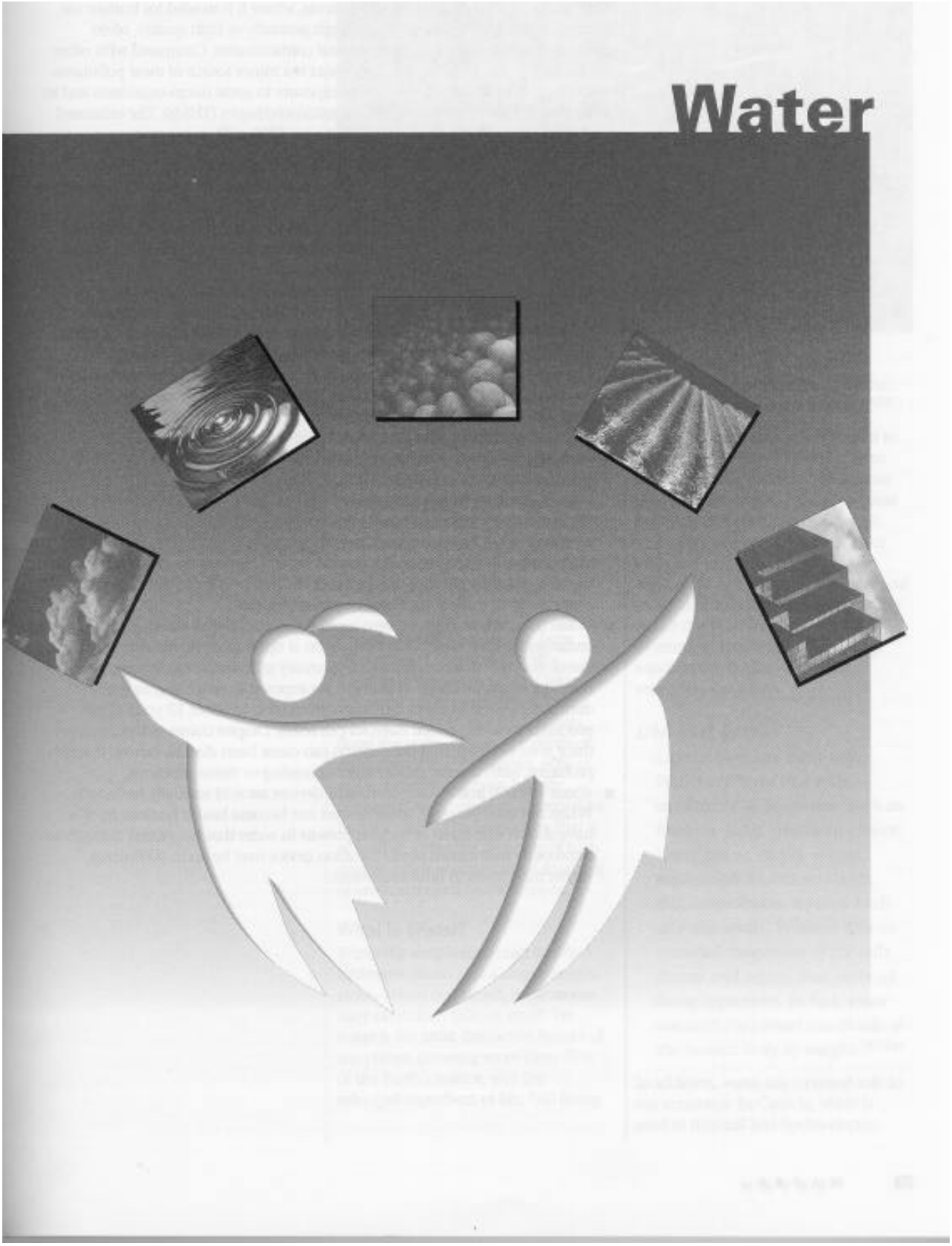
Water



Chapter Highlights:

Canada contains 15% of the Earth's supplies of fresh water. However, 60% of our water exists far from heavily populated areas, where it is needed for human use. The proportion that is accessible, although generally of high quality, often contains small amounts of environmental contaminants. Compared with other media, such as food and air, drinking water is a minor source of most pollutants —although it is our principal source of exposure to some micro-organisms and to water disinfection by-products, such as trihalomethanes (THMs). The estimated health care costs related to water pollution are $300 million per year.

