Note

Readers should note that the analysis and discussion presented in this report is based on the THM data collected during the period of January 1, 1996 to December 31, 1999.

Data collection and analysis have continued since that date, and the collected data is reported every three months on the web page and annually to the communities.

Current THM data is available on the web:

http://www.gov.nf.ca/env/Env/waterres/Surfacewater/THM/THM.asp

Executive Summary

Background

A high level of public awareness about drinking water quality issues has arisen over the last several years. The issue of greatest concern is disinfection by-products (DBPs), most particularly, trihalomethanes (THMs). In the Province of Newfoundland and Labrador, provincial and municipal governments have been working to ensure that the integrity of drinking water sources is preserved and enhanced. In order to accomplish this goal, the provincial government, in cooperation with municipal governments, has initiated a number of activities to:

(i) protect the integrity of source water quality,
(ii) collect baseline information on drinking water quality,
(iii) keep the public informed about drinking water quality,
(iv) identify emerging drinking water quality related issues, and
(v) deal with these issues on a pro-active basis.

The Federal-Provincial Toxic Chemical Survey of Municipal Drinking Water Sources based on the data for 1985 to 1988 reported that numerous surface water sources in Newfoundland and Labrador have high values for dissolved organic carbon (DOC) and colour (alternatively referred to as NOM or natural organic matter). The study noted that since these two parameters are considered precursors for the formation of THMs, there is a potential for high levels of THMs in provincial public water supplies. It was recommended that close attention be given to this issue in the future. In line with the recommendations of this study and the department's own work in drinking water quality monitoring, the Water Resources Management Division of the Department of Environment and Labour established, in April 1996, a partnership program with municipal governments for the monitoring of drinking water quality in general and THMs in particular. This partnership program has been in place for the last four years. Routine THM monitoring in this province began in 1996 as a three-phase project to accomplish the following:

- Establish baseline THM data on all public water supplies;
- Analyze the data to identify water supplies with high THM levels; and
- Develop and implement THM reduction strategies.

Since the beginning of the program in April 1996, it has grown to include the monitoring of approximately 230 surface water sources throughout the province. With four years of THM data in place, the department is now in a position to analyze and interpret the available data to identify supplies with potential high levels of THMs. The preparation of this report is a step in that direction and its results will be used for the identification of future THM monitoring requirements and measures to control THM levels. The main focus of the report is to:

- Review the available water quality data on THM levels and analyze it to identify seasonal and spatial data gaps for each public water supply.

- Assess the water quality of public water supplies in reference to the national guideline for THMs and identify those which exceed the guidelines.

- Identify possible sources and causes of high levels of THMs, based on the available data.

- Review various available options for THM control and make recommendations for their implementation.

- Discuss in general a proposed strategy to address the problem of high THM levels across the province.

Disinfection By-products

Disinfection of drinking water is a treatment process for the purpose of the destruction or inactivation of microbial pathogens and to maintain residual levels for further protection throughout water storage and distribution. The process depends on the type and concentration (or intensity) of the disinfectant, type and concentration of the microorganisms, and the physical and chemical properties of the source water. The effectiveness of disinfection processes depends on their ability to kill or inactivate a wide variety of microbial pathogens and maintain a residual disinfectant.

The most commonly used disinfectants are:

- **chlorine**
- **chloramination**
- **chlorine dioxide**
- **ozone**
- **ultraviolet radiation**
- **mixed oxidants**
- **iodine**

Disinfection by-products are the result of the chemical reaction between disinfectants used for water treatment and natural organic matter (NOM) present in raw drinking water. Among DBPs, trihalomethanes have been the most controversial issue of research and debate and are considered to be the most common DBP. THMs are defined as halogen-substituted single carbon compounds with the general chemical formula CHX_3, where X is normally chlorine or bromine or some combination of the two.

The principle THMs are:

- **chloroform**
- **dibromochloromethane**
- **bromodichloromethane**
- **bromoform**

The formation of THMs is dependent on numerous factors including the presence of THM precursors, chlorine dose, pH, water temperature and contact time. THM levels also vary spatially within a distribution system depending on organic loading and chlorine residuals. THMs are the most common chlorination disinfection by-products (CDBPs) in drinking water, and are considered to be an indicator of the possible presence of other CDBPs. They are known to be carcinogenic in laboratory animals and are probably carcinogenic to humans. This report deals with the issue of THMs in drinking water due to the widespread use of chlorine as a disinfectant in the province, and the presence of high levels of NOM in our natural waters.

