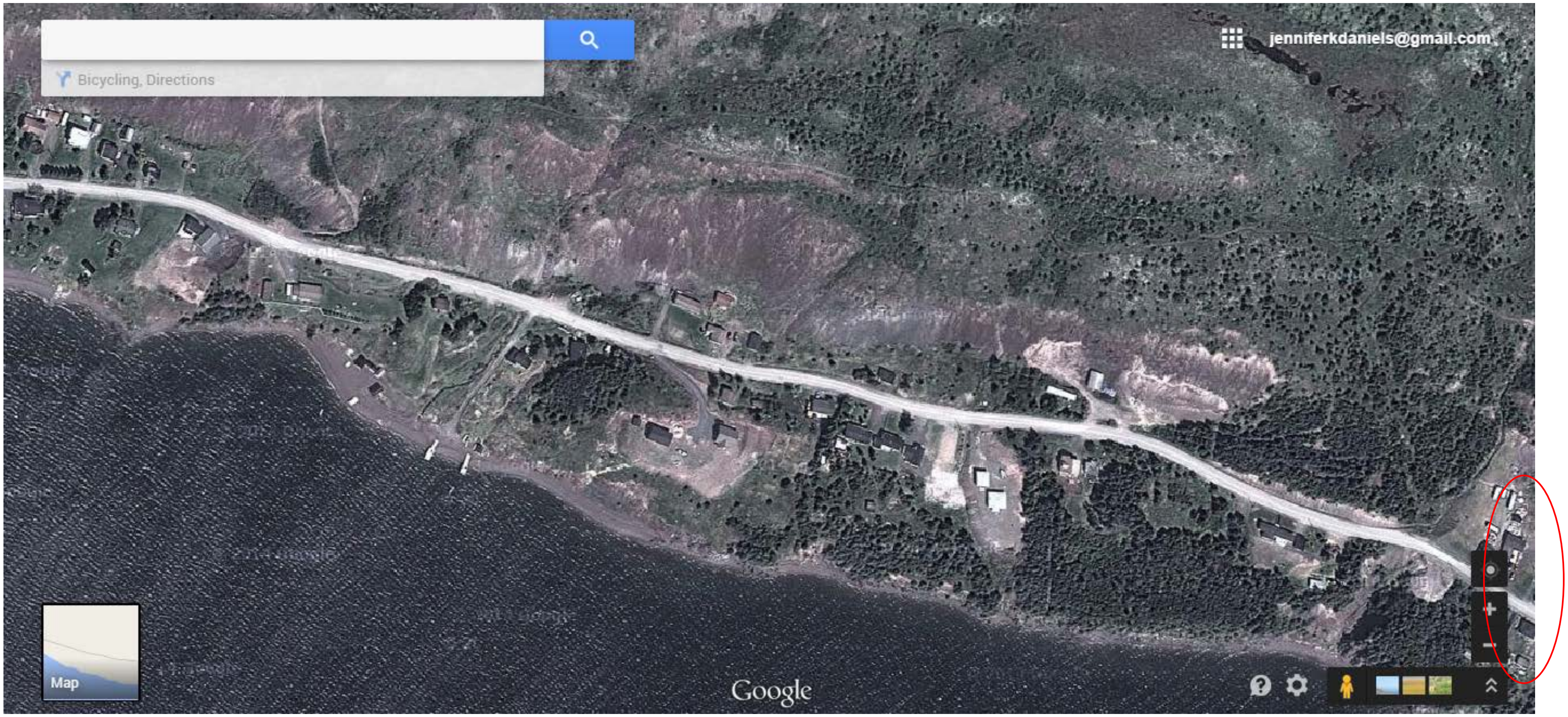
**(Reassure people is if they become distressed— you do not necessarily need to read this section)--**we are not medical professionals, and should you have any specific health-related questions or concerns we suggest that you consult with your healthcare provider. If you would like more information about DBPs we can take your email address strictly for the purpose of providing additional information, including ways to reduce your exposure at home (e.g. charcoal filters on your tap). NB: see additional printout through Service NL website.