- About 87% of Canadians receive treated municipal tap water. With a few exceptions, the most potentially serious contamination problems involve tap water from untreated sources, such as private wells. A 1993 study by Agriculture Canada and Health Canada found that about 40% of 1300 rural wells in Ontario had unacceptable levels of at least one of the chemical and microbiological contaminants surveyed.
- In 1993, more than 200 people became ill during an outbreak of cryptosporidiosis in Kitchener-Waterloo, Ontario. Since then, further outbreaks have been reported in Collingwood, Ontario, and Kelowna, British Columbia, affecting an estimated 15 000 people. The disease is caused by the *Cryptosporidium* parasite. Its symptoms appear from 2 to 10 days after drinking contaminated water and may include diarrhea, stomach cramps or a mild fever; the disease can be fatal in people with weakened immune systems.
- Chlorine is a simple, effective, yet relatively inexpensive agent for destroying harmful micro-organisms in tap water, although it can generate potentially harmful by-products, such as THMs, which have been linked to certain cancers. A recent Health Canada study found that long-term consumption of chlorinated surface water with elevated leves of THMs is associated with an increased risk of bladder cancer and possibly colon cancer. The health risks associated with drinking unchlorinated water, however, are much higher than the risks posed by chlorination by-products, as is evident in developing countries with inadequate water treatment systems.
- Water fluoridation helps prevent tooth decay in children without endangering their health. However, even at optimal levels, fluoride may cause dental fluorosis in some children, a generally mild condition involving tooth mottling or discoloration. If children are exposed to much higher levels during the period of tooth formation, from birth to about 12 years of age, moderate to severe dental fluorosis can result. Despite claims to the contrary, there is no evidence that fluoridation can cause heart disease, cancer, thyroid problems, birth defects, miscarriages or hearing or vision problems.
- About 100 000 home water treatment devices are sold annually in Canada. When not used properly, some devices can become health hazards. Studies have shown that levels of bacteria present in water that has passed through an improperly maintained home filtration device may be up to 2000 times higher than levels in unfiltered water.

WATER

Introduction

Fresh, clean water is a scarce resource. More than 97% of the water on Earth is saline and occurs in seas and oceans. About two-thirds of the available fresh water is trapped in glaciers and ice caps. The remainder, or less than 1% of the total water on Earth, includes water in our atmosphere; lakes, rivers and streams; wetlands; and the ground.[131]

Canada contains a relatively large proportion (15%) of the Earth's supplies of fresh water.[30] Our lakes and rivers cover nearly 8% of the country and hold enough water to flood the entire nation to a depth of more than 2 m.[238] However, 60% of our water exists far from heavily populated areas, where it is needed for human use.[238] The proportion that is accessible, although generally of high quality, often contains small amounts of environmental contaminants.

What Is *Water*?

Water is a simple molecule: just two hydrogen atoms plus a single oxygen atom. When combined, these atoms have no colour, taste or smell. Yet water is the most distinctive feature of our planet, covering more than 70% of the Earth's surface, and the principal ingredient of life. "All living things, from the tiniest insect to the tallest tree, need water to survive."[239]

To maintain good health, we need to consume about 2.5 L of water, from food and drink, each day.[240] But not only is water essential to our physical health, it is also vital to our mental and social well-being, by helping us relax and enjoy life. In winter, we skate on frozen water, ski on snow and swim in indoor swimming pools. The rest of the year, we use water for swimming, canoeing, water-skiing, windsurfing, fishing and other recreational pursuits.

Did you know?

Lakes, rivers and other water bodies are home to a wide assortment of organisms, such as bacteria, fungi, protozoa, viruses, insect larvae, snails, worms, microscopic plankton, plants, fish, amphibians, reptiles, birds and mammals. Water is also an essential component of the cells, tissues and organs that make up living organisms. In fact, water accounts for almost two-thirds of the human body by weight.[239,241]

In addition, water has a central role in our economy. In Canada, water is used in thermal and hydro-electric

power generation, manufacturing, agriculture, mining, transportation and municipal applications (including residential, commercial and public uses).[238,242] Within our homes, we depend on water for drinking, cooking, dishwashing, bathing, laundry and other needs.[131]

Did you know?