In understanding the issue of THMs in drinking water, it is essential to balance the human health risks associated with the consumption of drinking water with elevated levels of THMs with the significant amount of risk associated with improper disinfection. Health Canada has recognized that the use of disinfectants, namely chlorine, has almost eliminated the threat of waterborne microbial diseases and saved millions of lives since the turn of the century. Thus, the health risks from pathogenic microorganisms far exceed those potential health problems associated with THM production during water treatment. However, the challenge must be to minimize the potential risks from CDBPs, including THMs, without compromising disinfection efficiency.

THM Guidelines

The original THM guideline in Canada was a Maximum Acceptable Concentration (MAC) of 350 μg/L established in 1978. This was to be a one-time maximum value not to be exceeded. Presently, the current acceptable level of THMs in Canada is **100 μg/L** (micrograms per litre) or **100 ppb** (parts per billion). It is an interim guideline which is based on an annual running average of quarterly samples to account for seasonal variation. This guideline of 100 μg/L was established in 1993 by the Federal-Provincial Subcommittee on Drinking Water (DWS) and was based on the risk of cancer reported in animal studies of chloroform. The guideline is intended to be both practical and protective of health. The THM guideline is currently under review by Health Canada. Depending on the findings of this review, a new THM guideline may be available within the next few years.

Public Water Supplies

It is estimated that approximately 85% of all Newfoundland and Labrador public water supply systems use surface water, while the remaining 15% use groundwater. The data indicate that 312 of the total 772 communities meet their demand through surface-based water supply systems, 38 communities rely on groundwater-based systems and the remaining 422 unserviced communities rely on privately-owned systems which are comprised of dug and drilled wells. Approximately 71% of the total population meets its municipal water demand through surface water and the remaining 29% through groundwater. This report deals mainly with THM levels in surface-based water supply systems, as the available data indicate that groundwater is generally low in natural organic matter and consequently THMs. There are a total of 329 surface water supplies throughout the province with approximately 313 in active use. Among surface water sources, ponds and reservoirs are the common source of public water supplies.

THM Formation Potential

The methodology for assessing the THM formation potential of each public water source is based on an analysis of the correlation between the average measured THM levels of tap water, and the average DOC and colour levels of raw water for municipal water supplies with the available data. The analysis indicates the following:

(a) Most of the "low" THM levels (defined as less than 75 µg/L relative to the Guidelines for Canadian Drinking Water Quality of 100 µg/L) occurred when DOC was less than 4.5 mg/L and colour was less than 80 True Colour Unit (TCU). For DOC values greater than 4.5 mg/L, the data indicated that "low" THM levels were also possible when colour was between 60 and 100 TCU.

(b) Most of the "high" THM levels (defined as greater than 150 µg/L relative to the Guidelines for Canadian Drinking Water Quality of 100 µg/L) occurred when either (i) DOC was between 5 and 7 mg/L and colour was between 30 and 50 TCU or (ii) DOC was greater than 7mg/L and colour was greater than 100 TCU.

(c) Most of the "medium" THM levels (defined as between 75 µg/L and 150 µg/L) occurred for the remaining combinations of DOC and colour values.

The THM formation potential of the 258 public water supply sources for which DOC and colour data were available showed that at the provincial level, 144 water supply sources are classified as having "low" THM formation potential, while 69 have "medium" potential and 45 have "high" THM formation potential. This analysis indicates that about 50% of the surface drinking water sources throughout Newfoundland are "naturally" predisposed to have "medium" to "high" THM formation potential.

Water Treatment Practices

The most common types of water treatment practices used in the province include:

1) Chlorination
2) Conventional Water Treatment Plants
3) Non-Conventional Water Treatment Practices

Based on the available data, there are about 283 chlorination facilities in the province, of which about 116 are gas-based chlorination and about 167 are liquid-based chlorination. About thirty public water supplies are without chlorination. Liquid chlorination systems are generally far cheaper than gas chlorination systems, and thus are used more extensively for small size communities in the province. The comparative low-cost of chlorination facilities relative to other disinfection methods, as well as the reliability and simple handling, make chlorination the most popular method of water disinfection in this province.

