# Trihalomethanes (THM) Briefing Note



## What are THMs?

- Trihalomethanes are compounds formed when chlorine reacts with organic matter in water.

## Are they common?

- THMs occur in virtually every sample of tap water from a chlorinated source.
- Canadian studies have shown that TCM levels are higher in the summer than in the winter. On average, Canadian facilities that treat water with chlorine both at the plant and through the system have summer THM levels 56% greater than winter levels.

## What is considered a "safe" dose?

- Before 1993, the Canadian drinking water guideline recommended no more than 350 parts per billion (ppb).
- In 1993, the Canadian guideline reduced that level to 100 ppb.
- The Canadian guideline is again under review.
- The US Environmental Protection Agency has recently adjusted their guideline from 100 ppb to 80 ppb.
- Canadian studies have shown that prolonged exposure to levels of only 50 ppb significantly increases the risk of bladder and colon cancer.

## What are the risks?

- A study has shown that from 10-13% of all bladder and colon cancers in Ontario may be attributable to long-term exposure to chlorinated surface water.
- A study by the California Department of Health Services has shown that women who drink more than 5 glasses of water per day with a THM level of 75 ppb or greater, are more likely to have a first trimester miscarriage than women who drink water with a lower THM content.
- A host of other ailments are suspected to be linked to THMs in drinking water, though conclusive scientific evidence is not yet available. These other illnesses may include rectal cancer, pre term delivery, low birth weight and birth defects, and arteriosclerosis (high blood pressure).

## How am I exposed?

- Most scientific studies have been done on ingestion of contaminated drinking water. However, recent studies have shown that:
  - you can be exposed to as much water pollution during a 20 minute hot water shower as by drinking two quarts of tap water per day; and
  - THMs may enter the body by inhalation. Breathing water vapour while in the shower or lingering over a boiling pot may be a worrisome source of THM exposure.

**How can I lessen my exposure:**

- First, if possible, eliminate the addition of chlorine to your water. Though chlorine does an excellent job of killing harmful bacteria in water, there are other effective methods available. Water can be treated with ultraviolet light or with ozone oxidation to kill microorganisms. (Note, these techniques cannot prevent the contamination of water once it has left the water treatment facility.)
- When you pour yourself a glass of water, give it a whir in the blender first. This will aerate the water and lessen its THM content.
- THM levels can also be lessened if water is refrigerated for a period of 24 hours.
- Use of a water filter containing carbon can also greatly reduce the THM levels.

**What indications are there of high THM levels?**

- You cannot tell by scent, sight or taste if your drinking water contains high levels of THMs. The only sure way to know is to contact your water facility and ask. There are some indications, however, that your water may be at risk:
    - An Ontario study found that water from sources such as rivers, streams and shallow lakes had higher THM levels than water from natural springs. This is likely because of the organic matter present in the former sources.
    - A Canadian study found that THM levels are higher in summer than in winter.
    - Water treated with substances other than chlorine may lack the elements necessary to create THMs. Ask staff at your water facility how your water is treated. If chlorine is used at the source and through the distribution facility, your water may be at elevated risk.

http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/cancer_risk.pdf

Health Canada Santé Canada

December 1995

Great Lakes 2000 Grands Lacs 2000

Great Lakes Health Effects Program

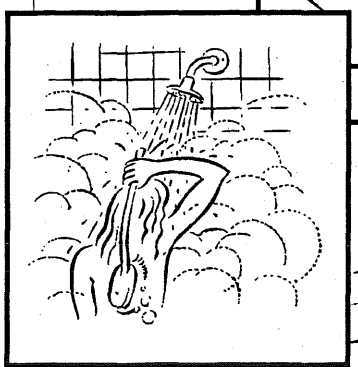
Grand Lacs: Impact sur la santé

# Great Lakes Water and Your Health

## A summary of "Great Lakes Basin Cancer Risk Assessment: A Case-control Study of Cancers of the Bladder, Colon and Rectum"

The Great Lakes and their connecting waterways are a vital source of drinking water, as well as an important recreational resource for a large number of Canadians living in the basin region. While there has been an overall reduction of contaminants in the Great Lakes basin since the 1970s, contamination of the lakes through human activity has led to public and scientific concern for the ecosystem, including the health of the people living in it. Since the most common way for people to be exposed to water in the Great Lakes basin is through the drinking water supply, health effects of contaminants in this water are of particular importance.

Municipally supplied water is carefully treated and systematically monitored. Many municipalities use chlorine for water disinfection because it is the most effective and cost-efficient means of reducing harmful bacteria and viruses capable of causing severe and life-threatening diseases. Chlorine, however, reacts with the organic material naturally present in water to produce a number of by-products. Evidence from toxicologic (animal) and epidemiologic (human) studies suggests a link between by-products of the chlorination process and increased risk of some cancers.



### What was the purpose of the study?

Health Canada began the *Great Lakes Basin Cancer Risk Assessment Study* in 1992 to look at the relationship between exposure to water from various sources in the Great Lakes basin and the risk of cancers of the bladder, colon and rectum. These cancers were chosen for investigation because previous studies had shown that they were linked to the use of chlorine-treated water. The study was led by Dr. Loraine Marrett and Will King (currently at Queen's University in Kingston) at the University of Toronto and the Ontario Cancer Treatment and Research Foundation. Dr. Yang Mao of Health Canada's Laboratory Centre for Disease Control in Ottawa was also involved in the study.

The focus of the study was exposure to contaminants through the use of municipally supplied water, with special emphasis on chlorination by-products. A group of chemicals called trihalomethanes (THMs) was chosen for particular attention because they are not only the most prevalent of the chlorination by-products, but are also good indicators of the presence of other chlorination by-products. Exposure to chlorination by-products in municipal water supplies can occur through consumption of the water, breathing the vapours through showering or absorbing these materials through bathing.

As a secondary objective, the study also examined the relationship between these cancers and recreational water use such as swimming and fish consumption.

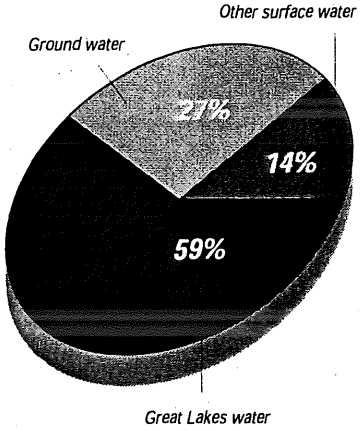
### Who participated in the study?

The *Great Lakes Basin Cancer Risk Assessment Study* was a case-control study. People diagnosed between 1992 and 1994 with the cancers being studied ("cases") were identified from a database called the "Ontario Cancer Registry," which is maintained by the Ontario Cancer Treatment and Research Foundation. Individuals were contacted with the consent of their physicians. The "control" group was chosen by contacting households at random from telephone directories in the study area, and selecting from these households volunteers who did not have cancer. Controls were chosen to be similar to cases based on age and sex. The

relationship between exposure to water factors and cancers of the bladder, colon and rectum was examined by comparing the exposures of the cases and the controls.

Roughly 5,000 residents of Ontario counties south of Sudbury and Timiskaming participated in the study. The study area contains 93% of the Ontario population (approximately 10 million people). In 1990, nearly 60% of the study population was served by a municipal water source taken from the Great Lakes (Figure 1).

**Figure 1: Water Source for the study population in 1990**




## How was the study carried out?

Information was collected through a questionnaire that participants answered over the telephone. Questions dealt with: the places people had lived in the past and the type of water supply at each place (i.e. public/ municipal or private well); their usual intake of various foods and beverages (including water and drinks made with hot/cold water); their consumption of freshwater fish; the amount and type of water-based recreational activities they took part in; and other basic information (age, sex, etc.). Information on other factors that might affect people's risk of cancer, such as eating habits and smoking, was gathered to allow the researchers to control for the effects these factors could have on cancer incidence and to ensure they did not influence the associations with water-related exposures.

Water treatment facilities in each study area were also sent a questionnaire to collect information dating back to 1940 on water sources and their characteristics (i.e. river, lake or ground water; temperature; depth of intake pipe; chlorination dose; and treatments employed), and also the area served. This information was used to estimate the concentration of THMs in public water supplies by geographic area and time. The concentration of THMs is measured in terms of parts per billion (ppb), which represents the

### *What are chlorination by-products and how are they formed?*

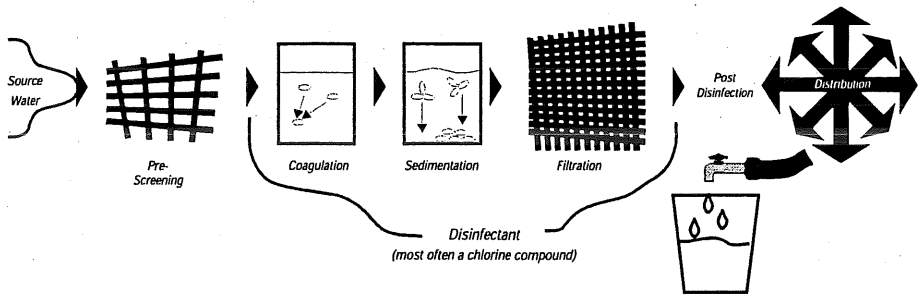
*Chlorination by-products are chemical compounds that form when water containing organic matter (the decay products of living things such as leaves, human and animal wastes, etc.) is chlorinated. While the chlorine is effective in inactivating disease-causing micro-organisms, its addition to water can lead to the formation of a number of chlorination by-products, such as trihalomethanes (THMs).*

***organic material + chlorine compounds = THMs and other by-products***

*Of the chlorination by-products, the THMs are present in the highest quantities. Other chlorination by-products have recently been identified (e.g. halogenated acids and halogenated acetonitriles) and are beginning to be evaluated for potential health risks. THMs are currently used as indicators of the presence of these other by-products.*

*Levels of THMs in drinking water are strongly dependent on several factors: where the water came from (rivers have higher organic content than lakes); the water temperature and acidity; the method used to screen out suspended matter; the season (there tends to be less organic matter in the water sources during the winter and therefore lower levels of chlorination by-products); chlorination dose; and other characteristics of the treatment process.*

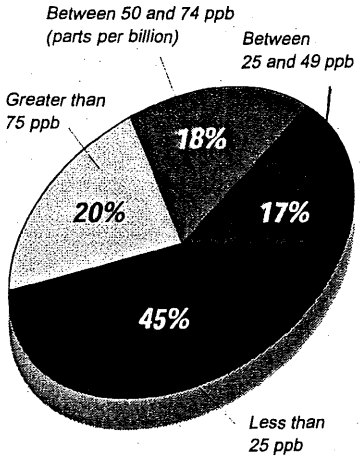
### *Water Treatment and Disinfection*




*The procedure used by water treatment facilities to make drinking water fit for human consumption varies. Depending on the quality of the raw water source, the volume of water treated and the distance over which the water is distributed to consumers, some facilities will use more treatment steps than others.*

*Water is drawn from a surface or ground source and passed through a screen that removes large debris (such as leaves). A disinfectant, typically a chlorine compound, may then be added to inactivate harmful bacteria, viruses and some parasites. Alum (which concentrates suspended particles) and lime (which changes the acidity of the water) may also be added. The water may then go through a process of coagulation (clumping of particulates—referred to as "flocs"), sedimentation (flocs settle and collect at the bottom of the tank) and/or filtration to remove smaller particles. Chlorine or chloramine is again added prior to distribution of the treated water to prevent it from becoming recontaminated with bacteria during its journey through the water pipes to the consumers.*

**Figure 2: Distribution of study population according to estimated THM levels in their water supply in 1990**




number of micrograms of THMs per litre of water. The distribution of THM levels in the study population in 1990 according to estimated THM levels in water supplies is shown in Figure 2.

***Relative Risk***

*The Relative Risk is a measure of the likelihood of developing some outcome (e.g. bladder cancer) in the presence of a particular factor (e.g. use of chlorinated surface water) as compared with the likelihood of developing the same outcome when the factor is not present.*

*Relative Risk*

***1.0:*** *no difference between cases and controls. (The relative risk in the group of the people with 0 to 9 years of exposure in Figures 3, 4 & 5 is fixed at 1.0).*

***Greater than 1.0:*** *the factor (i.e. water source, THM level) increases the risk of the cancer in question.*

***Less than 1.0:*** *the factor reduces the risk of the cancer in question.*

***In the graph the relative risks that are statistically significant are indicated by "SR" (increased risk: not likely due to chance). This means that relative risks as high or as low as those observed are not likely due to chance.***

Information from the two questionnaires was used to determine the water source used by each participant and its treatment for each year at each place of residence. Factors representing water characteristics were then examined in relation to the risks of the cancers being studied. These factors included the type of source water (ie. any surface water, Great Lakes surface water, ground water), whether or not the water was chlorinated, and the estimated levels of THMs in the treated water.

## Did the source of the water affect the level of risk for these cancers?

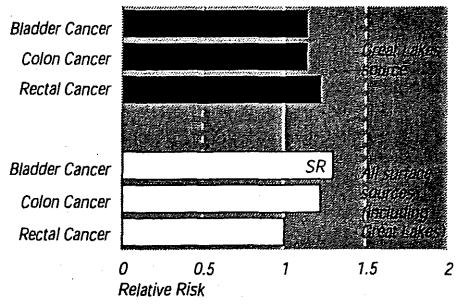
There is no suggestion that water from Great Lakes sources poses a higher risk for the cancers being studied than water from non-Great Lakes sources. In fact, the results of the study show that risks for bladder and colon cancer are slightly higher for those using water from all surface water sources (rivers and inland lakes in addition to Great Lakes sources) than for consumers of Great Lakes water specifically (Figure 3). This is likely due to the fact that treated water from rivers tends to be higher in organic content and is therefore more likely to contain higher levels of chlorination by-products after treatment.

## Were chlorination by-products from water treatment associated with higher risk of these cancers?

The study found that long-term consumption of chlorinated surface water was associated with increased risk of bladder cancer and was suggestive of an increased risk of colon cancer (Figure 4). In analysis examining years of exposure to an estimated THM concentration greater than 50 ppb, those exposed for 35 years or more were at significantly increased risk for both bladder and colon cancer, compared with those exposed for less than 10 years (Figure 5). For those subjects exposed to the same level of THMs in their water supply for 25 years or more, increased risk was observed for increased concentrations of THMs for both bladder and colon cancer (Figure 6).

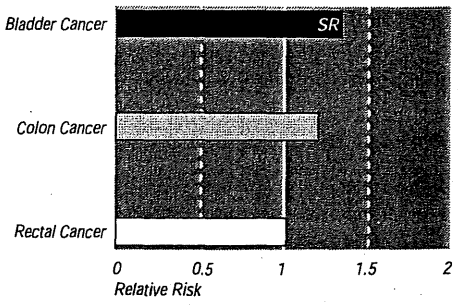
No evidence was found that chlorination by-products led to an increased risk of rectal cancer.

**Figure 3: Cancer risk associated with the use of water from Great Lakes sources and all surface sources for 35 years or more**




*The above risks are those associated with use of the specified water source for 35 years or more and are relative to the risks associated with use of water from this same source for 0 to 9 years.*
*SR = increased risk: not likely due to chance*

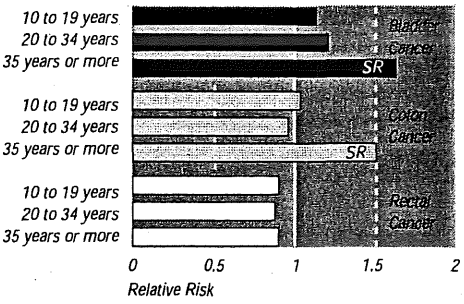
**Figure 4: Cancer risk associated with the use of chlorinated surface water sources for 35 years or more**




*The above risks are relative to the risks associated with use of chlorinated surface water sources for 0 to 9 years.*

*SR = increased risk: not likely due to chance*

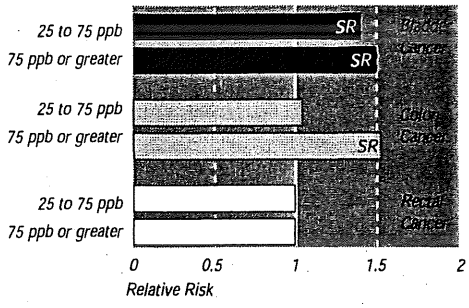
**Figure 5: Cancer risk associated with years using water with THM levels greater than 50 ppb (parts per billion)**




*The above risks are relative to the risk associated with use of water with THM levels greater than 50 ppb for 0 to 9 years of the past 40 years.*

*SR = increased risk: not likely due to chance*

**Figure 6: Cancer risk associated with the use of water with the specified THM levels for 25 years or more of the past 40 years**




*The above risks are relative to the risk associated with use of water with THM levels less than 25 ppb for 25 years or more.*

*SR = increased risk: not likely due to chance*

***Are there any alternatives to chlorination?***

*A few municipalities are now using ozonation as a primary disinfectant for drinking water treatment, since ozonation does not form chlorination by-products. Because ozone breaks down quickly, however, it is still necessary to add small amounts of chlorine to the water to ensure continued disinfection while the water passes through the distribution system. Modifying water treatment facilities to use ozone is expensive, and ozone treatment creates other undesirable by-products that can be harmful to health if they are not controlled (e.g. formaldehyde and bromate).*

*Chloramine or chlorine dioxide can also be used as alternatives to chlorine for primary disinfection. In the final, or secondary, stages of disinfection, chlorine or chloramine is used to keep water disinfected while it travels from the treatment plants to consumers.*

***What can be done to reduce the creation of chlorination by-products in municipally treated water?***

*Research is continuing to investigate various changes to current treatment methods through which the levels of chlorination by-products in treated water can be reduced. For example, reducing the extent of pre-treatment of water with chlorine reduces chlorination by-products. Other water treatment options include removing the organic matter from the raw water so that it cannot react with the chlorine to form by-products, and taking steps to remove the by-products by using activated carbon beds to adsorb these chemicals. The particular needs of each facility must be evaluated and the improvements most appropriate to its treatment process must be determined. Changes made to the process of water disinfection* ***must not*** *compromise its effectiveness.*

*Changes to current treatment and use of alternative water treatments will depend on a number of factors, including: the quality of source water; the cost of conversion; the length of the distribution system; and the assessments of the risks posed by the by-products produced by the alternatives.* ***The most appropriate treatment method varies between the individual plants and must be assessed on a case-by-case basis. Support your local treatment plant in efforts being made to optimize the use of chlorine in water treatment.***

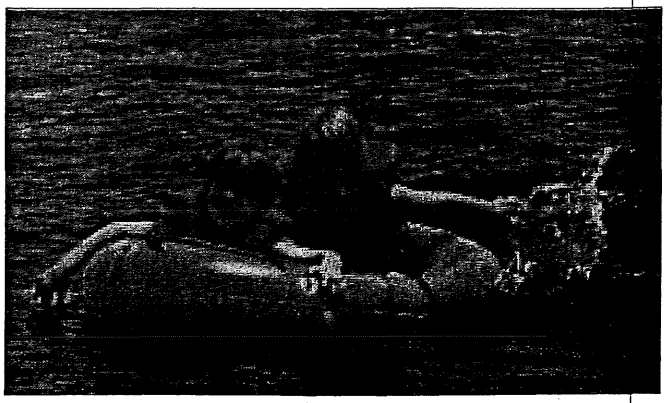
## Did the study find an association between the consumption of fish or recreational activity in the Great Lakes and cancer risk?

