Health Canada Santé Canada

December 1995

Great Lakes Health Effects Program

Grand Lacs: Impact sur la santé

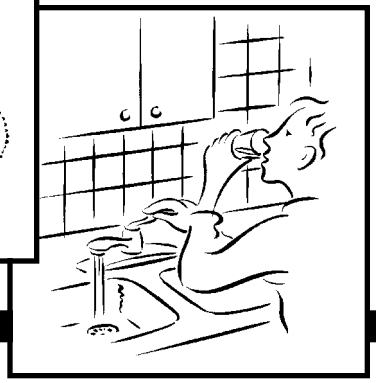
Great Lakes Water and Your Health

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.

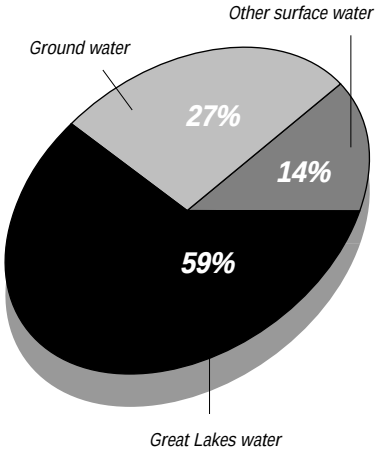
Who participated in the study?

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?

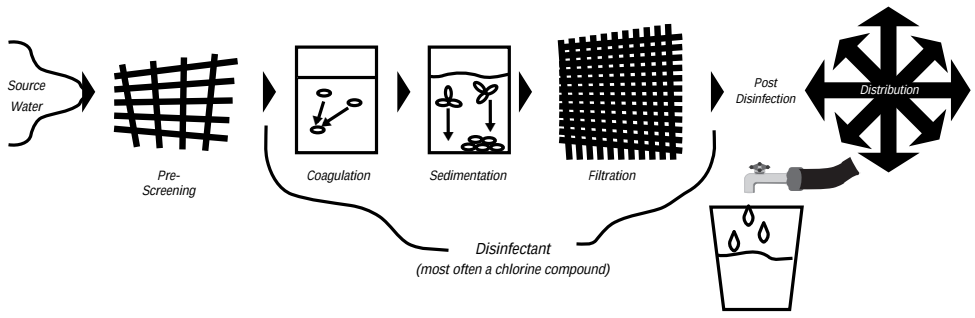
Chlorination by-products are chemical compounds that form when water containing organic matter (the decay products of living things such as leaves, human and animal wastes, etc.) is chlorinated. While the chlorine is effective in inactivating disease-causing micro-organisms, its addition to water can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

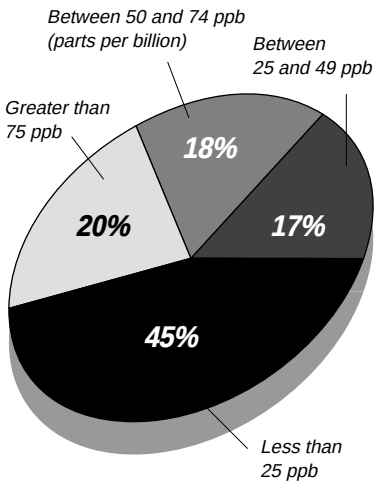
Water Treatment and Disinfection



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?

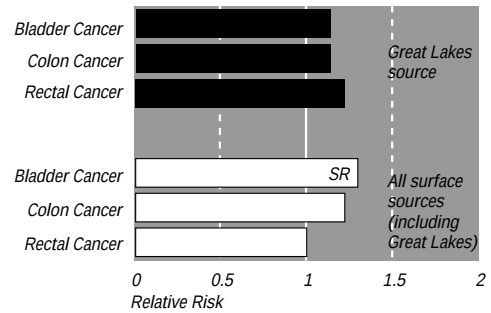
There is no suggestion that water from Great Lakes sources poses a higher risk for the cancers being studied than water from non-Great Lakes sources. In fact, the results of the study show that risks for bladder and colon cancer are slightly higher for those using water from all surface water sources (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).

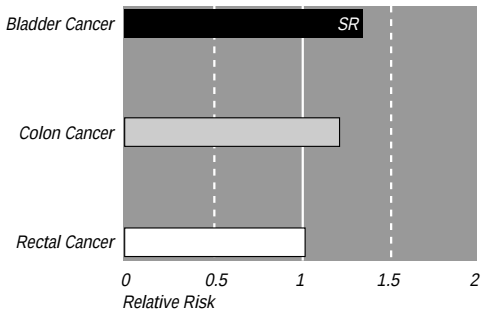
No evidence was found that chlorination by-products led to an increased risk of rectal cancer.

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

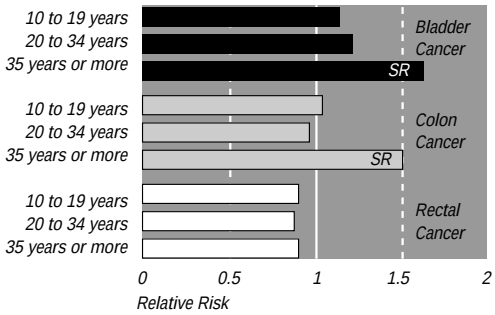
Figure 4: Cancer risk associated with the use of chlorinated surface water sources for 35 years or more



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

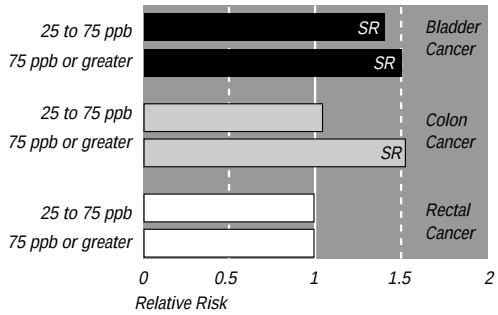
Figure 5: Cancer risk associated with years using water with THM levels greater than 50 ppb (parts per billion)



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.

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 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.***

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.***

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:

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(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

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