There are 11 conventional water treatment plants in the province. These plants provide water to about 124,543 people which is about 23% of the total population. In the majority of cases, treatment plants were commissioned to improve source water quality for larger centers.

There are 10 water supply systems that utilize non-conventional water treatment methods in the form of infiltration galleries and rock berms throughout the province. These non-conventional water treatment options service approximately 10,111 people which is about 2% of the total population. Non-conventional water treatment methods can be a lower-cost alternative to improve source water quality.

THM Monitoring Program in Newfoundland and Labrador

The total number of annual samples collected under the THM monitoring program has increased from 206 in 1996 to 945 in 1999. The monitoring program is carried out as a joint cost-shared or partnership program between provincial and municipal governments. Under the partnership arrangement, the provincial government is responsible for the sampling and data management costs while the analysis cost of samples is paid by the participating municipalities. According to the available data, there are a total of 313 active public surface water supplies in the province servicing approximately 312 communities. To date, 207 of 313 active surface water supplies have been involved in the THM monitoring program, while 106 surface water supplies remain uninvolved in the program.

All of the THM results for all water supplies across the province are stored in one provincial THM database. This database is designed to input and retrieve all THM data in a user-friendly manner. The THM database was created using Microsoft Access™ and Visual Basic™. The THM

data is disseminated annually at the beginning of the new year (January/February) after the sampling and analysis from the previous year is complete. Each community is provided with an annual report clearly stating the total THMs for each sampling event and the running annual average wherever applicable, along with a brief technical interpretation. Along with these annual reports, the Water Resources Management Division of the Department of Environment and Labour offers its technical assistance to explain the results and possible measures for reducing THM levels if desired or requested by any community.

The municipalities are advised to disseminate the drinking water quality data (THM and other contaminant information) to the residents of the community by displaying the annual data report on a public notice board or any other appropriate means.

The Water Resources Management Division of the Department of Environment and Labour maintains a THM web page which includes highlights of THM monitoring results. This web page is updated on a regular basis as appropriate.

Simple and Seasonal Averages of THM Data

There are a total of 2157 THM samples recorded in the THM database as of Dec. 31st, 1999. **However, it is important to note that the analysis presented in this report is based on the THM data collected during the period of Jan. 1st, 1996 to Dec. 31st, 1999.** This decision was based on the following factors:

- Routine departmental THM monitoring program began in 1996.
- Data discontinuity from 1989 to 1995 as no THM monitoring was carried out during this period.
- Data collected during 1985 to 1989 was on an ad hoc basis without any information on sampling and analytical protocols.

The total number of samples in the database, collected during the time period (1996 to 1999) and selected for data analyses, are 2054. Of the total 2054 records, 124 values are recorded as 0 µg/L, 1084 values fall between > 0 µg/L and 100 µg/L, and 846 values are recorded as > 100 µg/L. It is most likely that samples with zero THM values were collected at a time when chlorination was either non-operational or partially operational.

In order to compare THM values to the national guideline, it is necessary to collect THM samples for each of the four seasons. Keeping this in mind, the available data was analyzed for seasonal adequacy, inadequacy, and no data. It was found that of the 207 active water supplies with THM data, 82 have adequate seasonal data while 125 have inadequate seasonal data. There is no THM data for the remaining 106 active public water supplies. In all regions throughout the province, the number of water supplies with adequate seasonal data is slightly lower than the number of supplies

with inadequate seasonal data.

Using the simple and seasonal THM data, it was reported that approximately 70% of the water supplies recorded seasonal or simple averages below the national guideline of 100 µg/L while approximately 30% are above 100 µg/L. When the data is broken into ranges, 65 water supplies show THM values 50 µg/L; 67 water supplies between > 50 µg/L and 100 µg/L; 24 water supplies between > 100 µg/L and 150 µg/L; 21 water supplies between > 150 µg/L and 200 µg/L; 7 water supplies between > 200 µg/L and 250 µg/L; 2 water supplies between > 250 µg/L and 300 µg/L; and 2 water supplies between > 300 µg/L and 350 µg/L.