(III) Town maps



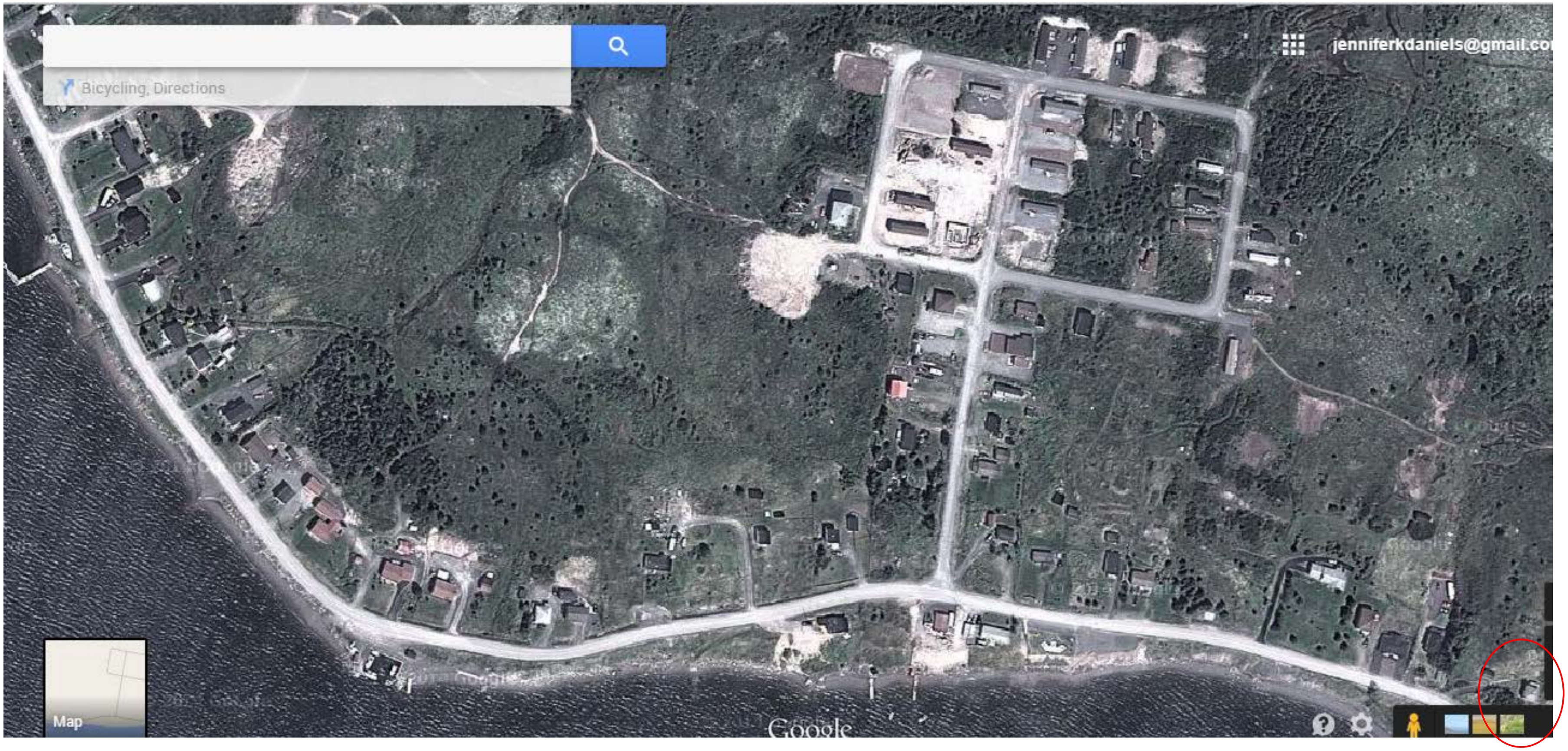

Centre Cove
Google
Map

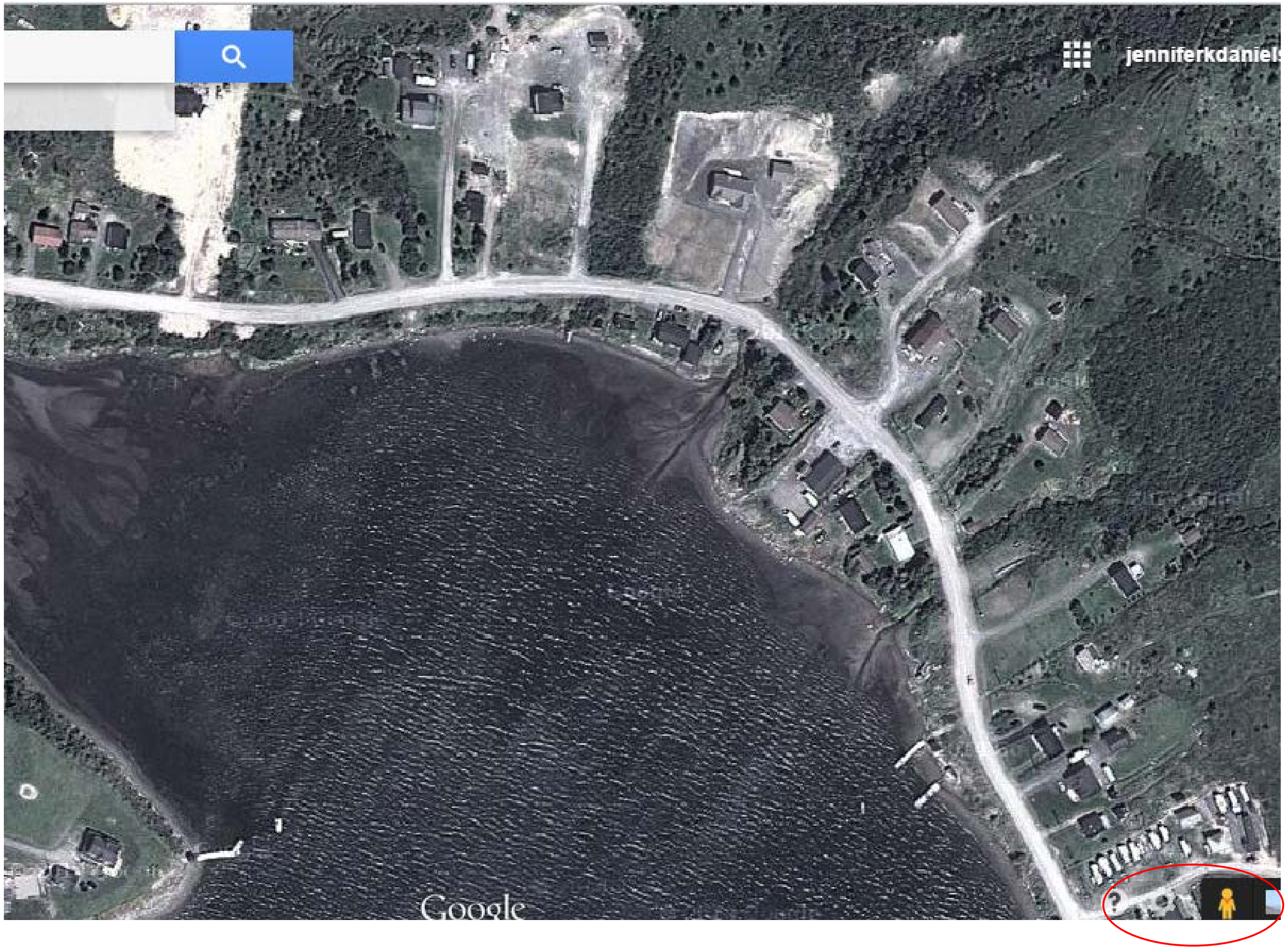

Centre Cove
Map
Google

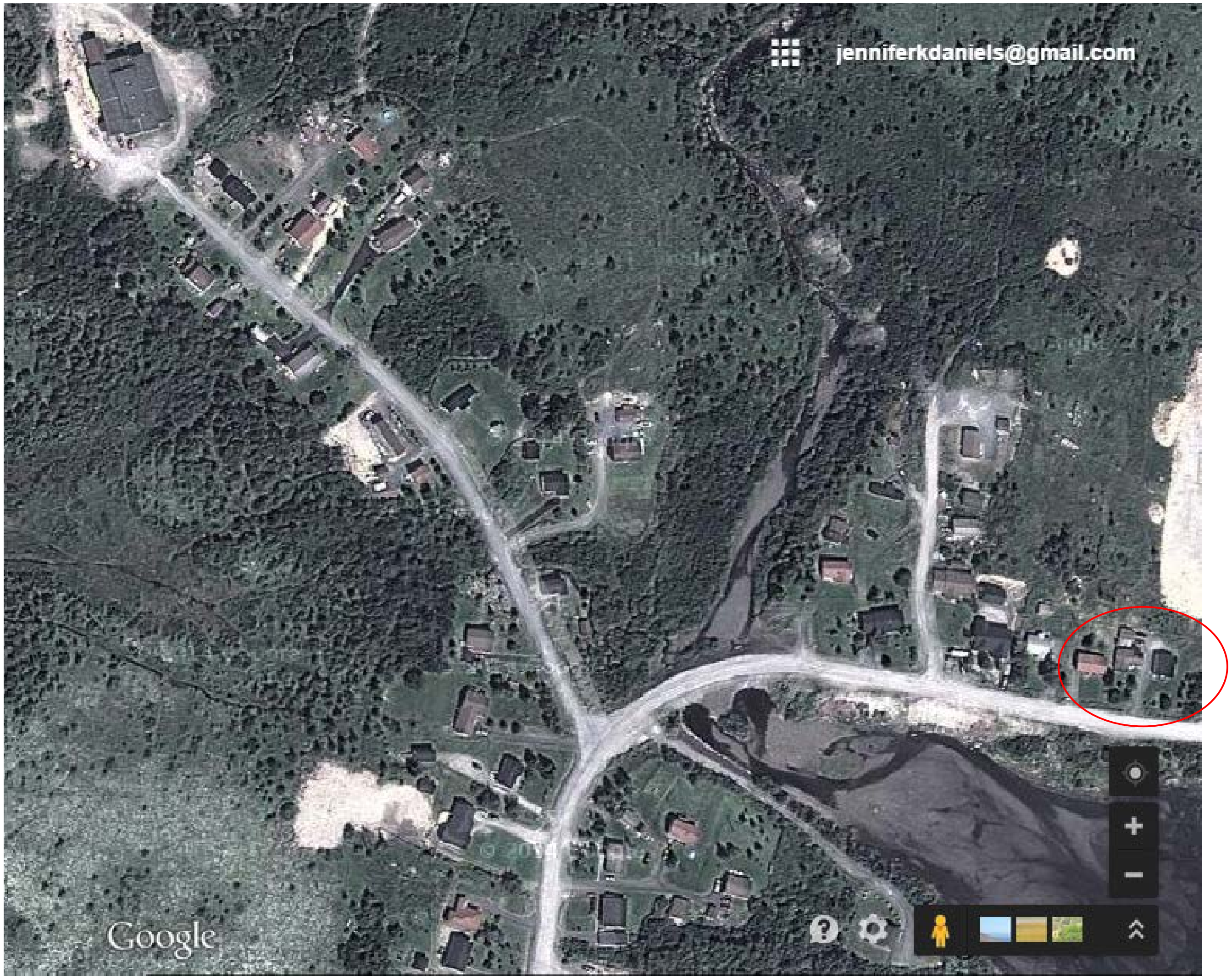


Bicycling, Directions
jenniferkdaniels@gmail.com
Map
Google

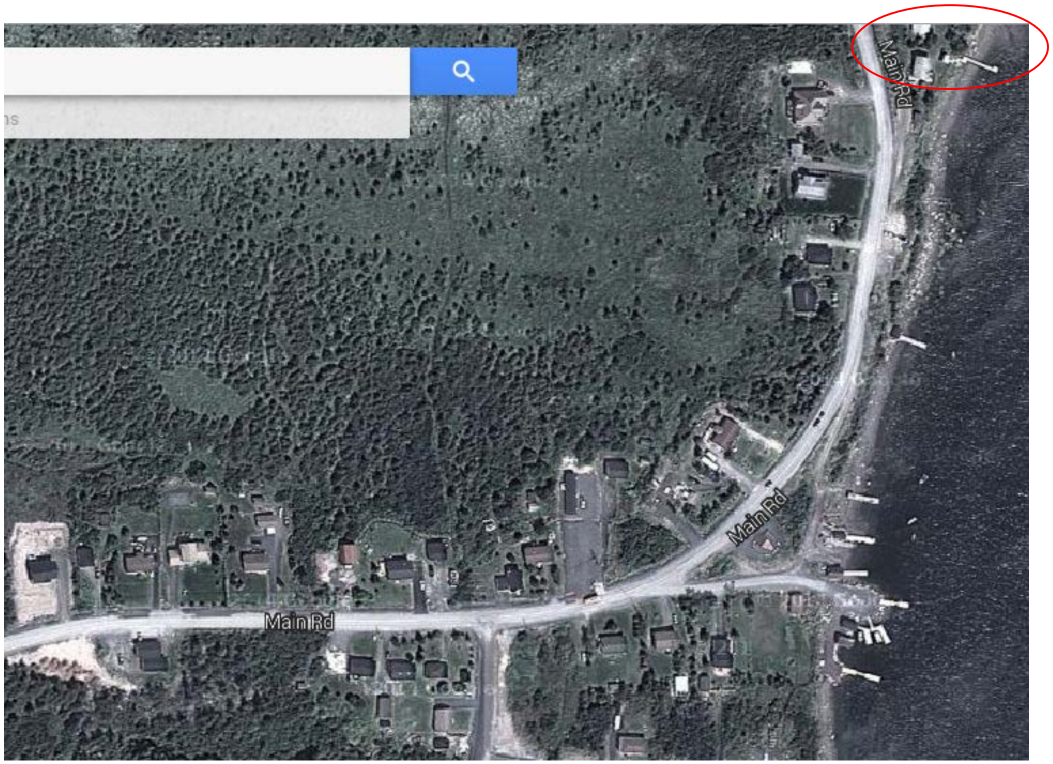
Developing area north along this road. Consult with town re. whether there are residences above.


Bicycling, Directions
jenniferkdaniels@gmail.co
Map
Google


jenniferkdaniels
Google


jenniferkdaniels@gmail.com
Google


jenniferkdaniels@gm
Main Rd
Main Rd
Google



Main Rd
Main Rd
Main Rd


Google
Imagery ©2014 DigitalGlobe, Map data ©2014 G


Main Rd
Main Rd
Google

**Appendix B- Survey data**

(I) Sunnyside survey responses

*Section 1: For all participants*

Q1.

Sex

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | both answered | 2 | 1.6 | 1.6 | 1.6 |