The study found no association between either recreational activity or the consumption of self-caught Great Lakes fish and bladder, colon or rectal cancer. These two risk factors, however, were not investigated as rigorously as exposure to chlorination by-products. Further analysis of these data is being considered.

## How much bladder, colon and rectal cancer in Ontario could be due to chlorination by-products in treated water?

Although the relative risks are small, they are important because of the substantial number of people in Ontario using chlorinated surface water over many years. Results of this study suggest that between 10% and 13% of all bladder and colon cancers in Ontario may be attributable to long-term exposure to chlorinated surface water. For comparison, over 50% of bladder cancers are probably due to smoking, and 40% to 60% of colon cancer may be related to dietary factors (i.e. high consumption of dietary fat and/or low consumption of fruit and vegetables).

Although there is considerable uncertainty in the risk estimates derived from this study, they suggest that some of these cancers could be prevented through further reduction of levels of chlorination by-products. Since study results indicate increasing risk with increasing years of exposure, it may be several years before



### *What do the results of this study mean to you and your family?*

*The results of this study suggest an increase in bladder and colon cancer risk associated with exposure to chlorination by-products in drinking water supplies. Risks are highest for those with the longest duration of exposure (35 years or more) and the highest concentrations. In general, levels of chlorination by-products are highest in chlorinated water from surface water sources (especially rivers and inland lakes which have high organic content). People using treated water from sources with low chlorination by-products (i.e. ground water), or those who have used water with high levels of chlorination by-products for shorter periods of time (less than 35 years), do not appear to be at increased risk.*

*The weight of evidence from toxicologic (animal) and epidemiologic (human) studies suggests a link between by-products of the chlorination process and increased risk of some cancers. The lifetime probability, however, that an individual living in Ontario will develop bladder or colon cancer due to the use of chlorinated water is quite low. For example, about 1.34% of men who are exposed to chlorinated surface water for 35 years or more will develop bladder cancer before the age of 70, while about 1.00% not exposed to chlorinated surface water will develop it. For women, approximately 0.37% of those exposed to chlorinated surface water will develop bladder cancer before the age of 70, compared with 0.27% of women who are not exposed.*

*It is important to remember that the risk of developing bladder or colon cancer is influenced by many things, not just factors related to drinking water. Several other factors, for example smoking for bladder cancer, and aspects of diet for colon cancer, will also influence your risk.*

***Because of the limitations of current treatment methods, the authors do not recommend eliminating the use of chlorine at this time since chlorination inactivates disease-causing viruses, bacteria and some parasites. The authors do, however, recommend that disinfection practices that reduce the formation of chlorination by-products be investigated further, with the objective of reducing these by-products.***

the health effects associated with the reduction of levels of chlorination by-products are apparent.

### How do these findings compare with those of other studies?

This study supports the overall weight of evidence from published scientific research that there is an association between the use of chlorinated water and bladder cancer risk, and a somewhat weaker association with colon cancer risk. Unlike some other studies, this study did not find an association between use of chlorinated water and rectal cancer.

### Are the THMs themselves causing the excess cancers?

It is not possible to determine whether the excess bladder and colon cancer risk detected in this study was due to THMs, or whether it was due to other by-products of chlorination that co-exist with THMs, or to other factors in water that were not measured or considered.

### *Are there Canadian Drinking Water Guidelines?*

*There are* Guidelines for Canadian Drinking Water Quality *(CDWG) which identify substances that have been found in drinking water and are known, or suspected, to be harmful. For each substance, the Guidelines establish a maximum acceptable concentrations (MACs) and/or aesthetic objectives for the physical, microbiological, chemical and radiological characteristics of public and private drinking water supplies. Guidelines are based on information published in scientific literature around the world, as well as on data collected by field research and through laboratory experiments. Interim maximum acceptable concentrations (IMACs) are established when the ideal value (based on scientific knowledge) is not yet achievable due to practical limitations (i.e. limitations in analytical and treatment technology, and cost of conversion to new technologies).*

*The provision of drinking water is a Provincial/Municipal responsibility. In Ontario, the Ontario Drinking Water Objectives (ODWO) are set by the Ontario Ministry of Environment and Energy (OMOEE) primarily following the* Guidelines for Canadian Drinking Water Quality.

### *Drinking Water Guidelines for THMs*

*In May of 1993, the Canadian drinking water guideline for total THMs was reduced from a MAC of 350 ppb (parts per billion) to an IMAC of 100 ppb. This IMAC is based on the risk associated with chloroform, the THM most often present and generally found in the greatest concentration in drinking water. The IMAC is based on assessments of health considerations, available treatment and analytical technology, as well as economic feasibility. The guideline will remain an IMAC until the risks from other disinfection by-products are determined. It is not expected that all water systems will be able to meet the revised THMs guideline immediately.* ***When water systems are expanded or upgraded, every effort should be made not only to meet the revised guideline, but to reduce concentrations of THMs to as low a level as possible. Many water treatment facilities have been implementing methods for several years to reduce levels of THMs and other chlorination by-products in treated water.***

Now 80 ppb in the USA.

***How can you reduce your exposure to THMs and some other chlorination by-products?***

*The following measures can be used to reduce the levels of THMs and some other chlorination by-products in treated water used for drinking:*

- *aerate tap water in a blender;*
- *store water in the refrigerator for 24 hours;*
- *use water treatment devices containing activated carbon (Note: it is important to follow all filter flushing and replacement instructions to avoid risks of bacterial contamination).*

## Are there other studies under way that examine the relationship between municipally treated water and human health?

A national study was recently initiated by the Laboratory Centre for Disease Control of Health Canada to investigate the potential risks associated with THMs, based on individuals' lifetime history of residence. Cancer sites being studied include the liver, testis, brain, pancreas, prostate, stomach, kidney and lung, as well as leukaemia and non-Hodgkin's lymphoma. Results from this study should further clarify the potential for health risks associated with chlorinated municipal water. The data collection is scheduled for completion by March of 1997.

Risk assessment of chlorine-based disinfectants (including chlorine dioxide, chlorate, chlorite and chloramines) and chlorination by-products is currently under way. The results of these studies could be especially significant since THMs may not be the cause of the increased bladder and colon cancer risk observed in this study.

A study is also being planned by Health Canada to investigate the effect of temperature on the formation of disinfection by-products. This will provide further information on the types of by-products present in treated water, as well as which by-products remain in the water when it is boiled. Results of this study are expected by the spring of 1996.

## Thanks to the Study Participants!

The study team at the Ontario Cancer Treatment and Research Foundation/ University of Toronto and Health Canada are very grateful to those who gave their time and effort to participate in this study: patients, people who served as controls, physicians and water treatment facility staff. Epidemiological studies involving questionnaires can be stressful for the families and individuals involved. These studies are made possible by a public willing to participate. They contribute to a better understanding of public health issues in the Great Lakes basin and also worldwide. Studies such as this can be used as the basis for risk reduction strategies, including environmental clean-ups, better treatment technology and pollution prevention initiatives.

## Contacts

(1) If you are interested in more information about the study, please contact:

Great Lakes Health Effects Program, Health Canada
Jeanne Mance Bldg., Tunney's Pasture
P.L. 1904B
Ottawa, ON K1A 0K9
(613) 957-1876

or

Ontario Cancer Treatment and Research Foundation
620 University Ave.
Toronto, ON M5G 2L7
Judy Irwin (416) 217-1213

(2) For information on guidelines for drinking water quality in Canada, please contact:

Drinking Water Section/Health Canada
Jeanne Mance Bldg., Tunney's Pasture
P.L. 1912A
Ottawa, ON K1A 0K9
(613) 952-2594

or visit the Water Quality home page on the WWW at:
**http://www.hc-sc.gc.ca/waterquality**

For more information on drinking water objectives in Ontario, please contact:

Standards Development Branch
Ontario Ministry of the Environment and Energy
2 St. Clair Ave. West, 12th Floor
Toronto, ON M4V 1L5
(416) 323-5095

Questions on the levels of THMs and other by-products in your community's drinking water should be directed to the municipal treatment plant serving your community.

(3) For information on public health issues related to drinking water in Ontario, please contact:

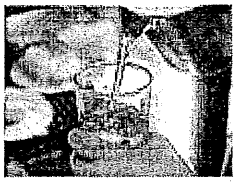
Public Health Branch
Ontario Ministry of Health
5700 Yonge Street, 8th Floor
North York, ON M2M 2K5
(416) 327-7427

Canada

# Chemical in water caused miscarriages: lawsuit

*Last Updated Wed, 26 Feb 2003 11:51:37*

CHESAPEAKE, VIRGINIA - More than 200 women in Virginia are filing a lawsuit against their town. They blame the drinking water for causing miscarriages.



The lawsuit centres on chlorination by-products called trihalomethanes, or THMs. The situation could also be of concern to towns in Newfoundland and Nova Scotia, where high levels of the same chemicals are found in drinking water.

- INDEPTH: Water Treatment

"They designed my life for me, and that's what hurt me the most," says Regina Morgan, a teacher who used to live in Chesapeake, Virginia.

Morgan had four miscarriages. After many painful biopsies she gave up trying to have a child and stopped wondering why she couldn't until a few years ago. That's when a local law firm started to do some digging.

- INDEPTH: Drinking water FAQ

The company discovered the town's water was high in THMs.

THMs are caused when chlorine is added to water supplies that are naturally high in organic acids.

The U.S. Environmental Protection Agency (EPA) has limited THMs in drinking water since the 1970s because the chemicals have been linked to an increased risk of bladder cancer.

But in 1998, the EPA revised its ruling and lowered the limit again. A study in California showed a connection between high THMs and early term miscarriages.



Monica Kidd reports for CBC Radio
(Runs: 1:42)

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EXTERNAL LINKS

- Health Canada: trihal
- World Health Organiz trihalomethanes
- EPA: trihalomethanes
- THM results: Newfoun
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The lawsuit says the city of Chesapeake falsified results to lower their THM readings and officials knew what they were doing.

"We've got documents from the state health department telling the city they are concerned over the practice of throwing out THM test results that show high levels and substituting low levels," says Gary Bryant, the lawyer handling the women's cases.

Bryant accuses the city of fraud and the women are asking for a billion dollars in damages.

"To suggest that workers...have done something illegal to harm people, I think is just simply outrageous and we'll disprove that," says Ronald Hallman, attorney for the city.

The judge will hear arguments this week to decide whether the lawsuit can proceed.

Written by CBC News Online staff

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# Water treatment methods

John Bowman & Owen Wood
CBC News Online | May 2001

The recent outbreak in North Battleford and the on-going Walkerton inquiry have brought the quality of Canada's drinking water under increasing scrutiny. Canadians are wondering whether they can trust that the water coming out of the tap is safe to drink.

A typical municipal water purification system involves several steps, from physical removal of impuries to chemical treatment.

## Coagulation, Flocculation and Sedimentation

Before the raw water is treated, it is passed through coarse filters to remove sticks, leaves and other large objects. Sand and grit settle out of the water during this stage, as well. During coagulation, a chemical such as alum is added to the raw water. When the water is stirred, the alum forms sticky globs that attach to small particles made up of bacteria, silt and other impurities.

The water is then kept in a settling tank where the globs, or floc, sink to the bottom. This is a much longer phase of purification called flocculation.

After this, the water is pumped very slowly across a large basin. Much of the remaining floc and solid material accumulates at the bottom of the basin, in a process called sedimentation or clarification.

## Filtration

Filtration involves passing the water through layers of sand, coal and other granular material to remove microorganisms – including viruses, bacteria and protozoans such as Cryptosporidium – and any remaining floc and silt. This

stage of purification mimics the natural filtration of water as it moves through the ground.

After the water is filtered, it is treated with chemical disinfectants to kill any organisms that might have made it through the filtration process. The most effective disinfectant is chlorine.

**Chlorination**

Chlorination is used in all of Canada's 3000 water treatment plants and, in many municipalities, it is the only chemical disinfection used. But it is not without its problems.

When the chlorine combines with organic material, such as dead leaves, it produces potentially dangerous trihalomethanes (THMs). While treatment plants in larger cities can filter out THMs to keep them at a safe level, those in small towns often don't, and THM warnings have been recently issued in many towns across the country, particularly in Newfoundland and Nova Scotia.

**Ozone oxidation**

Ozone oxidation is another effective disinfectant process, but unlike chlorine, ozone does not stay in the water after it leaves the treatment plant, so it offers no protection from bacteria that might be in the water pipes.

**Ultraviolet Light**

Water can also be treated with ultraviolet light to kill microorganisms, but it has the same limitation as oxidation: it is ineffective outside of the treatment plant. Nevertheless, UV treatment is being considered for water treatment in places such as North Bay, Ontario, Victoria, B.C. and Erickson, B.C., where residents oppose water chlorination.

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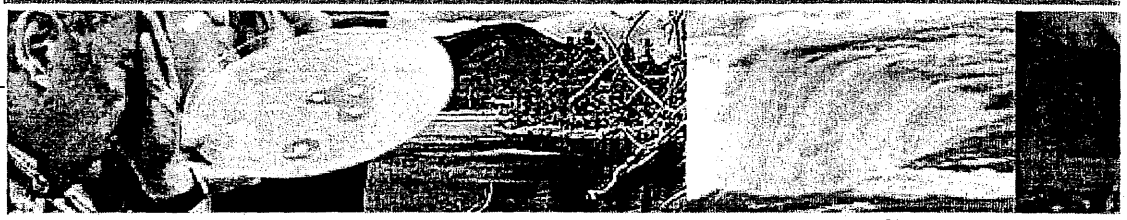

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# Drinking water Q & A

CBC News Online | May 2000

**What is good quality drinking water?**

According to Environment Canada, good drinking water is free from disease-causing organisms, harmful chemical substances, and radioactive matter. It tastes good and looks good — that means no bad odours or colour to the water.

Guidelines for Canadian drinking water quality specify limits for substances and describe conditions that affect drinking water quality.

**How are the guidelines enforced?**

Municipalities are responsible for the drinking water in their area. They are supposed to provide citizens with safe drinking water. It is also their responsibility to inform the public about pollution risks related to recreational use of water.

They do this by collecting water samples and having them analyzed. Results are then compared to the Canadian drinking water quality guidelines to decide whether or not the water is safe to drink, or to swim in.

**What about bottled water? Is that safe?**

Bottled water is regulated as a food product under the Food and Drugs Act.

Federal food inspectors regularly check the operations of bottled water companies to ensure compliance with the act. Some provincial and municipal agencies also keep tabs on bottled waters.

Manufacturers that are members of bottled water associations must follow additional specific requirements to ensure the quality of their products.

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For example: members of the Canadian Bottled Water Association, CBWA, who produce about 85% of the bottled water in Canada, are subject not only to federal and provincial regulations, but also to third-party inspections, water testing and analysis, and adherence to the CBWA Model Code.

For additional information on the standards required of CBWA members, contact:

Canadian Bottled Water Association
70 East Beaver Creek Road, Suite 203-1
Richmond Hill, Ontario L4B 3B2
Tel.: (905) 886-6928
Fax: (905) 886-9531
E-mail: ECGRISWOOD@aol.com

**What about well-water?**

The safety of well-water is the responsibility of the owner of the property where the well is located.

Ensure your well is properly constructed and located to prevent surface water from entering your water supply directly. Surface water is water from lakes, rivers, streams, ponds and reservoirs.

Take samples:

- from your house and cottage 3-4 times a season
- if your well has been flooded
- when your well is newly constructed, or has been renovated recently

*Sources: Environment Canada and Southwest Region Health Information Partnership*

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## Surface Water

# Safety of Drinking Water in Newfoundland and Labrador
## *Questions and Answers*

**How do the various levels of government in Newfoundland and Labrador ensure the safety of drinking water?**

Both provincial and municipal governments have some level of responsibility in ensuring the safety of Newfoundland and Labrador's drinking water. The provincial government, in cooperation with municipal governments protects source water quality through the watershed protection program. Under a partnership program with municipal governments, the provincial government monitors drinking water quality on a regular basis in order to ensure compliance with the "*Guidelines for Canadian Drinking Water Quality*" and to deal with emerging issues on a pro-active basis. The Department of Environment provide the drinking water quality data along with a brief interpretation to municipal governments on a regular basis. The Department is an active member of the Federal-Provincial Subcommittee on Drinking Water (DWS) which is responsible for the development of the *Guidelines for Canadian Drinking Water Quality.*

**How can I obtain a copy of the current Canadian drinking water quality guidelines?**

Contact the Department of Environment or check Health Canada's web site http://www.hc-sc.gc.ca/waterquality for a summary table of the current guidelines. Information on the development of these Guidelines can also be found on Health Canada's web site.

**What are chlorination disinfection by-products and how are they formed?**

Chlorination disinfection by-products (CDBPs) are chemical compounds that form when water containing natural organic matter (the decay products of living things such as leaves, human and animal wastes, etc.) is chlorinated. Chlorine disinfection of water can lead to the formation of a number of chlorination by-products of which trihalomethanes (THMs) are only one subgroup. Among the many chlorination by-products, THMs are most often present and in the greatest concentration in drinking water and as such are used as indicators of total disinfection by-product formation.