The number of water supplies with seasonal averages above and below the national guideline of 100 µg/L was determined for each of the three regions of the province. In total there are 82 water supplies with adequate seasonal data throughout the province. Of these 82 water supplies, 46 are below 100 µg/L and 36 are above 100 µg/L. In the eastern region, the majority of water supplies (21) are below the national guideline while 9 water supplies are above 100 µg/L. In the western region and Labrador, the number of water supplies (13) below 100 µg/L is slightly higher than the number of water supplies (9) above 100 µg/L. Finally, in the central region, 12 water supplies are below 100 µg/L while 18 water supplies are above 100 µg/L.

It has been reported in a number of CDBP surveys that THM concentrations vary from season to season due to variation in water temperature, natural organic matter loading, and chlorine demand. In most cases in Newfoundland and Labrador, this overall trend has been observed, however, the level of variation differed from site to site. The most significant increases in THM levels were seen between spring and fall.

Spatial variation in THM levels is another important aspect that must be taken into consideration, as it relates to actual THM exposure along the distribution system. It has been reported that THM values increase with increased distance from the point of chlorination. In this report, spatial variations were evident at several sites, however, the spatial variation was not consistent and predictable in all cases mainly due to the complex layout of distribution systems. In general, spatial THM levels are mostly affected by the residence time of the water in the distribution system. The residence time depends on a number of factors such as water reservoirs, length of distribution system, water demand, etc.

Preventative/Mitigative Measures

There are numerous options which could be used to reduce THM levels in drinking water. These options fall in the following two categories:

1) Source Control Measures (SCM)
2) Point-of-Entry (POE) and Point-of-Use (POU) Control Measures

The source control measures refer to THM control strategies at the source level which are generally in the form of joint initiatives of both municipal and provincial governments. On the other hand, the point-of-entry (POE) refers to the control measures adopted by consumers at the main water line into the house, and point-of-use (POU) refers to options that can be utilized by consumers at individual water taps in the house.

In this report, emphasis will be placed on source control measures which could achieve the fundamental objective of providing safe drinking water to all consumers. The applicability and suitability of a particular measure or measures will be decided on a case-by-case basis through site-specific assessment and evaluation. Such decisions will be made in consultation with appropriate government agencies and municipalities.

With respect to source control measures, one of the following options or combination of options should 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
6) Assessment of Alternative Water Supply Sources

With respect to point-of-entry and point-of-use control measures, consumers wishing to reduce their exposure to chlorination disinfection by-products can use a filter containing activated carbon certified to the NSF Standard 53 for THM removal. If a filter device is used it should be properly maintained because such devices can become sources of bacterial contamination in water. Although blending and boiling water will remove volatile (meaning easily evaporated) CDBPs such as THMs, they do not eliminate or necessarily reduce the health risks of other CDBPs that may not evaporate easily. As such, blending and boiling of water are not recommended by Health Canada as methods for reducing chlorination disinfection by-products. Health Canada laboratories are currently testing a range of carbon filters and other treatment methods to see if they are able to remove most CDBPs. The results will be made public within a year. **It should be noted that no one method will eliminate all disinfection by-products in drinking water.**

Future Direction

The THM monitoring program of the Water Resources Management Division has become more systematic and comprehensive since its inception in 1996. However, to ensure the continuous success and maximum benefit from the program, it is necessary to plan the long term future direction.

There are six main strategies that will be pursued in the upcoming years to address the problem of high THM levels in public water supplies across the province. These strategies are:

- **Data Gaps and Analysis**
- **Data Management and Dissemination**
- **THM Control Strategies**
- **Integrating with and Complementing other Programs**
- **Operator Training and Education**
- **Public Education and Communication**

Water treatment plant operators training and education is one of the important steps of overall THM control strategy. Lack of proper training and professional development of operators has been identified as a major problem with respect to the proper operation and maintenance of water treatment facilities. To address this, the Department is in the process of employing a new staff member whose primary responsibility would be to act as a department contact on THM issues, and provide required training to all operators in the province. The operators training and education will be highly beneficial in the implementation of source control measures. The control of THM levels in public water supplies will be the main priority in the upcoming years. However, disinfection of the water against microbiological contamination remains paramount.