In Canada, your tap water may come from either groundwater or surface water supplies. ***Groundwater*** *is water found in soil or in pores or crevices in rock.* ***Surface water*** *includes lakes, rivers, streams and ponds.*

How Does Water Become Contaminated?

One of the key properties of water is its capacity to dissolve other substances. "Pure" water does not exist in nature, as water is always found in combination with various minerals and chemical compounds of natural and human origin.[239] Some of the substances found in water are essential elements, some influence the acidity of water, whereas others may pose a human health risk if present at excessive levels. Natural contaminants that have the potential to cause harm include metals, such as arsenic and lead; radioactive compounds, such as radium and uranium; and micro-organisms, such as bacteria, protozoa and toxic blue-green algae. Contaminants released into water from human activities include pesticides and other organic compounds, some metals, fluoride, radionuclides, micro-organisms, nitrates and other substances.

Pollutants may enter groundwater, surface water or treated water supplies from a wide range of sources. In Canada, major sources of contamination include natural sources—such as soil and rock—and human sources, such as sewage and industrial discharges; runoff from roads, lawns, farmland, parkland and landfill sites; leaking underground fuel storage tanks; leaking septic tanks; and the deposition of airborne pollutants. In addition, water treatment and distribution systems can introduce small amounts of contaminants into municipal water supplies—although treated water is much safer to drink than untreated water.

Did you know?

In Canada, some municipalities discharge untreated or inadequately treated waste water directly into water bodies. This is a particular problem in older communities with combined storm and sanitary sewers and whose treatment facilities tend to overload during heavy rains.[238,243]

Water Quality and Our Health

Canadians may be exposed to water-borne contaminants by different routes. For example, people may ingest small amounts of pollutants in their drinking water; may absorb contaminants through their skin while bathing or showering and during recreational activities, such as swimming, windsurfing and water-skiing; or may inhale airborne droplets or vapours while showering. They may also ingest food that has been contaminated by water-borne pollutants.

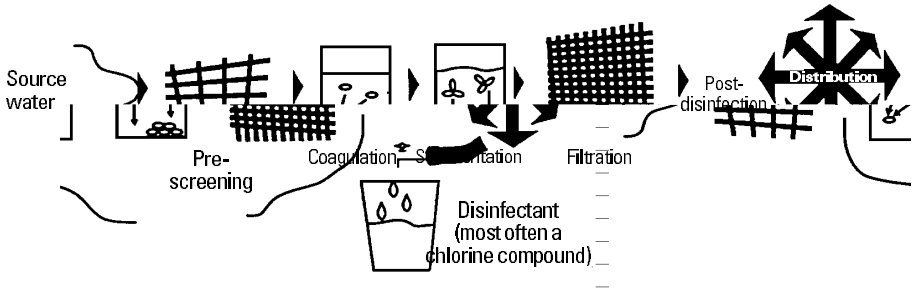
In general, drinking water is a minor source of exposure to environmental contaminants compared with other media, such as food and air, although it is our principal source of exposure to water disinfection by-products (e.g. trihalomethanes, or THMs) and to some micro-organisms. Less is known about the relative importance of recreational waters as a source of exposure to environmental contaminants. However, recent research suggests that, at least for some pollutants, significant amounts can be absorbed through the skin.[244] In Canada, the estimated health care costs related to water pollution are about $300 million per year.[245]

How Clean Is Our Water?

More than 9 out of every 10 Canadians believe that our land, air and water are more contaminated now than ever before.[59] This perception is a reflection of both our ability to detect lower and lower levels of environmental pollutants as well as real historic trends. For thousands of years, humans have used the aquatic environment as a convenient sewer for flushing their wastes.[246] Today, several important areas in Canada reflect the effects of past abuses, including the Fraser River, Red River, St. Lawrence River and lower Great Lakes.[238]

Source : Swimming Canada – Series #153000 (No. 600093). Corel Professional Photos CD-ROM, Sampler III. Copyright © Corel Corporation, 1994. Reproduced in accordance with the license agreement.