**Why is drinking water chlorinated?**

Chlorination is necessary for two reasons. First, almost all sources of surface water contain microbiological organisms, which have to be removed in order to prevent the outbreak of waterborne diseases such as typhoid fever and cholera. Second, once the treated water leaves the treatment plant, it may travel through water mains and pipes sometimes at significant distances, before it reaches it's destination. During this time, it is necessary to maintain a residual level of disinfectant in the water to ensure no possible regrowth of microorganisms. Without adequate disinfection, the health risks from microorganisms far outweigh the risks from THMs.

**What is the current Canadian drinking water guideline for THMs?**

The current Canadian drinking water quality guideline for THMs is 100 parts per billion (ppb) or micrograms per litre (m g/l). The guideline is based on an annual running average of quarterly samples to account for seasonal variations. THM levels are generally highest in the summer and lowest in the winter.

**What are the health effects associated with THMs?**

The Federal-Provincial Subcommittee on Drinking Water established the current guideline for THMs in 1993. The guideline is based on the risk of cancer reported in animal studies of chloroform, the THM most often present and in greatest concentration in drinking water. Since then, new epidemiological (human) studies had been published which reported associations between THMs and bladder and colon cancer, and adverse pregnancy outcomes including miscarriage, birth defects and low birth weight. In response to these new findings Health Canada, in its role as Secretariat to the DWS, established a multi-stakeholder task group in 1998 to oversee a comprehensive update of health risk information on THMs and to develop recommendations for controlling the risks.

**Which public water supplies have the highest/lowest levels of THMs?**

Levels of THMs are generally highest in treated water from sources with high organic matter content, such as rivers and lakes. Lower levels of THMs are usually found when the source water is groundwater.

THM levels can vary within single water supply depending on the season, water temperatures, amount of natural organic matter in water, pH, amount of chlorine added, point of chlorination, time in distribution system, and other factors such as

treatment processes used.

**What are the alternate disinfectants?**

Alternate disinfectants include chloramine, chlorine dioxide and ozone. Each of these alternate disinfectants have their own advantages and disadvantages regarding handling and storage, disinfection by-product formation and cost. The use of chlorine is, however, essential to maintain the required residual in the water distribution system in order to ensure microbiologically safe water.

**What is being done to reduce the levels of THMs in municipal drinking water in Newfoundland and Labrador?**

The government of Newfoundland and Labrador in consultation with municipal governments has developed a three-phase approach to deal with this issue. The first phase is data collection through THM surveys, the second phase deals with data assessment and identification of remediation methods and the third phase will be the implementation of mitigation measures where necessary. It must be emphasized that any changes made to water treatment practices must not compromise the effectiveness of disinfection.

The government of Newfoundland and Labrador is also actively participating, with its provincial colleagues of the DWS in the *Chlorinated Disinfection By-Products Task Group* that is overseeing a coordinated effort to estimate the health risks from THMs and to develop risk management recommendations.

**Should I stop drinking my tap water?**

Tap water provided by municipal governments is generally safe and regularly monitored by the provincial government for physical, chemical and bacteriological quality. You do not need to stop drinking tap water unless you are have been advised to do so by the provincial or municipal governments.

**Are there risks from CDBPs through showering, bathing or swimming?**

While showering, bathing or swimming in chlorinated water may result in significant exposure to CDBPs through breathing in vapors and absorption through the skin, the health risks of prolonged exposure to CDBPs from these sources are currently unknown. Research is in progress to better understand the contribution of inhalation and skin absorption from showering in overall exposure

to CDBPs.

**How can I reduce exposure to THMs?**

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.

**How can I obtain information about my drinking water quality?**

Contact your Town Council office or call the Department of Environment at:

- (709) 729-2563 (Eastern)
- (709) 292-4285 (Central)
- (709) 637-2367 (Western and Labrador)

June 8, 2000

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# press release

February, 1998

**FOR IMMEDIATE RELEASE**

SWEETWATER AUTHORITY RESPONDS TO STUDY LINKING MISCARRIAGE AND WATER DISINFECTION BYPRODUCTS

A new study by the California Department of Health Services (DHS) has identified possible links between first trimester miscarriage and high levels of Trihalomethanes (THMs) in drinking water. For women who drank more than five glasses of cold tap water with THM levels greater than 75 micrograms per liter, the study found that miscarriages occurred at a rate of 15.7 percent, compared to a 9.5 percent rate for women who drank less than five glasses of water with elevated THM levels, or women whose tap water contained less than 75 micrograms of THMs per liter. 103 women out of more than 5,000 studied were found to meet the criteria for high exposure.

State officials, according to the Sacramento Bee, "were careful to point out that their research contradicts a similar study in North Carolina and that additional research must be conducted by the United States Environmental Protection Agency (EPA) before conclusions are drawn." Current regulations allow up to 100 micrograms per liter of THMs. Pending regulations may reduce this level to 80 micrograms per liter in the near future.

Trihalomethanes are formed when chlorine, which is used to kill microorganisms in the water, combines with broken-down vegetable matter like weeds or tree roots. There have been concerns about THMs for several years, said Dr. Raymond Nuetra, chief of the CA Division of Environmental and Occupational Disease Control, "because some of these agents at high doses will cause tumors or cancer in mice."

Sweetwater Authority has responded to prior concerns, and worked to reduce THM levels in several ways. "Our primary concern," said spokeswoman, "will always be to protect our customers. We are very concerned about the results of this study, and about continuing to

**For additional information you may contact:**

California Department of Health Services
(510) 450-3818

Metropolitan Water District of Southern California
(213) 217-6485

Association of California Water Agencies
(916) 441-4545

**Other:**

News Media Reports DHS Study of Water and Miscarriages

THM Questions and Answers

**INFORMATION SOURCES Regarding the California Department of Health Services Study and Trihalomethanes in General**

Dr. Raymond Neutra, Division of Environmental and Occupational Disease (CDHS) (510) 450-2400

Shanna Swan, Ph.D., Chief of Reproductive Epidemiology (CDHS) -- study author (510) 540-2669

Christine Arnesen, Chief of Consumer Relations & Training (CDHS) (510) 450-3818

Ken August, Press Office, (CDHS), (916) 657-3064

**Water Industry**

provide protection from diseases caused by the bacteria, viruses and similar threats which chlorine eliminates."

The spokeswoman said her agency would closely follow further studies related to pregnancy outcomes and to determine methods of reducing disinfection side-effects without increased public health risks. She explained that Sweetwater Authority contributes annually to the national American Water Works Research Foundation, and is an active participant in the EPA's Information Collection Rule (ICR) process. As participants in the process, Sweetwater Athority's staff will examine the use of enhanced coagulation and Granular Activated Carbon to reduce disinfectant byproducts, including the THMs identified in the DHS study.

The spokeswoman noted that Sweetwater Authority has a long history of working to manage THM levels. The agency renovated its Robert A. Perdue Water Treatment Plant in 1987 to provide chloramine disinfection (using a combination of chlorine and ammonia) which reduced levels of chlorinated byproducts because less chlorine was necessary to provide disinfection. In 1988, a brush removal program was instituted at Sweetwater Reservoir to eliminate plants which would otherwise decay in the water. The first phase of Sweetwater Athority's Urban Runoff Diversion System was constructed at Sweetwater Reservoir in 1992 to keep the worst quality water out of the reservoir entirely. (A second phase is currently under construction.) The agency has begun work on a Watershed Management Program to further protect water entering its reservoirs from upstream pollution, and is considering a future conversion to ozone disinfection at its Perdue Water Treatment Plant.

The most current THM measurements taken at Perdue Treatment Plant indicated a level of 41 micrograms per liter, well below the level identified in the study. However, she noted that THM levels can vary widely based on the season, rainfall levels, and whether the agency is drawing most of its water from its reservoirs, as opposed to its groundwater and imported water sources. The Department of Health Services is urging pregnant women to continue drinking water, but said those concerned about possible risks can boil their drinking water for two minutes, drink California-certified bottled water (not vending machine type), or use an approved home filtering device (a list is available from CA DHS).

**Water Industry Representatives"**

Association of California Water Agencies, Stephen K. Hall, Executive Director (916) 441-4545

American water Works Association, Jack W. Hoffbuhr, Executive Director (303) 794-7711

**Treatment and Trihalomethanes:**

John Gaston, California Water Quality Expert, (510) 251-2426

**General:**

U.S. EPA Safe Drinking Water Horline: (800) 426-4791

California Department of Health Services: (916) 323-4344

**Bottled Water:**

DHS Food and Drug Division (916) 229-3125

**Certified Home Filtration Devices:**

Bob Burns, CDHS, (916) 323-6111

# A National Survey of Chlorinated Disinfection By-Products in Canadian Drinking Water

Environmental Health Directorate
Health Protection Branch

Published by authority of the
Minister of National Health and Welfare
1995

Également disponible en français sous le titre
*Étude nationale sur les sous-produits de désinfection chlorés dans l'eau potable au Canada*

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K1A 0K9

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ISBN 0-662-24295-5

95-EHD-197

http //www.hc-sc.gc.ca/ehp/ehd/catalogue/bch-pubs/pdf/national_

# Summary

The study was designed to determine the concentrations of halogenated disinfection by-products in Canadian drinking water supplies where chlorine was used at some stage in the treatment process. The effects of applied disinfectants (chlorine, chloramine and ozone), seasonal variation (winter and summer) and spatial variation (treatment plant and distribution system) were examined. Trihalomethanes and haloacetic acids were the major disinfection by-products found in all facilities for all treatment processes and haloacetic acid levels often equalled or exceeded trihalomethane concentrations. Haloacetonitriles, halopropanones, chloral hydrate and chloropicrin were usually detected in treated water samples but at lower concentrations. Mean and median trihalomethane levels were higher in the summer than the winter for all three treatment processes and increased in the distribution system except for chlorine-chloramine treatment. Mean and median trichloroacetic acid levels for chlorine-chlorine disinfection increased in the distribution system but winter and summer levels were similar. Mean and median trichloroacetic acid levels for chlorine-chloramine and ozone-chlor(am)ine treatment and mean and median dichloroacetic acid levels for all processes were slightly higher in summer compared to winter but levels were not higher in the distribution system. Additional research is required to delineate more clearly the spatial and temporal variations in disinfection by-product levels in drinking water at specific facilities. To obtain an accurate estimation of human exposure to disinfection by-products from drinking water, it would appear that samples should be collected at the consumer tap and not at the treatment plant. Further studies are in progress to define the most appropriate sampling strategy.

# Acknowledgement

This survey report was prepared by David T. Williams, Guy L. LeBel and Frank M. Benoit. Thanks are extended to treatment plant personnel for assistance in sample collection and to R. O'Grady and S. Shah for technical assistance.

# Introduction

The treatment of water supplies by disinfection has proven highly effective in destroying or inactivating human pathogenic microorganisms, particularly those responsible for typhoid fever and cholera (Ellis 1991). However, the lack of adequate disinfection can still lead to cholera epidemics (Glass *et al.*, 1992). Consequently, in Canada, it is recognized that disinfection of all surface waters used for human consumption is crucial and that the health risks from pathogenic microorganisms far exceed those potential health risks associated with chemical disinfection by-products (DBPs) produced during potable water treatment. The challenge is, therefore, to minimize the potential risks from DBPs without compromising disinfection efficiency.

Chlorine is effective as both a primary and residual disinfectant and is also relatively easy to use. However, chlorine also reacts with biogenic organic matter, such as humic and fulvic acids, present in all natural surface water supplies. The resultant chlorinated organic contaminants have been widely reported in drinking water supplies but since the chemistry involved is extremely complex, it is not yet feasible to predict the concentrations of the various DBPs that will be formed in any given water sample. Following the first reports by Rook (1974) and Bellar *et al.* (1974), initial concerns focused on the health effects and levels of trihalomethanes (THMs) in drinking water. More recent surveys have also included haloacetic acids (HAAs), haloacetonitriles (HANs), chloropicrin (CPK), chloral hydrate (CH) and other DBPs. The World Health Organization has published drinking water guidelines (WHO 1993) for chloroform (TCM, 0.2 mg/L), bromodichloromethane (BDCM, 0.06 mg/L), dibromochloromethane (DBCM, 0.1 mg/L) and bromoform (TBM, 0.1 mg/L) and provisional guideline values for dichloroacetic acid (DCAA, 0.05 mg/L), trichloroacetic acid (TCAA, 0.1 mg/L), chloral hydrate (CH, 0.01 mg/L), dichloroacetonitrile (DCAN, 0.09 mg/L), dibromoacetonitrile (DBAN, 0.1 mg/L) and trichloroacetonitrile (TCAN, 0.001 mg/L). In addition to the guidelines for individual THMs, the World Health Organization suggests (WHO, 1993) that a guideline for the total THM (TTHM) be derived from the sum of the ratios (ratio not to exceed 1) of the measured values to the guideline values for each individual THM. It should be emphasized that WHO guidelines do not have any formal recognition in Canada, and they do not include consideration of achievability, which is a feature of Canadian guidelines. The current USEPA maximum contaminant level for TTHMs was set at 0.1 mg/L but a Disinfectants-Disinfection By-products Rule, expected to be promulgated by the USEPA in 1996 (USEPA 1991, AWWA 1994, Pontius 1995), will set new maximum contaminant levels for TTHMs (0.08 mg/L) and the sum of five haloacetic acids (HAA5, 0.06 mg/L). An interim maximum acceptable concentration (IMAC) for TTHMs (0.1 mg/L) has recently been assigned in the Guidelines for Canadian Drinking Water (Health Canada in press). No Canadian guidelines exist for other disinfection by-products although a guideline is under development for the haloacetic acids.

80 ppb is the new EF standard maximum

The formation of DBPs has been reported to be a function of precursor concentration, chlorine dose, chlorination pH, temperature, contact time and bromide ion concentration. Stevens *et al.* (1989) have discussed the formation and control of DBPs and have confirmed that the most important chemical variable in chlorination DBP formation was pH. THM formation was increased at high pH and decreased at low pH. TCAA formation was minimized at high pH and maximized at low pH whereas DCAA formation was essentially independent of the reaction pH. This implies that some measures used to decrease THM production might favour the formation of other DBPs. The occurrence of THMs, HANs, HAAs, CPK and other DBPs in drinking water has been reported for thirty-five US water treatment facilities (Krasner *et al.*, 1989) and for thirty-five Utah water treatment facilities (Nieminski *et al.*, 1993). The 1976 national survey of Canadian drinking water focused on THMs (Williams and Otson, 1978; Williams *et al.*, 1980).

The current survey on the levels of DBPs in Canadian drinking water was intended to provide data which could be used in the preparation of future Canadian Drinking Water Guidelines. A total of 17 different chlorinated DBPs were determined as well as bromide ion, total organic carbon and total organic halides.

## Sample Collection and Analytical Procedures

The 53 sites investigated (Table 1) were selected in consultation with provincial officials and represented most of the large population centres in nine provinces; Prince Edward Island was not included in the survey because of the limited use of chlorine in that province. The 53 sites were selected to represent the major populated geographical areas of the country and were distributed according to population as follows: <10,000 – 2 sites, 10,000 to 100,000 – 17 sites and > 100,000 – 34 sites. A questionnaire (Appendix 1) on water treatment processes and operating practices was prepared to record the plant operating conditions at the time of sampling and to record the location of each sampling point. The treatment plants drew raw water from the main types of Canadian sources: lakes, rivers and wells. Three main disinfection treatment processes were in use in the water treatment plants included in this survey. These were chlorine-chlorine, chlorine-chloramine and ozone-chlor(am)ine.

Samples were collected in 1993 during the winter season (February-March) and the summer season (August-September) when DBP levels were expected to be lowest and highest respectively. In order to minimize variations in sampling technique, the number of persons involved in sampling was kept to a minimum. Four technologists were involved in winter sample collection and one technologist was responsible for the summer sample collection. Replicate samples were collected of raw water, treatment plant water (after final disinfection but before distribution) and treated water from a well-flushed tap at a point in the distribution system (approximately the mid-point) some 5-10 kilometres from the treatment plant. Water samples for the analysis of HAAs were collected in amber bottles containing sodium thiosulphate; those for analysis of THMs, HANs, chloropropanones, chloral hydrate and chloropicrin were collected in amber bottles containing ammonium chloride and were adjusted to pH 4.5 at the time of collection. LeBel and Williams (1995) have shown that it is critical to adjust the water samples to pH 4.5 at the time of collection to prevent or minimize the production of additional THMs during transportation and storage. Samples also were collected in prewashed bottles for the analysis of total organic carbon, total organic halogen and bromide ion. The bottles were filled just to overflow with samples, sealed with Teflon-lined caps, returned to the laboratory in a cooler by the fastest available route and stored in a cold room until analyzed (usually within 1-4 days). Complete details of the sampling protocols are given in Appendix 2.