| | female | 66 | 53.2 | 53.2 | 54.8 |
| | male | 56 | 45.2 | 45.2 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q2.

Age range

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 18-29 | 2 | 1.6 | 1.6 | 1.6 |
| | 30-44 | 29 | 23.4 | 23.8 | 25.4 |
| | 45-59 | 38 | 30.6 | 31.1 | 56.6 |
| | 60 years or greater | 53 | 42.7 | 43.4 | 100.0 |
| | Total | 122 | 98.4 | 100.0 | |
| Missing | no answer | 2 | 1.6 | | |
| Total | | 124 | 100.0 | | |

Q3.

Number of people in household

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1 | 9 | 7.3 | 7.3 | 7.3 |
| | 2 | 64 | 51.6 | 51.6 | 58.9 |
| | 3 | 20 | 16.1 | 16.1 | 75.0 |
| | 4 | 24 | 19.4 | 19.4 | 94.4 |
| | 5 or more | 7 | 5.6 | 5.6 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q4.
Respondent's main household?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 3 | 2.4 | 2.5 | 2.5 |
| | yes | 117 | 94.4 | 97.5 | 100.0 |
| | Total | 120 | 96.8 | 100.0 | |
| Missing | No answer | 4 | 3.2 | | |
| Total | | 124 | 100.0 | | |

Q5.
Respondent pays municipal water taxes?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 2 | 1.6 | 1.6 | 1.6 |
| | not sure | 1 | .8 | .8 | 2.4 |
| | yes | 121 | 97.6 | 97.6 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q6.
Household connected to municipal water supply

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 14 | 11.3 | 11.3 | 11.3 |
| | not sure | 1 | .8 | .8 | 12.1 |
| | yes | 109 | 87.9 | 87.9 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q7.
If not connected to municipal water supply, household paying for water service?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 109 | 87.9 | 88.6 | 88.6 |
| | yes | 14 | 11.3 | 11.4 | 100.0 |
| | Total | 123 | 99.2 | 100.0 | |
| Missing | No answer | 1 | .8 | | |
| Total | | 124 | 100.0 | | |