Figure 14
Water Treatment and Disinfection



Source: ***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,*** *Health Canada, 1995, p. 2.*

Although there is need for improvement in some areas of Canada, the overall quality of our drinking water is very high.[246] For example, many surveys have shown that when chemicals are detected in municipal tap water, their levels are generally many times lower than the maximum acceptable levels set by federal-provincial-territorial guidelines.[238] With a few exceptions, such as chlorination by-products, the most potentially serious contamination problems in Canada generally involve elevated levels of natural contaminants in tap water from inadequately treated surface water or groundwater sources, such as private wells and water sources used by First Nations communities.

Water-borne Diseases

In 1882, 180 out of every 100 000 people in Ontario died of diseases such as typhoid and cholera, which are caused by the presence of bacteria in drinking water. Society eventually responded "by extending water intakes farther into lakes or upstream in rivers and by chlorinating drinking water supplies."[247]

Today, about 87% of Canadians receive treated municipal drinking water [248] (see Figure 14), resulting in one of the lowest incidences of serious water-borne diseases in the world.[30] For example, Canada has not experienced a major cholera outbreak since the early years of this century, whereas Peru has reported more than 500 000 cases related to contaminated water and food supplies since 1991.[238,249] This does not mean, however, that our water is absolutely safe. In recent years, some new threats to our health have been found in drinking water supplies, such as the protozoan *Cryptosporidium*.

Did you know?

In the world as a whole, diarrhea due to infectious (water-borne) microbes is responsible for more deaths each year than AIDS and cancer combined.[250] Globally, about 34 000 deaths occur daily from water-related diseases. This is equivalent to 100 jumbo jets crashing daily.[239]

Persistent Pollutants

In recent decades, concern over the presence of toxic chemicals in our drinking water has overshadowed other water quality issues.[239] Hundreds of different chemical compounds have been found in Canadian drinking water supplies, although generally at very low levels. Many of these substances are persistent, which means that they degrade very slowly and may remain in the environment for years or even decades.[251] Since the 1970s, controls have been placed on the most toxic pollutants, including lead, mercury, polychlorinated biphenyls (PCBs), chlorinated dioxins and chlorinated furans. Registrations of the remaining uses of the pesticide dichlorodiphenyltrichloroethane (DDT) in Canada were discontinued in 1985 with the understanding that existing stocks would be sold, used or disposed of by the next registration renewal date, December 31, 1990. Although these substances are still a health concern, their concentrations in many water bodies are declining.[252,253] Scientists have estimated that drinking water accounts for less than 1% of our total exposure to persistent pollutants, with most of our intake coming from food.[238]

Groundwater

Beneath our feet, a vast network of underground rivers and streams supplies the daily water needs of more than one in four Canadians, including 100% of the population of Prince Edward Island and over 60% of the population of New Brunswick and the Yukon.[238] Most of the people who rely on groundwater in Canada live in rural areas and draw their water from private wells.[242] Groundwater is naturally filtered by sand, soil and clay, which remove micro-organisms and some chemical contaminants.[246] However, when groundwater becomes polluted, its inaccessibility makes it difficult to clean up.[239]

In Canada, there are several locations where problems with groundwater have been observed as a result of the presence of naturally occurring contaminants, such as salt, arsenic and fluoride.[238] Pollutants resulting from human activities may also come from a range of sources, including septic systems, leaky storage tanks, municipal landfills, industrial discharges and land sprayed with pesticides and other agricultural chemicals (see Figure 15).[242]

A 1993 survey conducted by Agriculture Canada suggests that farm families relying on private wells have a higher risk of exposure to groundwater contaminants than those who receive treated water from municipal wells. The study, which analysed the water quality from 1300 rural wells, found that approximately 40% exceeded provincial drinking water objectives for at least one of the contaminants surveyed. The results showed that 25% contained fecal coliform bacteria (these include *Escherichia*, *Klebsiella*, *Citrobacter* and *Enterobacter* bacteria, which are present in fresh feces), 15% exceeded the Ontario maximum acceptable concentration for nitrate and 12% had detectable levels of pesticides (two wells had pesticide concentrations that exceeded Ontario interim maximum acceptable concentration values).[254] As a follow-up, Health Canada, Agriculture and Agri-Food Canada, the University of Guelph and the Ontario ministries of health and agriculture are investigating the relationship between well water contamination and gastrointestinal illness in 160 Ontario farm families.[255]

Key Issues

This section describes some of the principal health issues associated with contaminants in our water supply, including biological agents, such as bacteria and protozoa; water disinfection by-products; pesticides and other organic pollutants; metals, such as aluminum, arsenic and uranium; fluoride; nitrates; and radionuclides.