**Table 1**
**Sampling Locations**

| Province | Location | Water Source | Disinfectant |
|---|---|---|---|
| Newfoundland | St. John's(Windsor) | Lake | CL |
| | St. John's(Bull Pond) | Lake | CL,O |
| Nova Scotia | Dartmouth | Lake | CL |
| | Halifax | Lake | CL |
| | New Glasgow | Lake | CL |
| | Truro | Dam | CL |
| New Brunswick | Fredericton | Well | CL |
| | Moncton | River | CL |
| | Oromocto | River | CL |
| | Saint John East | Lake | CL |
| Québec | Drummondville | River | CL |
| | Gatineau | River | CL |
| | Granby | River | CL |
| | Laval | River | CL, O |
| | Lévis | River | CL |
| | Montréal | River | CL |
| | Pierrefonds | River | O,CA |
| | Québec | River | CL,O |
| | Repentigny | River | CL,O |
| | St. Jean | River | CL,O |
| | Trois-Rivières | River | CL |
| Ontario | Barrie | Well | CL |
| | Brantford | River | CL,CA |
| | Grand Bend | Lake | CL |
| | Guelph | Well | CL |
| | Kingston | Lake | CL |
| | Mississauga | Lake | CL,CA |
| | North Bay | Lake | CL |
| | Ottawa(Britannia) | River | CL,CA |
| | Ottawa(Lemieux) | River | CL,CA |
| | Peterborough | River | CL |
| | St Catharines | Lake | CL |
| | Sudbury | River | CL |
| | Toronto | Lake | CL,CA |
| Manitoba | Letellier | River | CL |
| | Portage-La-Prairie | River | CL,O |
| | Selkirk | River | CL |
| | Winnipeg | Lake | CL |
| | Whitemouth | River | CL |
| Saskatchewan | Moose Jaw | Lake | CL |
| | Prince Albert | River | CL |
| | Saskatoon | River | CL,CA |
| | Swift Current | Lake | CL |
| Alberta | Calgary | Lake | CL |
| | Edmonton | River | CL,CA |
| | Lethbridge | River | CL,CA |
| | Red Deer | River | CL,CA |
| British Columbia | Chilliwack | River | CL |
| | Kamloops | Well, River | CL |
| | Nanaimo | Lake | CL |
| | Penticton | Lake | CL |
| | Vancouver | Lake | CL |
| | Victoria | Lake, River | CL,CA |

CL – chlorine
CA – chloramine
O – ozone

The water samples which had been adjusted to pH 4.5 in the field were extracted with methyl t-butyl ether (MTBE) and analyzed for THMs, HANs, chloropropanones, chloral hydrate and chloropicrin by gas chromatography using a Varian Vista 6000 GC equipped with an electron capture detector, an on-column injector and a J&W DB-5 capillary column. The HAA water samples were pH adjusted in the laboratory, extracted with diethyl ether and the HAAs converted to their methyl esters which were analyzed by gas chromatography-mass spectrometry (selected ion monitoring) using a Finnigan MAT 90 GC/MS fitted with a DB-1701 capillary column. Bromide ion was determined by ion chromatography, total organic carbon was determined using a SKALAR SA5 segmented flow analyzer and total organic halogen was determined using a Mitsubishi TOX-10 analyzer. Instrumental parameters and full analytical details are provided in Appendix 2 and the minimum quantifiable limits for each parameter are listed in Table 2.

For quality control purposes all samples were collected at least in duplicate and control samples were included for all groups of target analytes (usually one field blank per two sites). All DBP analytical methods incorporated surrogate internal standards and quantification was based on response factors established by multi-level calibration with fortified samples analyzed under identical conditions. Additional fortified samples were analyzed at scheduled intervals. DBPs identified by GC-ECD were confirmed by GC-MS or by GC-ECD analysis on a second GC column (DB-17). Each week during the analytical period, duplicate 30 mL groundwater samples, known to be free of HAAs, were spiked with a HAA standard mixture of known concentration, stored in a refrigerator until the following week and, along with field samples, analyzed as described above.

# Results and Discussion

Raw, treatment plant and distribution system water samples were collected from fifty-three drinking water treatment facilities on two occasions (winter and summer) in 1993 and were analyzed for the DBPs listed in Table 2. The analytes listed in Table 2 were selected based on the known occurrence of halogenated DBPs in drinking water treated with chlorine disinfectants and on the possibility that they may at some time be considered for inclusion in Canadian drinking water guidelines. One site was subsequently excluded from the statistical analyses when it was determined that chlorine was added at the raw water source some 160 km from the municipality and, consequently, no representative raw or treatment plant samples were obtained. Water samples (raw, plant and system waters) were collected from the three sampling locations on the same day and hence, the raw and plant waters present similar organic profiles. However, the system water sample is older and represents water that was processed within the plant at some undetermined time prior to the sampling date. Such a water sample could have a different burden of organic material and could also have been the subject of minor variations in the water treatment process. The exact age (from treatment to sampling) of a water sample taken within the distribution system is difficult to ascertain because of the wide variety of parameters that determine the time spent within the distribution system before discharge from the tap. Certainly, the age of the system water will vary between facilities because of different treatment plant sizes, capacities and water consumption.

Thirty-seven of the fifty-two treatment facilities used disinfection coupled with alum coagulation and filtration as the main treatment processes. The other fifteen facilities used only disinfection as the main process. Pre- and/or post-chlorination (chlorine-chlorine) was used at thirty-five facilities and pre-chlorination coupled with post-chloramination (chlorine-chloramine) was used at ten facilities. Ozone coupled with chlorine or chloramine (ozone-chlor(am)ine) was used at seven facilities. Some of these facilities used significant levels of pre-chlorination during the summer to control algal growth and to prevent filter media fouling. The raw water sources were rivers (28), lakes (18), wells (3), a dam (1) and a mixture of these sources (2). Appendix 3 contains an individual data sheet for each municipality which lists the raw water source and the

general process used for water treatment. The data sheets also report the levels for the DBPs listed in Table 2 for raw, treated and distribution water samples collected in winter and summer.

**Table 2**
**DBPs analyzed in 1993 National Survey**

| Compound | MQL* | |
|---|---|---|
| Chloroform ($CHCl_3$) [TCM] | 0.2 | µg/L |
| Bromodichloromethane ($CHBrCl_2$)[BDCM] | 0.1 | µg/L |
| Chlorodibromomethane ($CHBr_2Cl$)[CDBM] | 0.1 | µg/L |
| Bromoform ($CHBr_3$)[TBM] | 0.1 | µg/L |
| Monochloroacetic acid ($CH_2ClCOOH$) [MCAA] | 0.01 | µg/L |
| Dichloroacetic acid ($CHCl_2COOH$) [DCAA] | 0.01 | µg/L |
| Trichloroacetic acid ($CCl_3COOH$) [TCAA] | 0.01 | µg/L |
| Monobromoacetic acid ($CH_2BrCOOH$) [MBAA] | 0.01 | µg/L |
| Dibromoacetic acid ($CHBr_2COOH$) [DBAA] | 0.01 | µg/L |
| Dichloroacetonitrile ($CHCl_2CN$) [DCAN] | 0.1 | µg/L |
| Trichloroacetonitrile ($CCl_3CN$) [TCAN] | 0.1 | µg/L |
| Bromochloroacetonitrile (CHBrClCN) [BCAN] | 0.1 | µg/L |
| Dibromoacetonitrile ($CHBr_2CN$) [DBAN] | 0.1 | µg/L |
| 1,1-Dichloro-2-propanone ($CHCl_2COCH_3$) [DCP] | 0.1 | µg/L |
| 1,1,1-Trichloro-2-propanone ($CCl_3COCH_3$) [TCP] | 0.1 | µg/L |
| Chloral hydrate ($CCl_3CH(OH)_2$) [CH] | 0.1 | µg/L |
| Chloropicrin ($CCl_3NO_2$) [CPK] | 0.1 | µg/L |
| Bromide ion (winter) | 0.01 | mg/L |
| Bromide ion (summer) | 0.002 | mg/L |
| Total organic carbon [TOC] | 0.1 | mg/L |
| Total organic halide [TOX] | 5.0 | µg/L |

*MQL = minimum quantifiable limit

The individual results were sent to each of the respective municipalities and provinces who participated in the study, together with relevant excerpts from the Canadian and WHO Drinking Water Guidelines, with a description of the toxic effects attributed to each of the disinfection by-products (see Appendix 4). Although the DBP data can be compared with guideline values, it should be emphasized that the present study was not designed to evaluate compliance with guideline values. As can be seen in Appendix 4, it is recommended that, for compliance purposes, TTHM be measured at least quarterly in order to obtain an annual running average. This approach is particularly appropriate for carcinogens which usually require very long exposures before an effect is seen. It is not the approach taken with non-carcinogenic effects; hence for DCAA, TCAA and CH, shorter periods of exceedance are considered significant. However, even in these cases, short-term excursions over the guideline, if only occasional, may not be a reason for concern. As is clearly stated in the TTHM guideline (Appendix 4), the solution to any problems with high concentrations of disinfection by-products is ***not to reduce disinfection since this would pose an unacceptable health risk***. The preferred approach is to reduce the organic precursors in the raw water that react with the disinfectant to produce the by-products. Fine tuning of the treatment system may also achieve a reduction in by-products without impairing disinfection.

Mean and median levels and concentration ranges for the major DBPs of each target group in summer and winter are reported in Table 3 for the three main disinfection processes for samples collected at the treatment plant just before distribution and for samples collected at the approximate mid-point of the distribution system. The target DBPs were either non-detectable or found at extremely low levels in the raw water samples. At most facilities, the dominant species found were chlorinated DBPs and, of these, TCM, DCAA and TCAA were the major components. The concentrations of the other target DBPs were usually an order of magnitude less.

## TriHaloMethanes

The percentage distributions of THMs in winter and summer for treatment plant and distribution system samples are shown in Table 4. The percentage of chloroform was higher in summer than in winter for all three treatment processes and was slightly higher for chlorine-chlorine treatment compared to the other two processes. The bromine-containing THMs were relatively higher in the winter samples and for the chlorine-chloramine and ozone-chlor(am)ine treatment processes. Chloroform was the major THM detected except at three facilities where ground water sources (low TOC) were treated with minimal chlorination and, therefore, had low TTHM levels (<15 µg/L). At these three sites, chlorodibromomethane (2 sites) and bromoform (1 site) were the major THMs detected. For chlorine-chlorine treatment, mean TTHM levels (Table 3) were higher in summer than winter (e.g. 62.5 µg/L compared to 33.4 µg/L for distribution system samples) and were higher in the distribution system than at the treatment plant (e.g. 62.5 µg/L compared to 33.5 µg/L for summer samples). For chlorine-chloramine treatment, mean TTHM levels were higher in summer than winter (e.g. 32.8 µg/L compared to 13.7 µg/L for distribution system samples) but mean and median treatment plant TTHM levels were similar to those in the distribution system in both winter and summer. Those facilities which used ozone in their treatment process had mean TTHM levels which were low in winter but in the summer had mean and median levels similar to or higher than those at facilities using chlorine-chlorine treatment. A probable reason for this was that pre-chlorination was commonly used to supplement ozone disinfection during the warm water months at some facilities. This can be clearly seen (Table 5) by the significant increase in mean TOX concentrations in the summer samples compared to the winter samples for those facilities using ozone. The frequency distributions of facilities based on TTHM concentrations are illustrated in Figure 1 for the plant and distribution system samples for the three treatment processes. While the majority of treatment facilities had relatively low TTHM levels (<50 µg/L) for all three treatment processes during both winter and summer, a small number of facilities had relatively high TTHM values (>100 µg/L), particularly in the summer (except for chlorine-chloramine disinfection). This can also be seen in Table 3 where the median TTHM values are lower than the mean TTHM values except for ozone treatment.

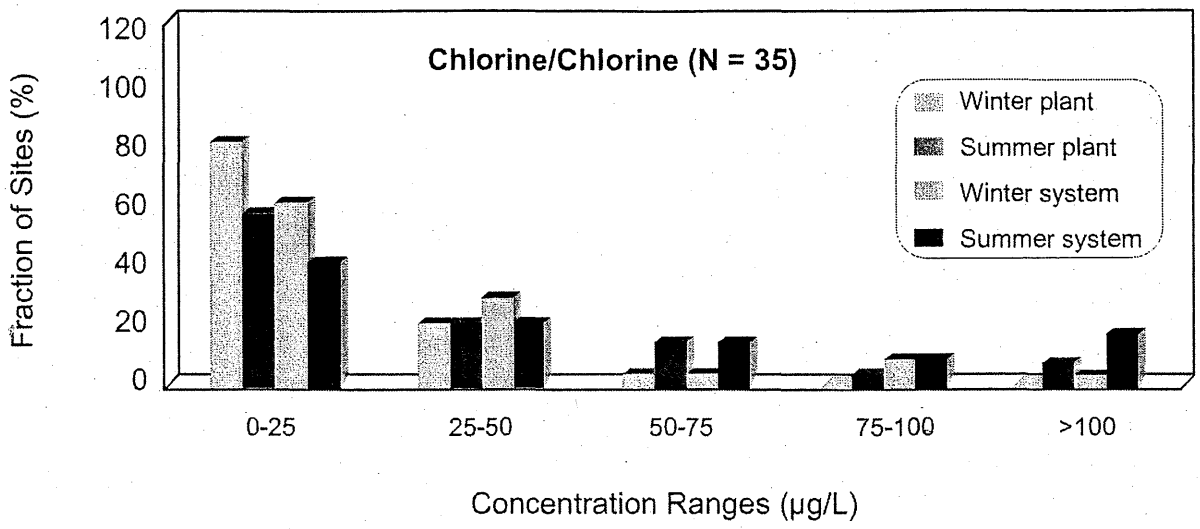
The TTHM data from the present Canadian survey are consistent with data reported for USA facilities. A 1987 survey of 727 US facilities reported median TTHM values of 44 and 30 µg/L for the summer and winter seasons for water samples collected at the treatment plant after disinfection but before distribution (McGuire and Meadow, 1988). A 1988-89 survey of 35 US facilities also reported median values for TTHM of 44 and 30 µg/L for the summer and winter seasons for water samples collected at the treatment plant (Krasner *et al.*, 1989). No breakdown of data by type of disinfectant was provided. In a 1990 survey of 35 Utah facilities which used chlorine as the only disinfectant, median (mean) summer values for TTHM of 22.4 (31.3) µg/L and 55.7 (60.0) µg/L for plant effluent and distribution system samples were reported; for a sub-set of 14 facilities, median (mean) values for TTHM of 21.6 (28.8) µg/L and 15.9 (20.9) µg/L for summer and winter plant effluent samples were reported (Nieminski *et al.*, 1993).

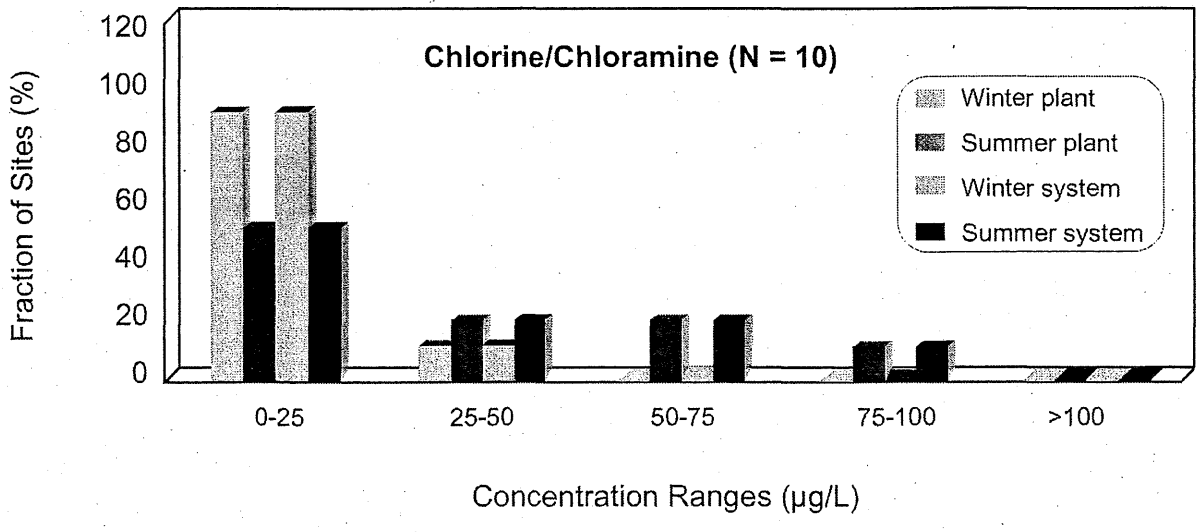
**Table 3**
**DBPs (µg/L) in Canadian Drinking Water - 1993**