Q8.
Main source(s) of drinking water

Case Summary

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| Water source | 122 | 98.4% | 2 | 1.6% | 124 | 100.0% |

| | | Responses | | Percent of Cases |
|---|---|---|---|---|
| | | N | Percent | |
| main sources of drinking water | dug/drilled well | 38 | 28.4% | 31.1% |
| | natural/roadside spring | 3 | 2.2% | 2.5% |
| | tap water | 41 | 30.6% | 33.6% |
| | purchased bottled water | 52 | 38.8% | 42.6% |
| Total | | 134 | 100.0% | 109.8% |

Q9.
Reasons residents use their main source(s) of drinking water
Case Summary

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| Reason for main source | 119 | 96.0% | 5 | 4.0% | 124 | 100.0% |

| | | Responses | | Percent of Cases |
|---|---|---|---|---|
| | | N | Percent | |
| Reason(s) for main source(s) of drinking water | accessibility | 46 | 23.0% | 38.7% |
| | affordability | 5 | 2.5% | 4.2% |
| | clarity/colour | 18 | 9.0% | 15.1% |
| | safety | 39 | 19.5% | 32.8% |
| | smell | 20 | 10.0% | 16.8% |
| | taste | 53 | 26.5% | 44.5% |
| | other (specifications provided) | 19 | 9.5% | 16.0% |
| Total | | 200 | 100.0% | 168.1% |

Q10.
Do you boil or treat this water?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 105 | 84.7 | 90.5 | 90.5 |
| | yes | 9 | 7.3 | 7.8 | 98.3 |
| | sometimes | 2 | 1.6 | 1.7 | 100.0 |
| | Total | 116 | 93.5 | 100.0 | |
| Missing | no answer | 8 | 6.5 | | |
| Total | | 124 | 100.0 | | |

Q11.
Do you use a water filter, and if so, what type?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | do not use a filter | 71 | 57.3 | 61.7 | 61.7 |
| | yes, but no filter specified | 6 | 4.8 | 5.2 | 67.0 |
| | Brita | 26 | 21.0 | 22.6 | 89.6 |
| | charcoal filter variety (not Brita) | 4 | 3.2 | 3.5 | 93.0 |
| | reverse osmosis | 2 | 1.6 | 1.7 | 94.8 |
| | filter system on fridge | 4 | 3.2 | 3.5 | 98.3 |
| | filter system on well | 1 | .8 | .9 | 99.1 |
| | not sure | 1 | .8 | .9 | 100.0 |
| | Total | 115 | 92.7 | 100.0 | |
| Missing | no answer | 9 | 7.3 | | |
| Total | | 124 | 100.0 | | |

Q12.
Is your town on boil water advisory (BWA)?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 109 | 87.9 | 88.6 | 88.6 |
| | not sure | 13 | 10.5 | 10.6 | 99.2 |
| | yes | 1 | .8 | .8 | 100.0 |
| | Total | 123 | 99.2 | 100.0 | |
| Missing | | 1 | .8 | | |
| Total | | 124 | 100.0 | | |

Q13.
Do you receive notification when town is on BWA?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 1 | .8 | .8 | .8 |
| | yes | 119 | 96.0 | 96.7 | 97.6 |
| | not sure | 3 | 2.4 | 2.4 | 100.0 |
| | Total | 123 | 99.2 | 100.0 | |
| Missing | no answer | 1 | .8 | | |
| Total | | 124 | 100.0 | | |

Type of notification received in event of BWA

| | | Responses | | Percent of Cases |
|---|---|---|---|---|
| | | N | Percent | |
| type of notification received | letter/mail | 36 | 23.8% | 30.3% |
| | Facebook/town website | 3 | 2.0% | 2.5% |
| | word of mouth/from neighbours | 6 | 4.0% | 5.0% |
| | call from town office | 95 | 62.9% | 79.8% |
| | notice on community channel/radio | 8 | 5.3% | 6.7% |
| | yes, but not specified | 3 | 2.0% | 2.5% |
| Total | | 151 | 100.0% | 126.9% |

Q14. How often do you drink the following types of water?
Bottled water

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | at least once a week | 83 | 66.9 | 68.6 | 68.6 |
| | at least once a month | 18 | 14.5 | 14.9 | 83.5 |
| | almost never | 11 | 8.9 | 9.1 | 92.6 |
| | never | 9 | 7.3 | 7.4 | 100.0 |
| | Total | 121 | 97.6 | 100.0 | |
| Missing | no answer | 3 | 2.4 | | |
| Total | | 124 | 100.0 | | |

Well water

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | at least once a week | 39 | 31.5 | 32.5 | 32.5 |
| | at least once a month | 1 | .8 | .8 | 33.3 |
| | almost never | 1 | .8 | .8 | 34.2 |
| | never | 79 | 63.7 | 65.8 | 100.0 |
| | Total | 120 | 96.8 | 100.0 | |
| Missing | not answer | 4 | 3.2 | | |
| Total | | 124 | 100.0 | | |