Recreational Water Hazards

In Canada, fresh and salt water are used for a variety of recreational purposes, such as swimming, water-skiing, windsurfing, boating and fishing.[256] Although the overall quality of our lakes and rivers is high, people may be exposed to small amounts of water-borne pollutants during recreational activities in certain areas.

Microbial contaminants such as bacteria and viruses from sewage pose the greatest potential health risk to recreational water users. Other common sources of contamination include industrial waste, agricultural runoff, urban runoff, storm water runoff, feces, oil and gasoline spills from power boats and marinas and pollution from boaters. Swimmers can also be a source of contamination, especially if some people have infections or open wounds.[257,258] Other hazards include exposure to phytoplankton and chemical contaminants.

Swallowing water is one of the ways in which pollutants may enter the body during outdoor water activities, although people may also be exposed to contaminants through their contact with the skin, eyes, ears or nose.[244,257]

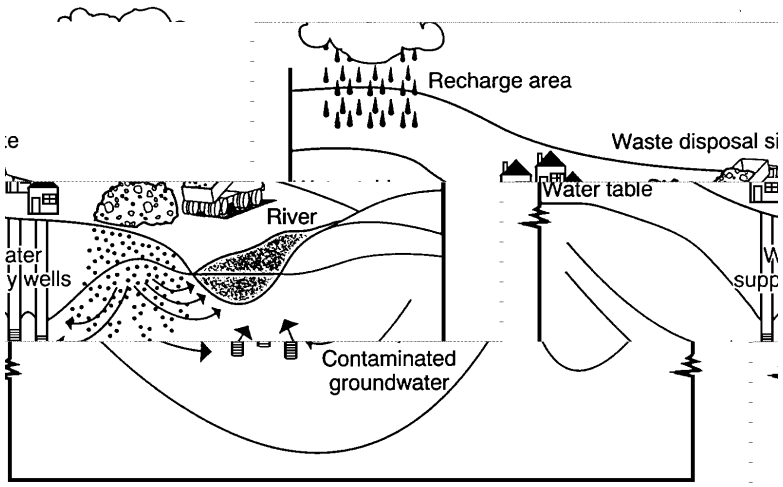


Figure 15
Groundwater Contamination from a Waste Disposal Site

Source: ***Groundwater—Nature's Hidden Treasure, Freshwater Series A-5****, Environment Canada, 1993. Reproduced with permission of the Minister of Public Works and Government Services Canada, 1997.*

Biological Agents

Water-borne diseases caused by bacteria, viruses and protozoa are the most common health hazards associated with drinking water (and recreational waters) in Canada.[259] In 1988 and 1989, 17 disease outbreaks that appeared to be caused by microbial contaminants in drinking water were reported in Canada, involving a total of 555 individuals.[260] However, the true incidence of water-borne diseases is likely much higher, because the majority of cases involve mild, flu-like symptoms that do not require medical treatment.[30]

Human and animal wastes are the main sources of microbial contaminants found in drinking water. Microorganisms can enter water bodies in inadequately treated sewage, bird droppings or runoff from farm fields and city streets—although properly treated drinking water should be free of disease-causing bacteria. Also, some bacteria can colonize water distribution systems and water treatment devices.[30,85] Groups that are at high risk of exposure to microbial contaminants include members of First Nations communities and rural Canadians who depend on private well water, since private well water is generally untreated.[30,248,261]

Bacteria

In Canada, some of the most common microbial pathogens found in untreated water supplies are bacteria such as *Campylobacter*, *Escherichia coli* (*E. coli*), *Salmonella*, *Shigella*, *Staphylococcus aureus* and *Pseudomonas aeruginosa*, which are responsible for a wide variety of water-borne diseases.[85,256] Infants, children, the elderly and people with weakened immune systems are highly susceptible to the effects of pathogenic bacteria. However, the actual incidence of water-related illness caused by these organisms is unknown.