| | | | Winter | | | Summer | | |
|---|---|---|---|---|---|---|---|---|
| Compound | Treatment | Site | Mean | Median | Range | Mean | Median | Range |
| TTHM | Chlorine – | Plant | 16.8 | 10.9 | 2.0 – 67.9 | 33.5 | 17.2 | 1.6 – 120.8 |
| | Chlorine | System | 33.4 | 21.8 | 2.8 – 221.1 | 62.5 | 33.8 | 0.3 – 342.4 |
| | Chlorine – | Plant | 12.1 | 10.1 | 0.6 – 40.3 | 31.2 | 19.7 | 2.9 – 80.1 |
| | Chloramine | System | 13.7 | 10.9 | 1.5 – 42.1 | 32.8 | 21.7 | 4.3 – 85.2 |
| | Ozone – | Plant | 6.8 | 5.7 | 1.7 – 12.3 | 44.0 | 57.4 | 2.5 – 74.9 |
| | Chlor(am)ine | System | 9.9 | 11.0 | 2.4 – 15.4 | 66.7 | 90.9 | 4.9 – 107.8 |
| DCAA | Chlorine – | Plant | 13.2 | 9.0 | 0.3 – 45.4 | 21.1 | 12.5 | 0.6 – 163.3 |
| | Chlorine | System | 15.6 | 11.8 | 0.2 – 63.6 | 19.0 | 10.4 | 0.3 – 120.1 |
| | Chlorine – | Plant | 9.8 | 7.7 | 1.2 – 23.3 | 12.5 | 10.5 | 5.3 – 27.6 |
| | Chloramine | System | 10.0 | 9.9 | 1.2 – 22.6 | 11.4 | 10.8 | 4.2 – 23.8 |
| | Ozone – | Plant | 6.9 | 6.4 | 1.6 – 15.0 | 21.2 | 22.6 | 5.3 – 47.6 |
| | Chlor(am)ine | System | 4.6 | 4.8 | 0.4 – 9.3 | 14.1 | 10.7 | 0.9 – 42.6 |
| TCAA | Chlorine – | Plant | 27.8 | 13.0 | 0.1 – 139.8 | 34.0 | 11.9 | 0.04 – 273.2 |
| | Chlorine | System | 56.7 | 24.7 | 0.1 – 473.1 | 48.9 | 25.1 | 0.1 – 263.4 |
| | Chlorine – | Plant | 13.7 | 6.9 | 0.5 – 66.2 | 25.1 | 9.3 | 2.1 – 85.9 |
| | Chloramine | System | 13.2 | 7.0 | 0.5 – 57.9 | 21.4 | 8.7 | 1.9 – 71.5 |
| | Ozone – | Plant | 5.8 | 1.5 | 0.7 – 16.9 | 24.6 | 21.6 | 1.3 – 66.1 |
| | Chlor(am)ine | System | 4.1 | 2.0 | 0.9 – 12.8 | 28.3 | 13.3 | 0.7 – 77.3 |
| CH | Chlorine – | Plant | 2.2 | 1.4 | <0.1 – 13.8 | 4.3 | 2.9 | <0.1 – 14.7 |
| | Chlorine | System | 3.8 | 2.5 | <0.1 – 22.5 | 6.1 | 4.8 | <0.1 – 18.9 |
| | Chlorine – | Plant | 1.2 | 0.8 | <0.1 – 3.2 | 3.9 | 3.3 | 0.3 – 15.1 |
| | Chloramine | System | 1.2 | 0.8 | 0.2 – 3.2 | 3.6 | 2.9 | 0.3 – 13.6 |
| | Ozone – | Plant | 1.5 | 1.0 | 0.2 – 2.9 | 8.1 | 10.4 | 0.7 – 14.5 |
| | Chlor(am)ine | System | 2.2 | 1.9 | 0.2 – 5.8 | 8.4 | 5.6 | 0.2 – 20.1 |
| DCAN | Chlorine – | Plant | 2.1 | 1.0 | 0.1 – 12.6 | 2.7 | 1.7 | <0.1 – 9.0 |
| | Chlorine | System | 2.9 | 1.9 | 0.1 – 16.3 | 2.9 | 1.9 | <0.1 – 9.5 |
| | Chlorine – | Plant | 1.5 | 1.0 | <0.1 – 7.3 | 2.6 | 1.6 | 0.4 – 11.2 |
| | Chloramine | System | 1.7 | 0.9 | 0.2 – 7.3 | 2.5 | 1.4 | 0.4 – 10.7 |
| | Ozone – | Plant | 0.8 | 0.6 | 0.2 – 1.3 | 2.5 | 3.1 | 0.3 – 4.1 |
| | Chlor(am)ine | System | 0.8 | 0.7 | <0.1 – 1.6 | 2.2 | 1.7 | <0.1 – 5.0 |
| DCP | Chlorine – | Plant | 1.1 | 0.9 | <0.1 – 3.7 | 0.9 | 0.8 | <0.1 – 2.6 |
| | Chlorine | System | 1.0 | 0.9 | <0.1 – 3.3 | 0.8 | 0.6 | <0.1 – 2.1 |
| | Chlorine – | Plant | 0.8 | 0.9 | <0.1 – 1.5 | 1.3 | 1.4 | 0.3 – 2.4 |
| | Chloramine | System | 1.0 | 1.2 | 0.3 – 1.6 | 1.3 | 1.4 | 0.3 – 2.1 |
| | Ozone – | Plant | 1.5 | 1.2 | 0.9 – 2.3 | 1.5 | 1.3 | 0.5 – 2.9 |
| | Chlor(am)ine | System | 1.3 | 1.2 | 0.8 – 2.1 | 1.0 | 0.9 | 0.4 – 2.3 |
| TCP | Chlorine – | Plant | 1.7 | 1.4 | <0.1 – 7.6 | 2.7 | 2.0 | <0.1 – 9.1 |
| | Chlorine | System | 2.7 | 2.2 | <0.1 – 10.1 | 2.5 | 1.9 | <0.1 – 7.8 |
| | Chlorine – | Plant | 1.0 | 0.9 | <0.1 – 2.6 | 1.7 | 0.6 | 0.1 – 6.4 |
| | Chloramine | System | 0.9 | 0.7 | <0.1 – 2.6 | 1.3 | 0.6 | <0.1 – 5.3 |
| | Ozone – | Plant | 1.3 | 0.9 | 0.2 – 3.1 | 4.4 | 4.1 | 0.5 – 9.2 |
| | Chlor(am)ine | System | 1.6 | 1.3 | 0.3 – 3.3 | 2.5 | 1.5 | 0.4 – 10.4 |
| CPK | Chlorine – | Plant | 0.2 | 0.1 | <0.1 – 1.2 | 0.3 | 0.2 | <0.1 – 2.5 |
| | Chlorine | System | 0.3 | 0.2 | <0.1 – 1.6 | 0.3 | 0.2 | <0.1 – 1.2 |
| | Chlorine – | Plant | 0.2 | 0.2 | <0.1 – 0.9 | 0.2 | 0.2 | <0.1 – 0.9 |
| | Chloramine | System | 0.2 | 0.2 | <0.1 – 0.9 | 0.3 | 0.3 | <0.1 – 0.9 |
| | Ozone – | Plant | 0.2 | 0.1 | <0.1 – 0.3 | 1.2 | 1.5 | <0.1 – 2.2 |
| | Chlor(am)ine | System | 0.3 | 0.3 | <0.1 – 0.6 | 1.3 | 1.1 | <0.1 – 2.3 |

Note: levels of THM's in drinking water tend to be higher in summer than in winter.

## Figure 1. Distribution of facilities based on TTHM levels



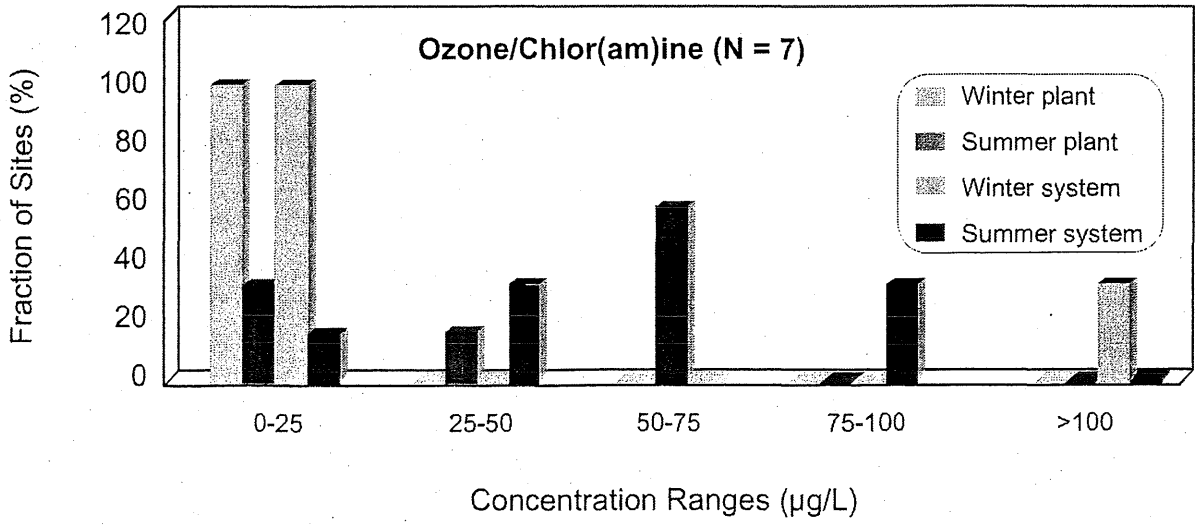



**Table 4**
**% THM Distribution in Drinking Water**

| | Treatment | Site | Winter % | Summer % |
|---|---|---|---|---|
| TCM | Chlorine - Chlorine | Plant System | 82.3 88.3 | 88.3 91.4 |
| | Chlorine - Chloramine | Plant System | 77.2 77.9 | 86.2 86.8 |
| | Ozone - Chlor(am)ine | Plant System | 78.6 75.5 | 85.2 86.7 |
| BDCM | Chlorine - Chlorine | Plant System | 13.1 9.4 | 9.1 7.1 |
| | Chlorine - Chloramine | Plant System | 16.9 16.5 | 10.6 10.3 |
| | Ozone - Chlor(am)ine | Plant System | 15.5 17.1 | 11.0 9.9 |
| CDBM | Chlorine - Chlorine | Plant System | 3.8 1.9 | 2.3 1.2 |
| | Chlorine - Chloramine | Plant System | 4.7 4.5 | 2.4 2.3 |
| | Ozone - Chlor(am)ine | Plant System | 5.0 5.7 | 3.2 3.1 |
| TBM | Chlorine - Chlorine | Plant System | 0.8 0.4 | 0.4 0.2 |
| | Chlorine - Chloramine | Plant System | 1.2 1.2 | 0.6 0.6 |
| | Ozone - Chlor(am)ine | Plant System | 0.9 1.6 | 0.3 0.3 |

**Table 5**
**TOX [µg Cl⁻/L] in Drinking Water**

| Treatement | Site | Mean | Winter Median | Range |
|---|---|---|---|---|
| Chlorine – Chlorine | Plant System | 95.0 126.1 | 81.5 96.5 | 6-396 11-572 |
| Chlorine – Chloramine | Plant System | 68.6 71.7 | 55.0 51.0 | 8-279 7-286 |
| Ozone – Chlor(am)ine | Plant System | 69.7 55.6 | 90.0 56.0 | 15-114 20- 85 |

| Treatement | Site | Mean | Summer Median | Range |
|---|---|---|---|---|
| Chlorine – Chlorine | Plant System | 103.5 141.3 | 66.0 106.0 | 8-473 <5-609 |
| Chlorine – Chloramine | Plant System | 109.0 92.2 | 79.0 71.0 | 27-283 20-218 |
| Ozone – Chlor(am)ine | Plant System | 130.0 124.0 | 156.0 87.0 | 23-225 17-229 |

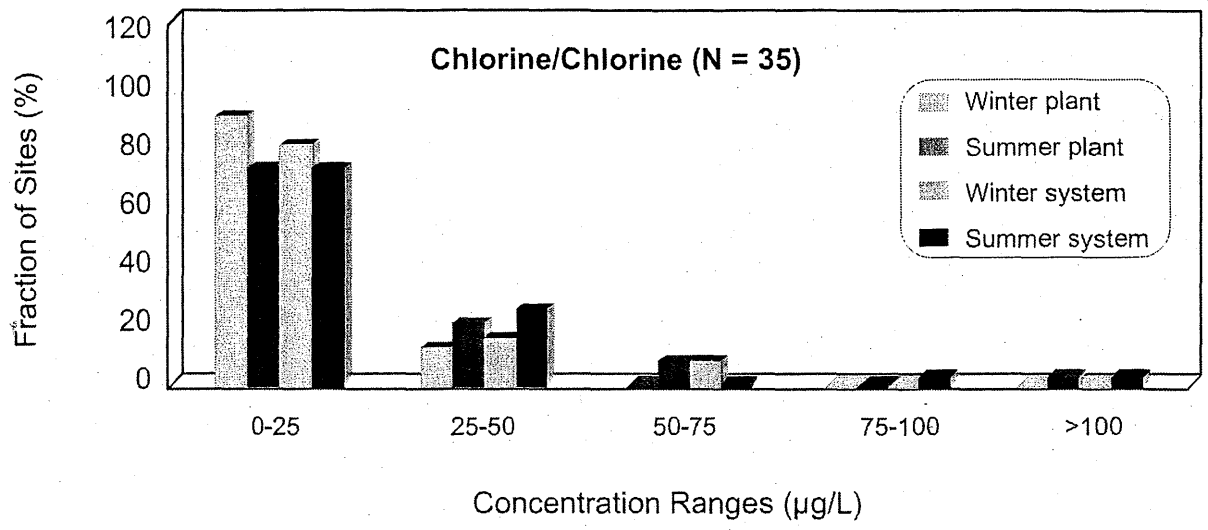
## HaloAcetic Acids

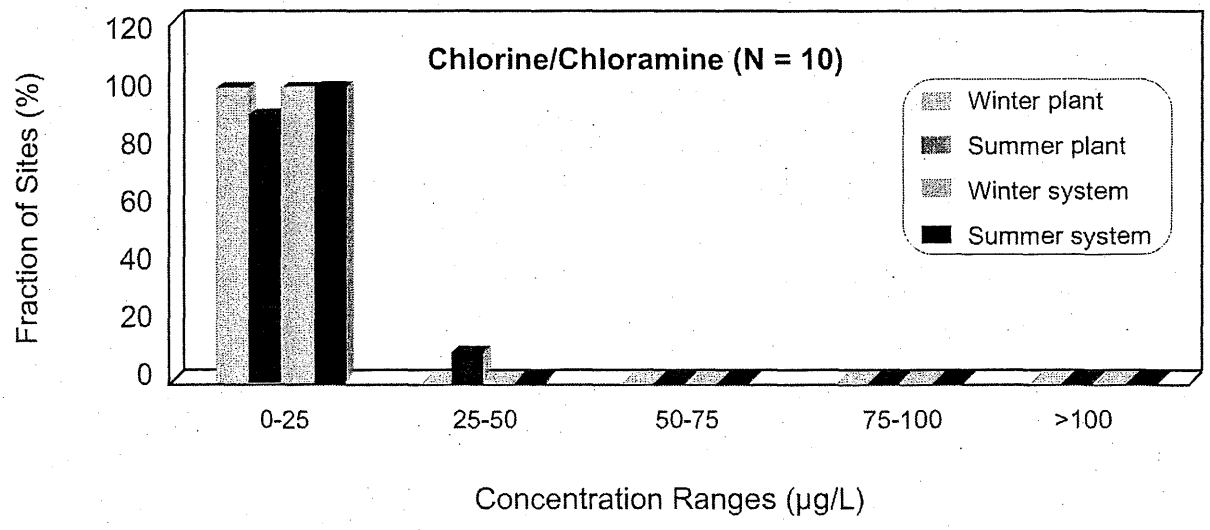
For all treatment processes, mean DCAA levels changed very little within the distribution system for either winter or summer samples (Table 3). For both chlorine-chlorine and chlorine-chloramine treatment, mean DCAA levels were only slightly higher in summer samples compared to winter samples. Those facilities which used ozone in their treatment process had mean DCAA levels which were low in winter (e.g. 4.6 µg/L, distribution system) but in the summer (e.g. 14.1 µg/L, distribution system) were similar to those for the other treatment processes. The frequency distributions of facilities based on DCAA concentration ranges are illustrated in Figure 2 for the plant and distribution system samples from the three treatment processes. While the majority of treatment facilities had relatively low DCAA levels (<50 µg/L) during winter and summer, there were a small number of facilities using chlorine-chlorine treatment which had relatively high DCAA values (>50 µg/L) in both summer and winter.

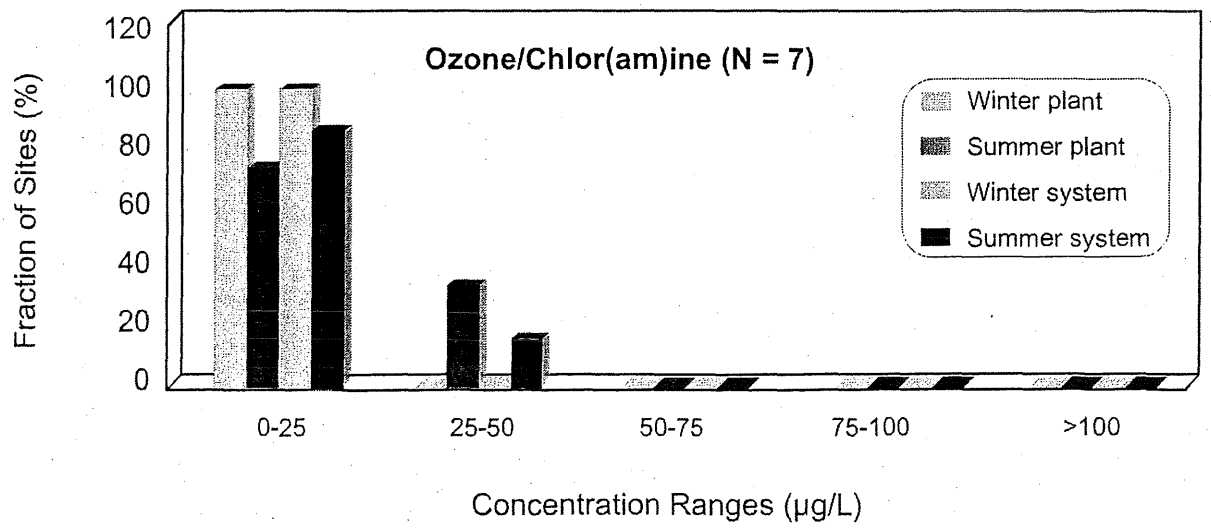
At facilities with chlorine-chlorine treatment, mean TCAA levels increased from the plant to the mid-point of the distribution system (from 27.8 to 56.7 µg/L and from 34.0 to 48.9 µg/L for winter and summer samples respectively) but the mean TCAA levels in winter (56.7 µg/L) and summer (48.9 µg/L) distribution system samples were similar (Table 3). For chlorine-chloramine treatment, mean TCAA levels were higher in summer than winter (e.g. 21.4 µg/L compared to 13.2 µg/L for distribution system samples) but did not appear to increase within the distribution system in either winter or summer. Those facilities which used ozone in their treatment process had mean TCAA levels which were low in winter (e.g. 4.1 µg/L, distribution system) but in the summer (e.g. 28.3 µg/L, distribution system) were similar to those at facilities using chlorine-chloramine treatment. The frequency distributions of facilities based on TCAA concentration ranges for the plant and distribution system samples are illustrated in Figure 3 for the three treatment processes. While the majority of treatment facilities had relatively low TCAA levels (<50 µg/L) during winter and summer, a few facilities had relatively high TCAA values (>100 µg/L) in both summer and winter for chlorine-chlorine disinfection. This can also be seen in Table 3 where the median TCAA values are lower than the mean TCAA values.

The other target HAAs – monochloroacetic acid (100% occurrence, range 0.3 to 9.7 µg/L), monobromoacetic acid (31% occurrence, range <0.01 to 9.2 µg/L) and dibromoacetic acid (62% occurrence, range <0.01 to 1.9 µg/L) – were present at lower levels than the DCAA and TCAA (Table 3). Tribromoacetic acid is unstable in aqueous solution and consequently was not amenable to analysis; the mixed (Cl-Br) haloacetic acid standards were not available and, therefore, quantitative values are not presented here.