Spring water

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | at least once a week | 3 | 2.4 | 2.5 | 2.5 |
| | at least once a month | 2 | 1.6 | 1.7 | 4.2 |
| | almost never | 12 | 9.7 | 10.0 | 14.2 |
| | never | 103 | 83.1 | 85.8 | 100.0 |
| | Total | 120 | 96.8 | 100.0 | |
| Missing | no answer | 4 | 3.2 | | |
| Total | | 124 | 100.0 | | |

Tap water

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | at least once a week | 39 | 31.5 | 32.5 | 32.5 |
| | at least once a month | 4 | 3.2 | 3.3 | 35.8 |
| | almost never | 8 | 6.5 | 6.7 | 42.5 |
| | never | 69 | 55.6 | 57.5 | 100.0 |
| | Total | 120 | 96.8 | 100.0 | |
| Missing | no answer | 4 | 3.2 | | |
| Total | | 124 | 100.0 | | |

Pond/river water

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | at least once a month | 2 | 1.6 | 1.7 | 1.7 |
| | almost never | 5 | 4.0 | 4.2 | 5.8 |
| | never | 113 | 91.1 | 94.2 | 100.0 |

| | | | | | |
|---|---|---|---|---|---|
| | Total | 120 | 96.8 | 100.0 | |
| Missing | no answer | 4 | 3.2 | | |
| Total | | 124 | 100.0 | | |

Q15.
Main source of cooking water

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | same as drinking water | 70 | 56.5 | 56.5 | 56.5 |
| | other: tap | 53 | 42.7 | 42.7 | 99.2 |
| | other: not specified | 1 | .8 | .8 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q16.
Average spent on bottled water per month

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | bottled water is not purchased | 9 | 7.3 | 7.4 | 7.4 |
| | under $10 | 49 | 39.5 | 40.5 | 47.9 |
| | $10-$24 | 38 | 30.6 | 31.4 | 79.3 |
| | $25-$49 | 18 | 14.5 | 14.9 | 94.2 |
| | over $50 | 7 | 5.6 | 5.8 | 100.0 |
| | Total | 121 | 97.6 | 100.0 | |
| Missing | no answer | 3 | 2.4 | | |
| Total | | 124 | 100.0 | | |

Q17.
Are taps left running over winter?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 119 | 96.0 | 97.5 | 97.5 |
| | yes | 3 | 2.4 | 2.5 | 100.0 |
| | Total | 122 | 98.4 | 100.0 | |
| Missing | no answer | 2 | 1.6 | | |
| Total | | 124 | 100.0 | | |

Q18.
Do you feel that the water portion of tax bill is…?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | does not pay taxes: renter | 2 | 1.6 | 1.6 | 1.6 |
| | about the right amount | 53 | 42.7 | 43.1 | 44.7 |
| | too high | 31 | 25.0 | 25.2 | 69.9 |
| | not sure | 37 | 29.8 | 30.1 | 100.0 |
| | Total | 123 | 99.2 | 100.0 | |
| Missing | no answer | 1 | .8 | | |
| Total | | 124 | 100.0 | | |

Q19.
With increased water quality, would you be willing to pay more for water?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Does not pay taxes: renter | 2 | 1.6 | 1.7 | 1.7 |
| | Yes | 53 | 42.7 | 43.8 | 45.5 |
| | No | 48 | 38.7 | 39.7 | 85.1 |
| | not sure | 18 | 14.5 | 14.9 | 100.0 |
| | Total | 121 | 97.6 | 100.0 | |
| Missing | no answer | 3 | 2.4 | | |
| Total | | 124 | 100.0 | | |

Q20.
How much more would you be willing to pay for drinking water services (annually)?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not willing to increase water taxes | 62 | 50.0 | 54.9 | 54.9 |
| | less than $100 | 38 | 30.6 | 33.6 | 88.5 |
| | between $100-250 | 6 | 4.8 | 5.3 | 93.8 |
| | between $251-400 | 1 | .8 | .9 | 94.7 |
| | not sure | 6 | 4.8 | 5.3 | 100.0 |
| | Total | 113 | 91.1 | 100.0 | |
| Missing | no answer | 11 | 8.9 | | |
| Total | | 124 | 100.0 | | |

Q21.
Rate the following statement: My tap water is safe to drink.

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | strongly disagree | 19 | 15.3 | 15.6 | 15.6 |
| | somewhat disagree | 26 | 21.0 | 21.3 | 36.9 |
| | neutral/not sure | 21 | 16.9 | 17.2 | 54.1 |
| | somewhat agree | 29 | 23.4 | 23.8 | 77.9 |
| | strongly agree | 27 | 21.8 | 22.1 | 100.0 |
| | Total | 122 | 98.4 | 100.0 | |
| Missing | no answer | 2 | 1.6 | | |
| Total | | 124 | 100.0 | | |

Case Summary

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| Reason tap water is perceived as unsafe | 113 | 91.1% | 11 | 8.9% | 124 | 100.0% |