Campylobacter

From a health perspective, the most noteworthy species of *Campylobacter* is *Campylobacter jejuni*, which causes gastroenteritis. This bacterium occurs primarily in human and animal wastes, including bird droppings, and often ends up contaminating water bodies following heavy rainfalls.[85]

Escherichia coli

Escherichia coli normally resides in human intestines without causing any ill effects. However, pathogenic strains of *E. coli* can cause gastrointestinal diseases, including a severe form of diarrhea that can lead to fatal kidney failure. *Escherichia coli* can enter water bodies from raw sewage or other sources. Infants and the elderly are particularly at risk from *E. coli* infections because they tend to have weaker immune systems.[85]

Salmonella

About 2000 different strains of *Salmonella* have been identified, most of which can cause illness. However, some *Salmonella* species are more harmful than others. These include *S. typhi*, the pathogen responsible for typhoid fever; and *S. paratyphi*, which causes paratyphoid fever. Both diseases are very rare in Canada. Other

Municipal Tap Water and Water-borne Disease[262–265]

In Canada, municipally treated tap water is generally safe to drink. But even treated water may contain some micro-organisms, although at very low levels. In a 1991 study funded by Health and Welfare Canada, scientists at the University of Quebec evaluated the risk of gastrointestinal illness due to consumption of treated water that was prepared from a sewage-contaminated water source but met provincial water quality standards. The study involved two groups of suburban Montreal residents. Over a 15-month period, one group drank municipally treated tap water, while the second group drank treated water that was further purified using reverse osmosis water filters installed inside their homes. Throughout the study, the incidence of gastrointestinal illness was significantly higher in every age group of those who drank plain tap water. The authors concluded that about 35% of the reported gastrointestinal illnesses among the tap water drinkers were water-related and preventable.

Salmonella species are associated with gastroenteritic diseases that vary in severity. In many cases, the symptoms are mild and resemble common flu symptoms, but some strains can cause severe infections that may persist for months if repeat exposures occur—and may ultimately prove fatal.[85]

Did you know?

For different pathogenic bacteria to cause infection, people must swallow anywhere from 10 to 10 million organisms.[265] Canadian drinking water quality guidelines (as set out in Health Canada's ***Guidelines for Canadian Drinking Water Quality****) specify that treated water should contain no more than 10 coliform bacteria per 100 mL, none of which should be fecal coliforms.[259] By controlling coliform bacteria, pathogenic bacteria in water can be controlled.*

Shigella

In the early 1970s, *Shigella* was the most commonly identified pathogen responsible for water-borne disease outbreaks in North America. In Canada, however, there have been no reported outbreaks of water-borne disease caused by *Shigella* bacteria since 1975. Like *Salmonella*, *Shigella* infections vary in their severity, ranging from mild diarrhea to vomiting, abdominal pain, fever and bloody stools.[256]

Staphylococcus

Staphylococcus aureus is responsible for some ear infections and skin infections, such as boils. This organism occurs naturally in our nose, throat, sweat glands and intestinal tract. Scientists believe that the presence of this bacterium in water bodies is mainly due to throat and nasal secretions as a result of coughing, spitting and sneezing by swimmers and other recreational water users.[85,256]

Pseudomonas

Pseudomonas aeruginosa is a common cause of skin rashes and eye infections, as well as the principal cause of swimming-related external ear infections. This bacterium can be introduced into water either through inadequately treated sewage or from infected humans and is most often found in heavily used swimming areas.[256]

Protozoa

Protozoa are single-celled organisms. Some of them can live in a wide variety of animals and in people and are excreted in their feces. Protozoa are capable of surviving for long periods of time in the aquatic environment as dormant cysts and are generally more resistant to chlorination than pathogenic bacteria or viruses. They can be removed from water supplies through filtration.[30,249,256]

Giardia

In Canada, *Giardia* is the most common pathogenic protozoan found in our water supplies. *Giardia* causes giardiasis or "beaver fever"—a long-lasting gastrointestinal disease. Symptoms include watery diarrhea, loss of appetite, dehydration, cramps and sometimes vomiting. In 1988 and 1989—the most recent years for which comprehensive data are available—five outbreaks of giardiasis were reported in Canada, involving 18 people.[260] Since then, further outbreaks have occurred in Newfoundland, Ontario and Manitoba—the latter involved 26 confirmed cases of giardiasis,[266] although the total could be as high as 2000 (roughly 25% of the population in small towns is affected in an outbreak; the population of Dauphin, Manitoba, is 9000). People can develop giardiasis by ingesting a relatively small number (10–100) of *Giardia* cysts.[249,267] Wilderness campers and other people who drink untreated water are most at risk of exposure to *Giardia*.