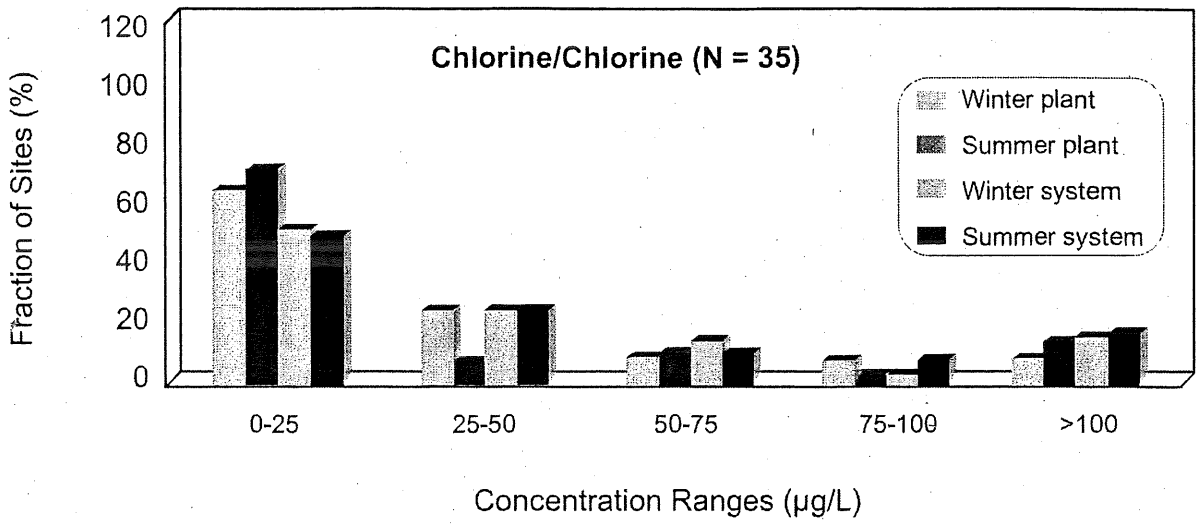
## Figure 2. Distribution of facilities based on DCAA levels

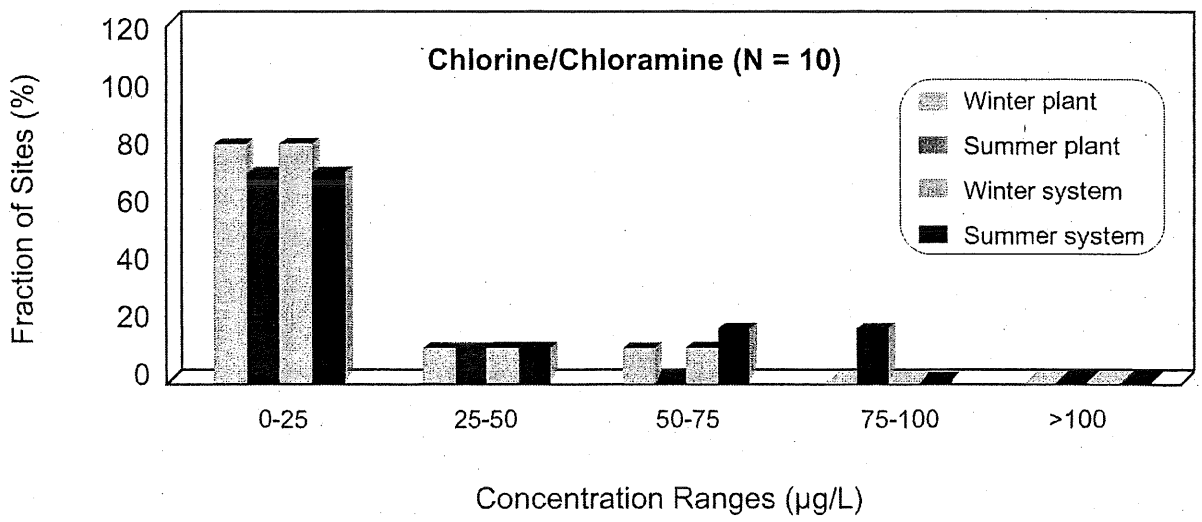


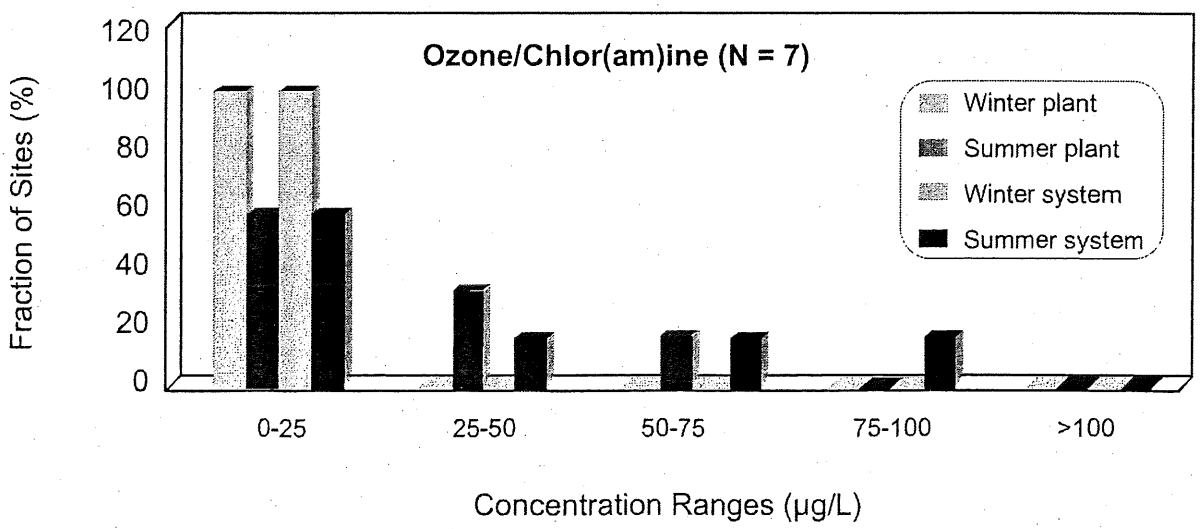



## Figure 3. Distribution of facilities based on TCAA levels



A 1988-89 survey (Krasner *et al.*, 1989) of 35 US facilities gave median values for total haloacetic acids (THAA) of 20 and 13 μg/L for the summer and winter seasons for water samples collected at the treatment plant. No breakdown of data by type of disinfectant was provided. In a 1990 survey (Nieminski *et al.*, 1993) of 35 Utah facilities which used chlorine as the only disinfectant, median (mean) summer values for THAA of 13.2 (17.3) μg/L and 20.9 (29.6) μg/L for plant effluent and distribution system samples were reported. For a subset of 14 Utah facilities, median (mean) values for THAA of 11.4 (12.6) μg/L and 14.4 (11.9) μg/L for summer and winter plant effluent samples were reported.

## Other Disinfection By-Products

Although the concentration of the other target DBPs were usually an order of magnitude lower, they were detected in most treated water samples and also exhibited spatial, seasonal and treatment types variations similar to those of the major DBPs. After the THMs and HAAs, CH (94% occurrence) was the most prominent DBP with concentrations ranging up to 22.5 μg/L for the winter samples and up to 20.1 μg/L for the summer samples. The frequency distributions of facilities based on CH concentration ranges for the plant and distribution system samples are illustrated in Figure 4 for the three treatment processes. In general, for all treatment types, the mean CH concentration (Table 3) was higher in the summer samples compared to the winter samples. Compared to TTHM the overall mean CH concentrations were 14% (plant) and 11% (distribution) of the overall mean TTHM concentration in both winter and summer samples. Based on treatment types, a significant variation was observed with ozone disinfection where the mean CH concentrations were 22% (plant) and 23% (distribution) of the mean TTHM concentration for the winter samples. For the summer samples, the mean CH concentrations were 18% (plant) and 13% (distribution) of the mean TTHM concentration, probably due to the added pre-chlorination used during the summer months.

The other target DBPs had mean concentrations less than 5 μg/L and occurred with the following frequencies – DCAN 97%, TCAN 9 %, BCAN 92%, DBAN 57%, DCP 93%, TCP 91%, CPK 73%. Very little spatial variation was seen for DCAN, TCP, DCP and CPK with the chlorine-chloramine treatment. For the chlorine-chlorine treatment for both seasons DCAN concentrations increased in the distribution system whereas DCP and CPK remained relatively unchanged. TCP increased only for the winter samples and was relatively unchanged in the summer samples. For the ozone treatment, mean concentrations of DCAN, DCP and TCP in distribution water compared to treated water were similar in winter but decreased in summer; the CPK mean concentration did not exhibit marked spatial variation but was considerably higher for the summer samples than for the winter samples (e.g. 1.2 μg/L compared to 0.3 μg/L). These data for CH, HAN, DCP, TCP and CPK are consistent with those reported in other surveys (Uden and Miller 1983; Krasner *et al.*, 1989; IARC 1991; Nieminski *et al.*,1993).

## Correlation of DBPs with Other Parameters

The effect of bromide ion on DBP formation has been shown to be dependent on the bromide ion concentration, the chlorine dose and residual, the pH and the concentration and nature of the organic precursors (Pourmoghaddas *et al.*, 1993; Summers *et al.*, 1993; Symons *et al.*, 1993). The percentage of brominated and mixed halogenated DBPs increases both as the molar ratio of bromide ion to chlorine increases and as the TOC concentration decreases. Some countries have reported that brominated DBPs are significant components of their drinking waters (Peters *et al.*, 1991; Fayad 1993). In this study only four sites in winter and eight sites in summer had raw water bromide ion levels >0.01 mg/L (maximum 0.5 mg/L) and at these sites the relative percentage of brominated and mixed halogenated DBPs increased. The changes in speciation for THMs, HAAs and HANs in winter, treatment plant samples are shown in Table 6, expressed as μg/L concentrations, and in Figure 5, expressed as % speciation, for three sites with very low (Site A, <0.01 mg/L), low (Site B, 0.06 mg/L) and moderate (Site C, 0.5 mg/L) bromide ion concentrations. As the bromide ion concentration increases the relative percentage of brominated and mixed halogenated DBPs increases for all three groups. This is consistent with data reported in laboratory and field studies (Krasner *et al.*, 1989; Fayad 1993; Pourmoghaddas *et al.*, 1993; Summers *et al.*, 1993).

A comparison of total DBP as a function of raw water source for chlorine-chlorine treated waters suggested that the DBP burden was least with groundwater, higher with lake water and highest with river water in both summer and winter periods. This trend may be a reflection of the TOC content of the various water sources, however, only weak correlations ($r^2$=0.2-0.4) were found between TOC and DBP burden. Correlations of individual DBP levels with TOX were weak but the correlation of total DBP (μmoles/L) with TOX (μg/L) was significantly stronger ($r^2$=0.71-0.87) for all chlorine-chlorine treated water samples. No significant correlations were observed between DBP levels and any other parameters. Because of the wide variety of parameters and the treatment variations at each facility, the database obtained in the present study was not large enough and was too heterogeneous to permit meaningful multivariate analysis.

## Figure 4. Distribution of facilities based on CH levels

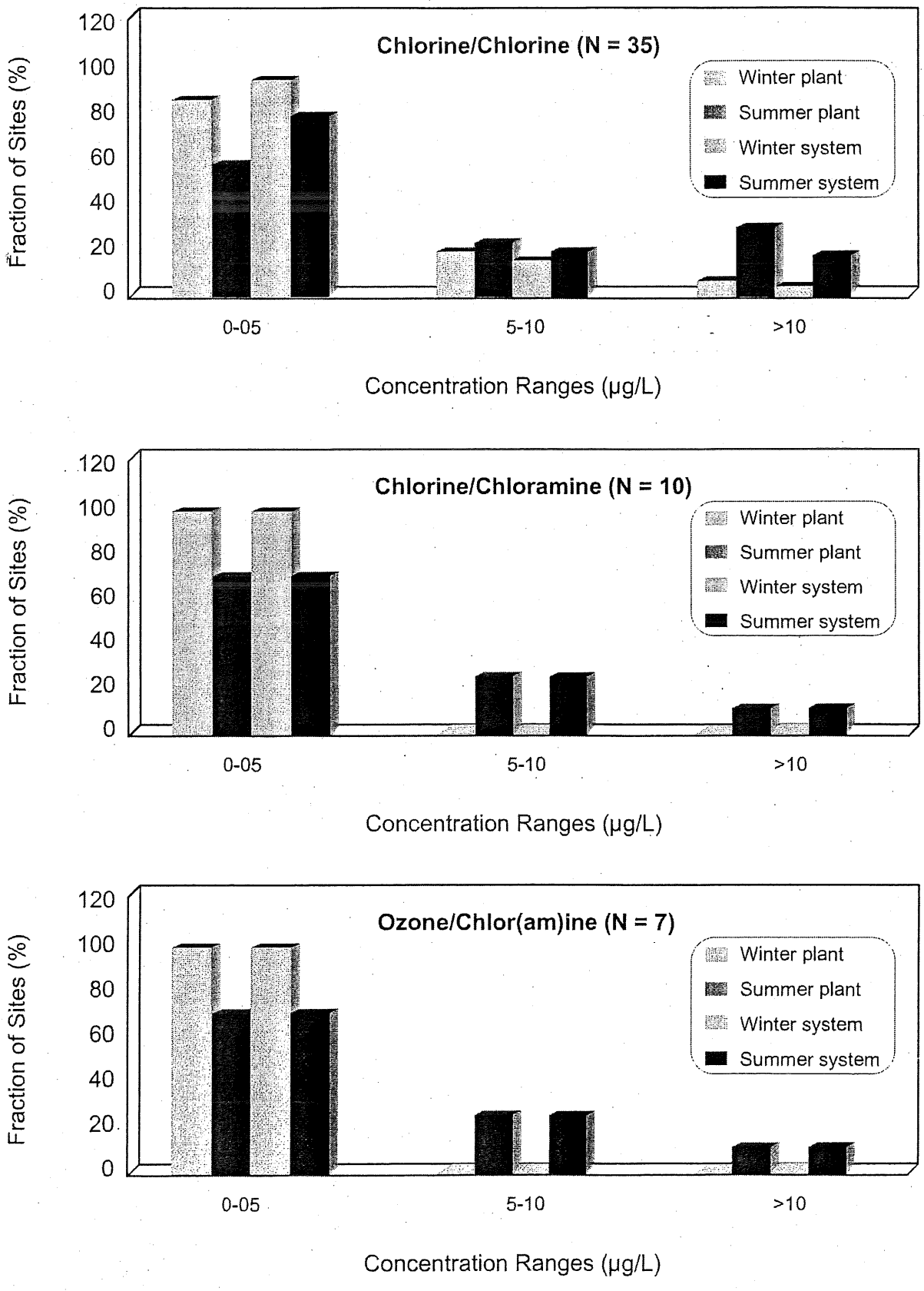
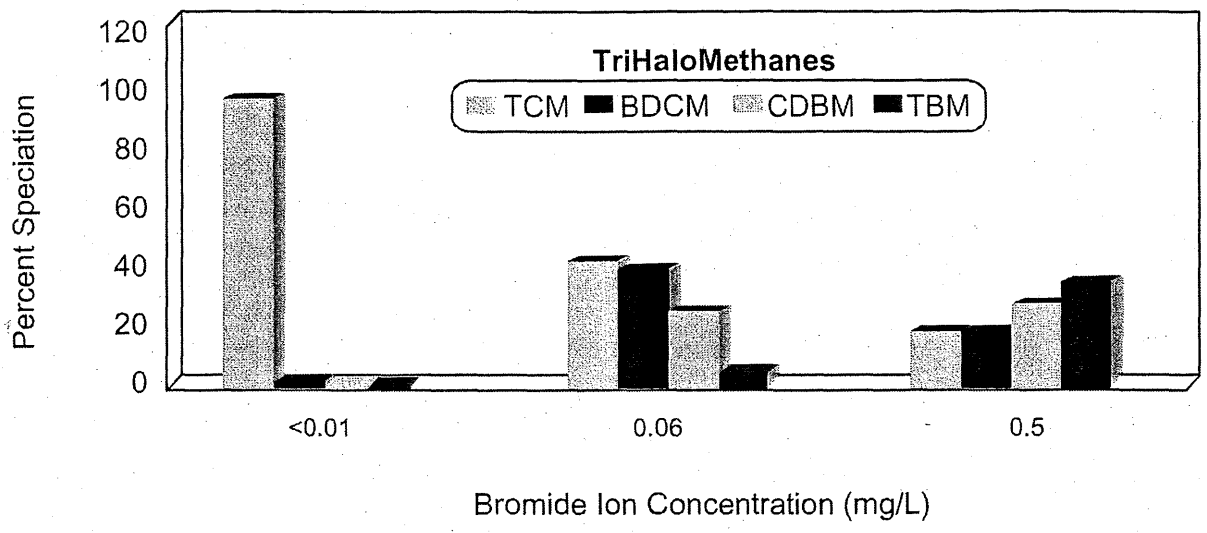
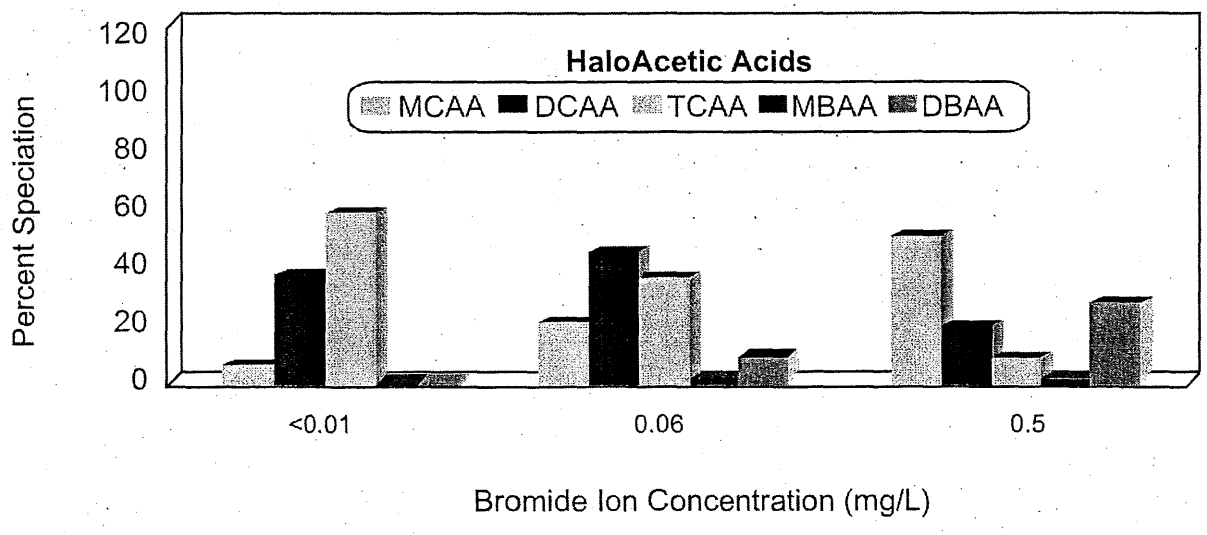