Reasons tap water is perceived by residents as unsafe

| | | Responses | | Percent of Cases |
|---|---|---|---|---|
| | | N | Percent | |
| Reason | chlorine/chemicals (including DBPs) | 20 | 14.8% | 17.7% |
| | poor appearance or taste | 27 | 20.0% | 23.9% |
| | I don't trust local water supply | 13 | 9.6% | 11.5% |
| | another reason | 2 | 1.5% | 1.8% |
| | high BWA frequency | 3 | 2.2% | 2.7% |
| | I believe I've been sick due to tap water | 2 | 1.5% | 1.8% |
| | old/outdated pipes | 1 | 0.7% | 0.9% |
| | does not perceive tap water as unsafe | 67 | 49.6% | 59.3% |
| Total | | 135 | 100.0% | 119.5% |

Q22.
Has household changed main source of drinking water in last five years?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 108 | 87.1 | 88.5 | 88.5 |
| | yes | 14 | 11.3 | 11.5 | 100.0 |
| | Total | 122 | 98.4 | 100.0 | |
| Missing | no answer | 2 | 1.6 | | |
| Total | | 124 | 100.0 | | |

Case Summary

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| Reason for change | 117 | 94.4% | 7 | 5.6% | 124 | 100.0% |

Reason for change in household drinking water source

| | | Responses | | Percent of Cases |
|---|---|---|---|---|
| | | N | Percent | |
| Reason household changed source of water | change in quality | 1 | 0.9% | 0.9% |
| | ease of access | 7 | 6.0% | 6.0% |
| | did not change water source | 109 | 93.2% | 93.2% |
| Total | | 117 | 100.0% | 100.0% |

Q23.
Aware of water-related illness in your community?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 118 | 95.2 | 95.2 | 95.2 |
| | not sure | 2 | 1.6 | 1.6 | 96.8 |
| | yes | 4 | 3.2 | 3.2 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q24.
Concerned about water-related illness in your community?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | very concerned | 25 | 20.2 | 20.5 | 20.5 |
| | somewhat concerned | 27 | 21.8 | 22.1 | 42.6 |
| | neutral/not sure | 13 | 10.5 | 10.7 | 53.3 |
| | mostly not concerned | 21 | 16.9 | 17.2 | 70.5 |
| | not concerned at all | 36 | 29.0 | 29.5 | 100.0 |
| | Total | 122 | 98.4 | 100.0 | |
| Missing | no answer | 2 | 1.6 | | |
| Total | | 124 | 100.0 | | |

Q25.
Activities perceived as a current threat to local drinking water supply
Case Summary

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| Current threats to water supply | 122 | 98.4% | 2 | 1.6% | 124 | 100.0% |

| | | Responses | | Percent of Cases |
|---|---|---|---|---|
| | | N | Percent | |
| Activity | I do not see any current threats | 104 | 82.5% | 85.2% |
| | not sure | 1 | 0.8% | 0.8% |
| | garbage dumping | 1 | 0.8% | 0.8% |
| | flooding at source water dam | 2 | 1.6% | 1.6% |
| | oil refinery (Come By Chance) | 7 | 5.6% | 5.7% |
| | transmission lines | 1 | 0.8% | 0.8% |
| | recreational use | 5 | 4.0% | 4.1% |
| | hunting & fishing | 4 | 3.2% | 3.3% |
| | cabin development | 1 | 0.8% | 0.8% |
| Total | | 126 | 100.0% | 103.3% |

Q26.
Familiar with the term disinfectant by-product (DBP)?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | No | 55 | 44.4 | 44.7 | 44.7 |
| | Yes | 46 | 37.1 | 37.4 | 82.1 |
| | somewhat | 22 | 17.7 | 17.9 | 100.0 |
| | Total | 123 | 99.2 | 100.0 | |
| Missing | no answer | 1 | .8 | | |
| Total | | 124 | 100.0 | | |

Q27.
Level of concern regarding DBPs

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not familiar with DBPs | 55 | 44.4 | 45.1 | 45.1 |
| | very concerned | 11 | 8.9 | 9.0 | 54.1 |
| | somewhat concerned | 27 | 21.8 | 22.1 | 76.2 |
| | neutral/not sure | 17 | 13.7 | 13.9 | 90.2 |
| | mostly not concerned | 8 | 6.5 | 6.6 | 96.7 |
| | not concerned at all | 4 | 3.2 | 3.3 | 100.0 |
| | Total | 122 | 98.4 | 100.0 | |
| Missing | no answer | 2 | 1.6 | | |
| Total | | 124 | 100.0 | | |

Q28.
Notice the effects of climate change?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | No | 34 | 27.4 | 27.9 | 27.9 |
| | Yes | 74 | 59.7 | 60.7 | 88.5 |
| | not sure | 14 | 11.3 | 11.5 | 100.0 |
| | Total | 122 | 98.4 | 100.0 | |
| Missing | no answer | 2 | 1.6 | | |
| Total | | 124 | 100.0 | | |

Q29.
Perceives climate change affecting water quality

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 43 | 34.7 | 35.8 | 35.8 |
| | yes | 37 | 29.8 | 30.8 | 66.7 |
| | not sure | 40 | 32.3 | 33.3 | 100.0 |
| | Total | 120 | 96.8 | 100.0 | |
| Missing | no answer | 4 | 3.2 | | |
| Total | | 124 | 100.0 | | |

*Section 2: For Town of Sunnyside watershed users (including cabin owners)*
Q30.
Spend time in Sunnyside watershed?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | no | 45 | 36.3 | 80.4 | 80.4 |
| | yes | 11 | 8.9 | 19.6 | 100.0 |
| | Total | 56 | 45.2 | 100.0 | |
| Missing | no answer | 68 | 54.8 | | |
| Total | | 124 | 100.0 | | |