**Figure 5. DBP% Speciation in presence of bromide ion**



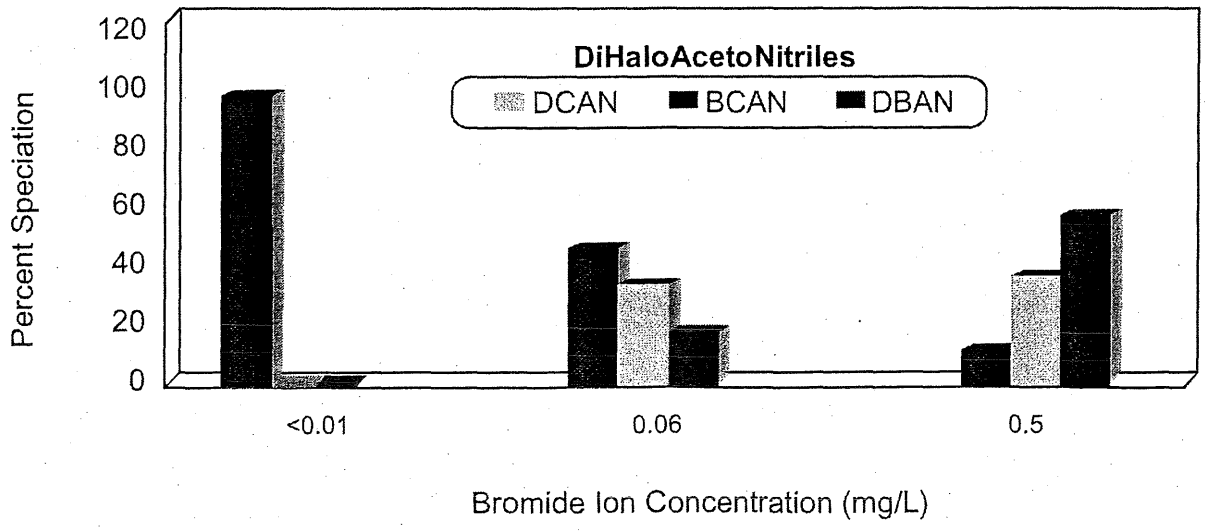



**Table 6**
**DBP Speciation in Drinking Water**

| Compound | Site A | Site B | Site C |
|---|---|---|---|
| TOC (mg/L) | 1.3 | 0.9 | 1.2 |
| $Br^-$ (mg/L) | <0.01 | 0.06 | 0.5 |
| THM (μg/L) | | | |
| TCM | 15.4 | 3.1 | 0.5 |
| BDCM | 0.5 | 3.9 | 0.7 |
| CDBM | <0.1 | 2.9 | 1.5 |
| TBM | <0.1 | 0.8 | 3.3 |
| HAA (μg/L) | | | |
| AMCA | 2.1 | 1.2 | 0.6 |
| ADCA | 20.6 | 3.8 | 0.3 |
| ATCA | 43.4 | 3.8 | 0.1 |
| AMBA | 0.1 | 0.1 | <0.01 |
| ADBA | <0.01 | 0.9 | 0.8 |
| HAN (μg/L) | | | |
| TCAN | <0.1 | <0.1 | <0.1 |
| DCAN | 0.9 | 0.9 | 0.1 |
| BCAN | <0.1 | 0.9 | 0.6 |
| DBAN | <0.1 | 0.6 | 1.2 |

# Conclusions

TTHMs and HAAs were the major DBPs found in all facilities for all treatment processes and HAA levels often equalled or exceeded TTHM concentrations. Mean and median TTHM levels were higher in the summer than the winter for all three treatment processes and increased in the distribution system except for chlorine-chloramine treatment.

Mean and median TCAA levels for chlorine-chlorine disinfection increased in the distribution system but winter and summer levels were similar. Mean and median TCAA levels for chlorine-chloramine and ozone-chlor(am)ine treatment and mean and median DCAA levels for all processes were slightly higher in summer compared to winter but levels were not higher in the distribution system. Further studies are required to delineate more clearly the spatial and temporal variations in DBP levels in drinking water at specific facilities. To obtain an accurate estimation of human exposure to DBPs from drinking water, it would appear that samples should be collected at the consumer tap and not at the treatment plant. Further studies are in progress to define the most appropriate sampling strategy.

# *For Your Information - Water Articles*

## Consumer's Guide to Showerhead Filters

Many people regard a long, hot shower as one of life's unalloyed pleasures. The gentle liquid pelting...the soothing hot steam...the billowing cloud of toxic chlorine gas—whoa! Something's wrong with this picture, but fortunately it can be made right with a relatively simple technical fix.

The fix is a filter for your showerhead. Shower filters have become much more popular in recent years as evidence continues to mount that the chlorine added as a disinfectant to public water systems is a health hazard, and that many people may be getting much more exposure to chlorine and its toxic byproducts by inhaling it in the shower than by drinking it in their tap water. Chlorine and other chemicals are evaporated from hot shower water and easily inhaled, not only in the close confines of the shower but also in the bathroom, where other members of your family can be exposed as well. The pores of your skin also open up from the steam and allow increased absorption of waterborne pollutants. One estimate is that you can be exposed to as much water pollution during a twenty-minute hot shower as by drinking two quarts of tap water per day.

### Is Chlorine a Hidden Menace in Your Shower?

Even if you can't smell its pungent odor, chlorine may be a hidden menace in your shower, causing ailments ranging from headaches to neurotoxic reactions. In the digestive tract chlorine can upset the balance of intestinal flora and promote candida or other infections. Researchers have suggested that chlorine and its toxic byproducts may be responsible for an increased risk of heart disease, allergic reactions, and spontaneous abortions. Studies indicate that consumption of chlorinated water is linked to significantly increased rates of bladder, colon, and rectal cancer. One recent researcher has even noted that chlorine-related toxins may be proven in the future to be "the most important environmental carcinogens in terms of the number of attributable cancers per year."

In addition to its adverse effects on health, chlorine has unwanted topical and cosmetic actions on hair and skin. Anyone who has spent too much time in an overly chlorinated pool can attest to chlorine's ability to irritate the eyes and aggravate mucous membranes in the nose and throat. Chlorine bonds with proteins in the hair, making it dry and brittle and causing color to be washed out. Chlorine strips skin of its natural oils, leaving it dry, itchy, and prematurely aged.

Chlorine has its place, as we'll see, but that place should not be in your shower.

### Chlorine: A Versatile Germ-Killer

A greenish-yellow gaseous element that readily dissolves in water, chlorine may seem to be an unlikely health hazard—after all, water treatment officials routinely add it to the public drinking supply throughout the United States. They do this for a good reason: since it began to be used as a disinfectant almost two centuries ago, chlorine has probably saved hundreds of thousands of lives because of its ability to destroy harmful bacteria, viruses, and other pathogens.

Chlorine disinfection was recognized as a potential lifesaver as early as the 1820s by European physicians who were concerned about the extremely high rates of post-birth deaths in hospital maternity wards. Well before Pasteur's work in the early 1860s convincingly established the germ theory for transmitting disease, a number of pioneering physicians had begun to use chlorine to disinfect hospital rooms. Some concerned physicians also had doctors wash their hands in a chlorine solution before they examined patients. Such practices dramatically reduced maternal mortality from puerperal fever, a highly contagious streptococcus infection of the uterus after birth, which was killing as many as one in six recently delivered mothers in some hospitals. In hindsight we know that many if not most of these deaths were from bacterial infections induced by "the examining finger"—doctors and medical students at the time routinely went directly from dissecting cadavers to probing the genitals of women.

Chlorine began to be used in U.S. water systems in the early 1900s because it killed the salmonella bacteria that were causing outbreaks of typhoid fever, and the vibrio bacteria responsible for cholera. Chlorine is now used in approximately 75 percent of public water systems in the U.S. to prevent waterborne diseases. It is added routinely in many areas to prevent bacterial growth in water mains. Water systems with leaky and aging pipes and other infrastructure are especially prone to contamination by microorganisms, such as from fecal matter from leaky septic systems. Water officials often add chlorine in higher amounts during the summer, when the risk of bacterial contamination of water increases. If a routine water test suggests a potential bacterial contamination, public water may be spiked with higher-than-average levels of chlorine, in some instances up to 8 parts per million (ppm).

Most people can smell residual chlorine at a concentration of about 3-4 ppm. If you're not sure whether your drinking water is being treated with chlorine, check with your local water officials.

## A Double-Edged Tool

Although chlorine has no doubt saved many lives by preventing deadly diseases, its toxicity toward microorganisms is a double-edged tool. Although relatively small amounts are used to disinfect water supplies, even low concentrations of chlorine are clearly detrimental to human and animal health. It is widely considered an air pollutant at a mere 1 ppm. Inhaling high levels, like 600 ppm, for 10 minutes can be fatal, a fact that militaries recognized back in World War One, when chlorine was used to make poisonous gas weapons. Chlorine is also toxic and irritating to the skin.

Chlorine is an effective bacteria-killer in part because it is so reactive. Free chlorine in water oxidizes and kills microorganisms, and it also readily combines with other chemicals, such as carbon, to form toxic compounds such as carbon tetrachloride. When organic matter such as leaves fall into a reservoir, they decay and release organic compounds into the water. As chlorine combines with these, it forms water pollutants known as trihalomethanes (THMs). These highly toxic chlorination byproducts include chloroform and trichloroethylene (TCE). If chlorine is present in water, in all likelihood the volatile chemicals chloroform and TCE are as well.

## Don't Underestimate Shower Exposure

Until the mid-1980s, most studies that looked at adverse effects from waterborne contaminants considered people's exposure through only one route: drinking. Research conducted since then, however, has demonstrated that this was a very one-dimensional approach to the issue. Trichloroethylene and chloroform in particular may be much more worrisome as water toxins that are inhaled or absorbed through the skin. Both TCE and chloroform are readily absorbed from the lungs into the blood. A number of recent studies have added to the weight of concern:

> According to a 1999 study conducted by researchers at the Environmental and Occupational Health Sciences Institute in Piscataway, N.J., "Strong relationships were identified between the

THM breath concentrations collected after a shower and both the THM water concentration and the THM exposure from a shower."

A 1998 study conducted in Taiwan compared the cancer risk at three major metropolitan areas with chloroform exposure during showering. The researchers considered exposure from all three major routes: ingestion, inhalation, and skin absorption. They concluded that a ten-minute shower would result in chloroform exposure with a 3:4:3 ratio (ingestion, inhalation, skin absorption); for a 20-minute shower the ratio was 1:7:2. In other words, those who were taking 20-minute showers were getting 90 percent of their exposure to chloroform from the shower. The researchers also determined that the cancer risk was almost thirteen times as high for a person who took a 20-minute shower in the area with the highest chloroform concentrations in the water compared to the risk for a person who took a ten-minute shower in the area with the lowest concentration.

According to the authors of a 1996 study, "The volatilization of volatile organic chemicals during domestic water usage can result in significant indoor air concentrations, and the subsequent inhalation of these contaminants is an important route of exposure....The simulated daily exposure is well described by a simplified equation that is a function of the amount of time the individual spends in the shower, the bath, and the bathroom; the total water usage in the home; and the fraction of time the individual is at home."

The authors of another 1996 study set up an experimental shower to measure the release of toxins. At 104 degrees F., a common shower temperature, volatilization was found to be approximately 80 percent for TCE and 60 percent for chloroform. According to the researchers, "The temperature of the water typically had a dominant effect on the total release of each of the three chemicals from the shower water to the air."

The National Academy of Sciences estimated in 1986 that up to 1,000 Americans die each year from cancers resulting from drinking water; but the figure may be many times higher when you consider people's exposure to these chemicals from inhaling them while taking showers.

## New Shower Filter Technology Limits Chlorine

Chlorine's adverse health effects has caused the administrators of public water systems, and the owners of private and public swimming pools, to explore alternative, less toxic methods of germ control. New technologies such as the use of ozone may eventually replace chlorine, but in the meantime consumers can rely on water filters. Whole-house systems can remove chlorine in shower water, as well as various other contaminants, but the simplest and most cost-effective solution for many people is to install a filter for the showerhead.

In recent years a new type of showerhead filter, dubbed KDF, has become available. The filter medium is made from a copper zinc alloy, which works by attracting chloride ions and converting them to zinc chloride. Effective showerhead filters can remove chlorine to less than 0.1 ppm and reduce dirt, rust, and bad odors, leaving your shower water looking and smelling fresh and clean. High-output showerhead filters are available with replaceable and reversible (that is, able to operate in either direction) filter cartridges. (Periodic reversing of the filter ensures balanced filtration and back-flushes the cartridge as it is filtering.)

Adding a filter to your showerhead can make that long, hot shower the unalloyed pleasure it ought to be.

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# INFORMATION

November 1999

# Chlorinated Water and Health Effects

**What is the current Canadian drinking water guideline for THMs?**

In 1993, the Federal-Provincial Subcommittee on Drinking Water (DWS) established a Canadian drinking water guideline of 100 parts per billion (ppb) or micrograms per litre (µg/L) for THMs. Trihalomethanes (THMs) are only one subgroup of the many disinfection by-products formed during chlorination and are used as indicators of overall chlorination disinfection by-product (CDBP) formation. The guideline was based on the risk of cancer reported in animal studies of chloroform, the THM most often present and in greatest concentration in drinking water. The guideline is based on an annual average to account for the fact that THM levels are generally highest in the summer and lowest in the winter.

By 1998, new epidemiologic studies had been published which reported associations between THMs and cancer (e.g., bladder, colon) and adverse pregnancy outcomes (e.g, miscarriage, birth defects, low birth weight). In response to these new findings, the DWS decided in April 1998 to re-open the THMs guideline. In its role as Secretariat to the DWS, Health Canada established a multi-stakeholder Task Group in July 1998 to oversee a comprehensive update of health risk information on THMs and to develop recommendations for controlling the risks.

**How is the safety of drinking water ensured by the various levels of government in Canada?**
All levels of government have some level of responsibility in ensuring the safety of Canada's drinking water. In most areas of Canada, the provinces/territories are responsible for setting and enforcing standards to ensure adequate drinking water treatment. Municipal governments are responsible for supplying safe drinking water to their residents as an essential public service, and do so in conformity with standards or objectives for drinking water established by the province in which they are located.

Health Canada provides health and safety advice, sponsors research and cooperates with provincial and territorial authorities under the auspices of the DWS to develop the *Guidelines for Canadian Drinking Water Quality*. The *Guidelines* are used by the provinces and territories as the basis for regulatory and other means of maintaining the quality of drinking water.

**Why is drinking water chlorinated?**
Drinking water is disinfected with chlorine to kill micro-organisms such as bacteria and viruses that can cause serious illnesses and deaths. The chlorination of drinking water has virtually eliminated typhoid fever, cholera and many other waterborne diseases from the western world and represents one of the greatest achievements of public health protection. Without adequate disinfection, the health risks from micro-organisms would far outweigh the risks from THMs.

**I am pregnant. Should I stop drinking my tap water?**
It is very important to maintain fluid intake during pregnancy. Based on the current state of knowledge, the

potential risks of adverse pregnancy outcomes associated with drinking water containing THMs are much lower than the risks of serious illness and death that could result from consuming drinking water that has not been properly disinfected. If, however, you decide to reduce your exposure to THMs from drinking water, options include using a water filter containing activated carbon or aerating tap water in a blender. Neither of these actions will, however, completely eliminate disinfection byproducts in drinking water. If a filter device is used it should be properly maintained because such devices can become sources of bacterial contamination in water. Also, the manufacture and sale of these devices is not currently regulated in Canada, so it is important to choose a dealer with care. Health Canada is conducting research to assess the effectiveness of various charcoal filters, blending and heating in removal of CDBPs and expects to have results available by late 2000.

**Should I drink bottled water?**
Bottled water, in general, have lower THM levels than tap water and, as a food commodity must meet all of the requirements of the *Food and Drugs Act* and Regulations. Based on the results of inspection, monitoring and post market surveillance activities, Health Canada has no reason to question the safety of bottled water currently in the marketplace. Nevertheless, Health Canada recognizes that the disinfection process and/or sources of water used by the bottled water industry may also introduce traces of chemical contaminants to bottled water. Some of these could be of potential health concern. Health Canada's Food Program is involved in initiatives on disinfection byproducts health risks and continues to investigate and evaluate any chemicals that may be inadvertently present in bottled water to ensure that the consumption of bottled water does not pose a health hazard to the consumer.

**Which communities have the highest/lowest levels of THMs?**
Levels of THMs and other disinfection byproducts are generally highest in treated water from sources with high organic matter content, such as rivers and lakes. Lower levels of THMs are usually found when the source water is ground water.

THM levels can vary within a single water supply depending on the season, water temperature, amount of natural organic matter in the water, pH, amount of chlorine added, point of chlorination, time in distribution system, and other factors such as additional or replacement treatment process used.