Q31.
Activities performed on Sunnyside watershed
Case Summary

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| Activities on watershed | 124 | 100.0% | 0 | 0.0% | 124 | 100.0% |

| | | Responses | | Percent of Cases |
|---|---|---|---|---|
| | | N | Percent | |
| Activity | fishing | 4 | 2.9% | 3.2% |
| | hiking, sight seeing | 3 | 2.2% | 2.4% |
| | own a cabin in the watershed | 2 | 1.5% | 1.6% |
| | hunting/trapping | 6 | 4.4% | 4.8% |

| | | | | |
|---|---|---|---|---|
| | know someone who owns a cabin in watershed | 1 | 0.7% | 0.8% |
| | motorized vehicles | 6 | 4.4% | 4.8% |
| | work related | 2 | 1.5% | 1.6% |
| | do not spend time in the watershed | 113 | 82.5% | 91.1% |
| Total | | 137 | 100.0% | 110.5% |

Q32.
Rating of overall water quality in Sunnyside watershed

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 113 | 91.1 | 91.1 | 91.1 |
| | very good | 6 | 4.8 | 4.8 | 96.0 |
| | good | 3 | 2.4 | 2.4 | 98.4 |
| | neutral/not sure | 2 | 1.6 | 1.6 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q33.
Drinking water source when in watershed

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 113 | 91.1 | 91.1 | 91.1 |
| | bottled water | 6 | 4.8 | 4.8 | 96.0 |
| | tap water brought from home | 1 | .8 | .8 | 96.8 |
| | water directly from ponds or streams | 4 | 3.2 | 3.2 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q34.
Do you treat drinking water when in watershed?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 113 | 91.1 | 91.1 | 91.1 |
| | no | 11 | 8.9 | 8.9 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q35.
Aware Sunnyside watershed is designated protected water?

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 113 | 91.1 | 91.1 | 91.1 |
| | no | 1 | .8 | .8 | 91.9 |
| | yes | 10 | 8.1 | 8.1 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Aware of restrictions under protected status

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 114 | 91.9 | 92.7 | 92.7 |
| | yes | 8 | 6.5 | 6.5 | 99.2 |
| | not sure | 1 | .8 | .8 | 100.0 |
| | Total | 123 | 99.2 | 100.0 | |
| Missing | no answer | 1 | .8 | | |
| Total | | 124 | 100.0 | | |

For the next four responses, state the extent to which you agree or disagree:

Q36.
Recreational activities are a threat in the watershed

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 113 | 91.1 | 91.1 | 91.1 |
| | strongly disagree | 5 | 4.0 | 4.0 | 95.2 |
| | somewhat disagree | 3 | 2.4 | 2.4 | 97.6 |
| | somewhat agree | 1 | .8 | .8 | 98.4 |
| | strongly agree | 2 | 1.6 | 1.6 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q37
Hunting, trapping, wood cutting are threats in the watershed

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 113 | 91.1 | 91.1 | 91.1 |
| | strongly disagree | 5 | 4.0 | 4.0 | 95.2 |
| | somewhat disagree | 2 | 1.6 | 1.6 | 96.8 |
| | somewhat agree | 3 | 2.4 | 2.4 | 99.2 |
| | strongly agree | 1 | .8 | .8 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q38.
Cabin development is a threat in the watershed

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 113 | 91.1 | 91.1 | 91.1 |
| | strongly disagree | 6 | 4.8 | 4.8 | 96.0 |
| | somewhat disagree | 2 | 1.6 | 1.6 | 97.6 |
| | somewhat agree | 2 | 1.6 | 1.6 | 99.2 |
| | strongly agree | 1 | .8 | .8 | 100.0 |
| | Total | 124 | 100.0 | 100.0 | |

Q39.
If the above activities were demonstrated a threat, I would be willing to modify my behavior

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | not applicable | 113 | 91.1 | 93.4 | 93.4 |
| | strongly disagree | 1 | .8 | .8 | 94.2 |
| | somewhat agree | 6 | 4.8 | 5.0 | 99.2 |
| | strongly agree | 1 | .8 | .8 | 100.0 |
| | Total | 121 | 97.6 | 100.0 | |
| Missing | no answer | 3 | 2.4 | | |
| Total | | 124 | 100.0 | | |

(II) Regression tables

| | | | Average spent on bottled water per month |
|---|---|---|---|
| | Age range | Correlation Coefficient | -.281** |
| | | Sig. (2-tailed) | .002 |
| | | N | 119 |
| | Do you use a water filter | Correlation Coefficient | -.198* |
| | | Sig. (2-tailed) | .036 |
| | | N | 112 |

| | | | Do you feel your tap water is safe? | Concerned about water related illness in your community |
|---|---|---|---|---|
| | Average spent on bottled water per month | Correlation Coefficient | -.457** | -.319** |
| | | Sig. (2-tailed) | .000 | .000 |
| | | N | 119 | 120 |
| | Do you feel your tap water is safe | Correlation Coefficient | 1.000 | .328** |
| | | Sig. (2-tailed) | | .000 |
| | | N | 122 | 120 |