**How do Canadians find out what the levels of THMs are in their municipal water supply?**
Because the monitoring and control of THM levels in drinking water are the responsibility of the provinces/territories and their municipalities, consumers should contact their local water supplier or municipality for information on the levels of THMs in their communities

**If consumers are concerned about the levels of THMs or other disinfection byproducts in their water are there any steps they can take to reduce those levels?**
For those consumers wishing to reduce the levels of disinfection byproducts in their drinking water, options include using a water filter containing activated carbon or aerating the water in a blender. Neither of these actions will, however, completely eliminate disinfection byproducts in drinking water. If a filter device is used it should be properly maintained because such devices can become sources of bacterial contamination in water. Also, the manufacture and sale of these devices is not currently regulated in Canada, so it is important to choose a dealer with care. Health Canada is conducting research to assess the effectiveness of various charcoal filters, blending and heating in removal of CDBPs and expects to have results available by late 2000.

**What is being done to reduce the levels of THMs and other disinfection byproducts in municipal drinking water?**
A number of municipalities across the country have already modified their water treatment practices or are considering modifications to reduce levels of THMs and other disinfection byproducts. In addition, research is continuing on developing new treatment methods that will reduce the levels of byproducts produced while maintaining sufficient levels of disinfection to kill micro-organisms. The preferred approach of controlling

THMs is by removing the organic matter from the source water before disinfection so that it cannot react with chlorine or other disinfectants to form byproducts. Before any changes or improvements are made each treatment facility must be evaluated and the improvements most appropriate to its treatment process must be determined. It must be emphasized that any changes made to water treatment practices must not compromise the effectiveness of disinfection.

**Are there any alternatives to chlorination?**
A number of municipalities across the country treat their water with alternative disinfectants such as ozone, chloramine or chlorine dioxide. Ozone, however, breaks down very quickly, making it necessary to add small amounts of chlorine to the water to ensure continued disinfection while the water passes through the distribution system on the way to the consumer. Modifying water treatment facilities to use ozone can be expensive, and ozone treatment creates other undesirable byproducts that can be harmful to health if they are not controlled (e.g., formaldehyde and bromate). Chloramine is a good secondary disinfectant for reducing chlorine byproduct levels and for keeping water disinfected while it travels from the treatment plants to consumers, but it is generally a weaker disinfectant than free chlorine and is not recommended as a primary or sole disinfectant. In addition, both chloramine and chlorine dioxide can form other disinfection byproducts, many of which have not been characterized for their health effects.

**Are there risks from CDBPs through showering, bathing or swimming?**
While showering, bathing or swimming in chlorinated water may result in significant exposure to CDBPs through breathing in vapours and absorption through the skin, the health risks of prolonged exposure to CDBPs from these sources are currently unknown. Health Canada is conducting research to better understand the contribution of inhalation and skin absorption from showering in overall exposure to CDBPs. Results should be available sometime in the fall of 2000.

**What is Health Canada's recommendation?**
To protect public health, Health Canada strongly supports the disinfection of drinking water to reduce the risk of waterborne infectious diseases, and supports the reduction of levels of disinfection byproducts. The microbiological safety of water is of primary importance and the effectiveness of water disinfection must not be compromised. However, Health Canada is actively working with its provincial colleagues to assess the need for reducing the levels of disinfection by-products in drinking water and options for achieving this.

**What steps is Health Canada taking to address links between chlorination disinfection byproducts and health effects?**
Health Canada, as Secretariat to the DWS, has established a multi-stakeholder CDBP Task Group to oversee a coordinated effort to estimate the health risks from THMs and to develop risk management recommendations. This is being done through a series of subgroups to evaluate human (epidemiologic) and laboratory animal (toxicologic) evidence of health effects from THMs, drinking water quality data and water treatment facility characteristics and costs for communities across Canada. The subgroups are likely to have interim reports by late 2000. Recommendations will be formulated and following approval by the Task Group, the recommendations will be submitted for consideration by the DWS. If necessary, the DWS could then revise the THMs drinking water guideline as early as fall 2001.

**Would the proposed *Drinking Water Materials Safety Act* (formerly Bill C-14) assist in reducing the risks presented by disinfectant by-products and other contaminants?**
Yes. The proposed *Drinking Water Materials Safety Act*, would require all drinking water materials to be certified as meeting health-based performance standards before they can be sold in or imported into Canada. Drinking water materials fall into three major categories: treatment devices, treatment additives and system components. Responsibility for drinking water quality would remain with the provinces, with the exception of federal lands.

**Contacts:**
For more information on *the Guidelines for Canadian Drinking Water Quality* or to obtain the name of your provincial representative on the Federal-Provincial Subcommittee on Drinking Water, please contact:

Drinking Water Section
Environmental Health Directorate
Health Canada
Jeanne Mance Building
Tunney's Pasture, A.L. 1912A
Ottawa, ON K1A 0K9
Tel. (613) 952-2594

For more information on Health Canada's Water Quality Program and the CDBP Task Group, see Health Canada's Water Quality WWW site at

http://www.hc-sc.gc.ca/waterquality

or send an e-mail to water_eau@hc-sc.gc.ca

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# and

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## Trihalomethanes and Our Water Supply

by John Capece, Ph.D.

Created on November 20, 1998, Updated on 03/13/2002



Southern DataStream

# Introduction

Chlorination has made the U.S. water supply safe from illness producing bacteria, viruses and parasites. Fortunately for our country chlorine disinfection technology has almost completely eliminated from our lives the risks of waterborne diseases such as typhoid fever, cholera, and dysentery. However, the health benefit of chlorination has introduced some ***possible*** risks from the byproducts of the disinfection process.

Total Trihalomethanes (TTHM) are a byproduct of chlorinating water that contains natural organics. The water of southwest Florida has always had these organics derived from decaying plant materials and thus, we have probably always had TTHM in our chlorinated water. A U.S. Environmental Protection Agency survey discovered that trihalomethanes are present in virtually all chlorinated water supplies. Many years ago the U.S. Environmental Protection Agency (EPA) required large towns and cities to reduce TTHM levels in potable water. However, recent changes in national drinking water quality standards now require that water treatment systems of smaller towns begin to reduce TTHM. TTHM do not pose a high health risk compared to waterborne diseases, but

they are among the most important water quality issues to be addressed in the U.S. water supply.

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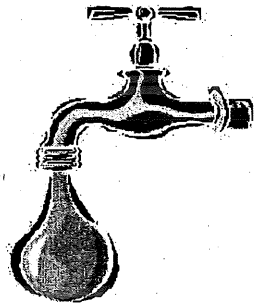

## Comparing risks in our daily lives

Modern society attempts to reduce risks in our lives starting with the most severe risk factors (hunger, disease, etc.) and continuing to secondary risk factors (traffic laws, cigarette warning labels, etc.). Some people are inclined to exaggerate risks while others completely discount potential problems. We've all heard someone say "If you feed enough of anything to a rat, it will get cancer." While that statement may or may not be true, tests done on laboratory animals are helpful in protecting human health. These test results should not be ignored, nor should they be exaggerated.


- Index of Risk Articles
- Recognizing Risks and Paying for Risk Reduction
- Comparing Florida's Environmental Risks (big report file)


The Florida Center for Public Management at FSU ranks drinking water contaminants as a medium to low-level risk. Higher on the scale are *indoor air quality, ambient air quality, and food quality.* In assessing risks you may also hear comparisons that may or may not be valid, for example "The cancer risk of eating one peanut butter sandwich (containing 2 ppb afiatoxin) is larger than that of drinking a glass of water (containing one ppb chloroform)." That assertion may be comforting for people whose water supplies have one ppb chloroform, but not for people whose water contains ten or more times that amount of chloroform (a component of TTHM).

In the case of TTHM, it does seem prudent to take reasonable steps to reduce this contaminant from our water supply given that some legitimate scientific studies do suggest some health risk and given that the cost of fixing the problem is reasonable. EPA estimates that, nationally, one life might be saved by the investment of $200,000 towards reducing TTHM levels in drinking water. For a given community, however, spending $200,000 on law enforcement, education, health clinics, or some other priority might yield greater life savings than spending that money on TTHM reduction. Thus the dilemma of public health management and governance.

On the individual level, most of us might benefit more by addressing higher risk factors in our lives (driving habits, smoking, exercise, food choices, etc.) before worrying too much about TTHM. For others it may be prudent to take special steps to reduce TTHM. Highest on this list is pregnant women. Pregnant women should discuss this issue with their physicians. While deciding what to do on the household level is an individual decision, deciding what to do on the community level is a governmental decision. After much consideration our federal government has decided that the health questions surrounding TTHM are sufficient to require community water treatment plants take corrective action to achieve low TTHM levels in water.

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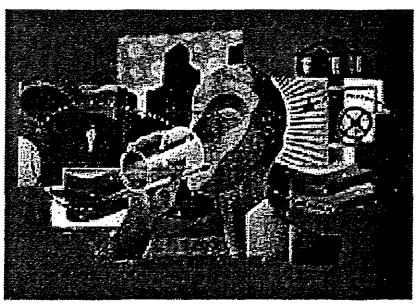

## TTHM health issues

Some scientific studies have linked TTHM to increased risk of cancer. Several studies suggest a small increase in the risk of bladder cancer and colorectal cancer. Beyond the cancer and reproduction concerns, some investigations have found that chlorination by-products may be linked to heart, lung, kidney, liver, and central nervous system damage. Other studies have linked TTHM to reproductive problems, including miscarriage. A California study found a miscarriage rate of 15.7% for women who drank 5 or more glasses of cold water containing more than 75 ppb TTHM, compared to a miscarriage rate of 9.5% for women with a low TTHM exposure. A North Carolina study investigating the same question but found no strong relationship between TTHM and problem pregnancies. Exposure to TTHMs is not limited only to water you drink. An article in the Washington Post Health Section on (March 12, 2002) stated that one study showed that a 10 minute shower produced more absorbtion of TTHM through the skin than drinking 5 glasses of water. When taken in total, the cancer evidence is probably the strongest among the possible TTHM health risks. For these reasons total trihalomethanes (TTHM) in public water supplies are limited to 0.08 ppm (80 ppb). This represents a reduction in the limit from the previous EPA threshold of 0.1 ppm (100 ppb).

↳ US. Environmental Protection Agency.

Of the THMM compounds, Dibromochloromethane was the most closely associated with cancer risk, (0.6 ug/l to cause a one in one million cancer risk increase) followed in order by Bromoform, Chloroform, and Dichlorobromomethane. These distinctions among the specific chemical by-products of is a result of toxicological, not empidemiological studies. Current regulations limit the concentration of these four chemicals added together (total trihalomethane or TTHM levels) to 100 ug/l. TTHM can be be found in chlorinated water supplies and in the air of buildings where running water and showers release the chemicals into the room, however, the EPA has determined that this airborne exposure is minimal compared to that from consumption. The National Institutes of Health provides a searchable database on chemical health studies.

ppm = parts per million (1E-6)
mg/L = milligram per liter (same as parts per million)
ppb = parts per billion (1E-9)
ug/L = micrograms per liter (same as parts per billion)

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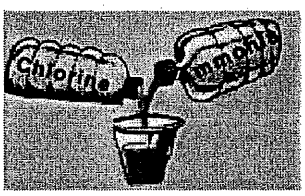
# The chloramine solution




One way to reduce TTHM levels is to change from CHLORINE disinfection to CHLORAMINE disinfection. This solution is being employed by both the Port LaBelle Utilities System and the City of LaBelle Public Works. Unlike chlorine, chloramines do not combine with organics in the water to form potentially dangerous trihalomethanes (TTHM). But since chloramines are a somewhat less effective disinfection agent, the amount of disinfectant added must be increased to maintain the proper level of drinking water safety. Therefore a water treatment plant changing from chlorine to chloramine must go through a period of testing to optimize the system performance for the control of TTHM.

Chloramines are formed from the reaction between ammonia and chlorine. Adding ammonia ($NH_3$) to a chlorination system converts the chlorine to chloramine. Chloramines can exist in three forms:

1. monochloramine ($NH_2Cl$)
2. dichloramine ($NHCl_2$)
3. nitrogen trichloride ($NCl_3$).

The proportions of the chloramines depend on the physical and chemical properties of the water. Many other communities have converted to this chloramination system. By switching from chlorination to a chloramine process, the tap resulting water may have more color. Color comes from natural organics in the water (tannins, humics) derived from decayed plant matter. Because the chlorine is no longer reacting with and consuming the organics, greater amounts of color may remain in the tap water.

Use of chloramines is not the only option available to reduce the production of TTHM in water treatment plants. Other options include:

1. Removal of organics prior to disinfection
2. Reduction of chlorine dosage
3. Use of alternate disinfectants (ozone and UV light)

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# Removing chloramines from your water

***Note: Water containing chloramines may not be used for aquariums or kidney dialysis.***

## FISH and AQUARIUMS

**A variety of commercial products and options are available for removing ammonia, chlorine, and chloramines from aquarium water.**

- *Ammonia Detox*
- *Filters*
- *Kordon*
- *Activated Carbon*
- *Additives*

**For more information about chloramines and fish, see the Candian website from the Ottowa Water Division.**

## HEALTH and KIDNEY DIALYSIS

**A number of options are available for removing chloramines from water prior to use by a kidney dialysis machine. These options include using an activated carbon filter. However before using any treatment for kidney dialysis machine water, consult your physician. He or she will recommend the appropriate type of water treatment for you. Additional information about chloramines and their health effects is available from the Ottawa Water Division website.**

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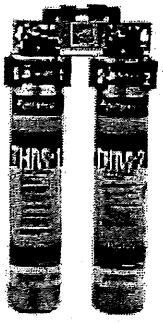

# What else you can do about TTHM

**Until a chloramine system is installed and operational, citizens can take steps in their homes to reduce TTHM if, after considering the facts, they believe it to be an important factor in their lives.**

- Filters
- Aeration or Boiling
- Distillation
- Bottled Water
- Activated Carbon
- Commercial Home Treatment Products (example)
- Commercial Filters (example)

General information about drinking water quality is available from a variety of Internet sources:

- EPA Drinking Water Guide
- Drinking Water Help Homepage
- University of Florida: Home Water Quality and Safety
- Other Drinking Water Web Sites
- Floirda Drinking Water Quality Records
- Florida DEP Drinking Water Section

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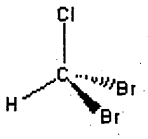
# TTHM chemistry and measurements




Trihalomethanes are a group of organic chemicals formed in water when chlorine reacts with natural organic matter (such as humic acids from decaying vegetation). Humic acids are present in all natural water used as sources of drinking water. Total trihalomethanes (TTHM) are not a single chemical but a class of compounds that includes:

- chloroform ($CHCl_3$)
- bromoform ($CHBr_3$)
- dichlorobromomethane ($CHCl_2Br$)
- dibromochloromethane ($CHClBr_2$)

## NATURAL ORGANIC COMPOUNDS IN WATER

Chlorine reacts with the natural organic carbon compounds in the water to form trihalomethanes. These organic compounds include:

### Humic Substances

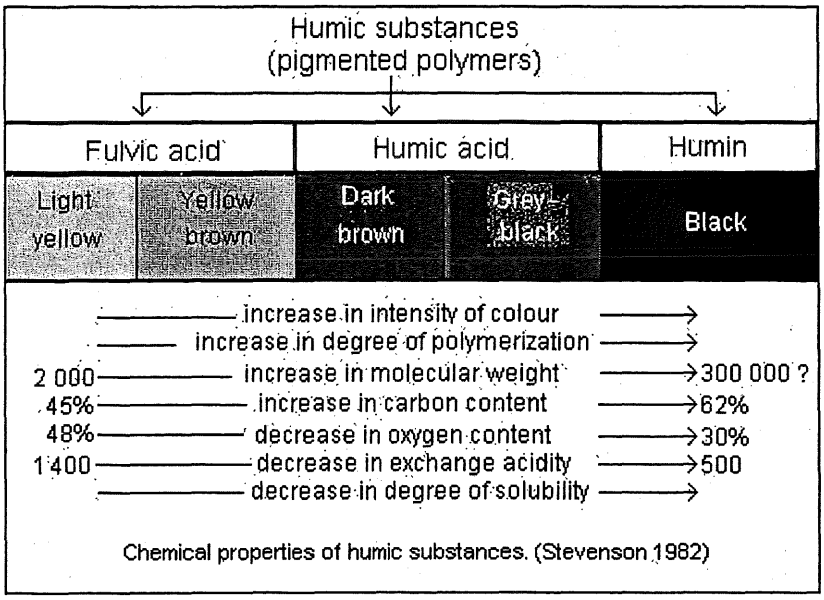
Humic substances are the organic portion of soil that remains after prolonged microbial decomposition, and that is formed by the decay of leaves, wood, and other vegetable matter. They can impart a yellowish-brown to brownish-black color to water; detectable to 0.1 ppm in water. Humic substances are commonly classified on the basis of solubility. If a material containing humic substances or humus is extracted with a strong base and the resulting solution is then acidified, the products are a) a nonextractable plant residue called humin, b) a material called humic acid that precipitates from the acidified (pH < 2) solution, and c) an organic material called fulvic acid that remains dissolved in the acidified solution. The high molecular weight and polyelectrolytic humic substance macromolecules range from a molecular weight of a few hundred for fulvic acid to tens of thousands for the humic acid and humin fractions. Humic substances are excellent chelating agents that bind with and hold metal ions in water, and they also effectively exchange cations with water.

### Fulvic Acid

**A water-soluble, natural organic substance of low molecular weight which is derived from humus, often found in surface water. Fulvic acid contributes to the formation of trihalomethanes in chlorinated water supplies, and can contribute to organic fouling of ion exchange resin beds.**

## COLOR

**Color in water can be caused by a number of contaminants such iron, tannins and humics. Color from iron is referred to as "apparent color" rather than "true color". True color is distinguished from apparent color by filtering the sample. The most common source of true color is decaying organic matter such as the yellowish "tea color" of water. True color is mostly found in surface water, although ground water may contain some color if the aquifer flows through a layer of buried vegetation, such as from a long buried slough of a river. Color is not a toxic characteristic, but is listed by the ADEC as a secondary (aesthetic) parameter affecting the appearance and palatability of the water. Color can be removed by activated carbon filters, sometimes marketed as taste and odor filters. The activated carbon or charcoal must be replaced after a period of time when its capacity for adsorption of the color is exhausted. Another treatment method is coagulation and sedimentation using alum or other chemicals. This process is normally used only in large plants since its complexity requires the care of a trained water treatment plant operator.**




Chemical properties of humic substances. (Stevenson 1982)

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