Cryptosporidium

Another common pathogen is *Cryptosporidium*, which is even more resistant to chlorination than *Giardia* but which can be killed by boiling water.[256,268] In April 1993, *Cryptosporidium* contaminated the water distribution system in Milwaukee, Wisconsin. Out of 800 000 people in the region, about 400 000 became ill and about 100 deaths occurred.[265,269,270] That same year, a smaller outbreak involving more than 200 people occurred in Kitchener-Waterloo, Ontario. Since then, further outbreaks have occurred in Collingwood, Ontario, and Kelowna, British Columbia—the latter incident left an estimated 15 000 people ill.[270] Symptoms of cryptosporidiosis

Giardia and *Cryptosporidium* in Canadian Water Supplies[271]

Between 1991 and 1995, Health Canada conducted a survey of treated and untreated drinking water from 72 municipalities across Canada. Out of 1173 untreated water samples examined, 20.9% contained *Giardia* cysts and 4.5% were contaminated with *Cryptosporidium*. Similarly, out of 423 treated water samples, 18.2% contained *Giardia* and 3.6% contained *Cryptosporidium*. Contamination was less common in those municipalities with water filtration systems.

appear from 2 to 10 days after drinking contaminated water and may include diarrhea, stomach cramps or a mild fever. The illness can be fatal in people with weakened immune systems, such as AIDS patients.[256,268]

Viruses

Viruses are tiny organisms that reproduce by infecting living cells. About 100 different viruses are known to inhabit our intestines. Some viruses are resistant to chlorine treatment but can be removed from municipal water supplies using filtration systems. Viral pathogens that have been found in water bodies include the hepatitis A virus as well as several families of viruses associated with gastro-enteritis.[249,256] The true incidence of virus-related water-borne diseases in Canada is unknown.[256]

Phytoplankton

Phytoplankton are microscopic plants that occur in saltwater and freshwater environments across Canada. To the naked eye, they may look like fine grass clippings in the water or a soupy mass. Some phytoplankton, such as certain species of blue-green algae, produce potent toxins that can damage the liver or nervous system. Toxic phytoplankton pose a potential health risk to humans, particularly when they occur in "blooms," which generally happens in late August and September.[256] The toxins produced by phytoplankton blooms have also been blamed for animal poisonings in Alberta, Saskatchewan, Manitoba and Ontario.

People are unlikely to drink lake or river water deliberately during phyto-plankton blooms, because of the foul appearance and odour of the water. However, accidental exposures may occur during recreational activities, such as swimming, canoeing and sailing. Symptoms associated with the ingestion of these organisms may include fever, headache, dizziness, stomach cramps, vomiting, diarrhea, skin and eye irritations, sore throat and swollen lips. Children are at higher risk because they spend more time in the water than adults, are more likely to swallow contaminated water and may have lower tolerance for toxic algae.[256]

Protecting Our Health

Provincial and municipal authorities routinely monitor community water supplies for microbial contaminants.[30,240] Before leaving municipal water treatment plants, drinking water generally goes through several steps designed to remove harmful bacteria, viruses and protozoa, including filtration and disinfection. According to the *Guidelines for Canadian Drinking Water Quality*, drinking water supplies may contain no more than 10 coliform bacteria per 100 mL of water, none of which should be fecal coliform bacteria. The guidelines also limit the *turbidity* of tap water, a measurement of the number of particles that are present, because organisms attached to water-borne particles cannot be detected using conventional methods.[259]

In 1982, the Federal–Provincial Advisory Committee on Environmental and Occupational Health established a voluntary mechanism for reporting water-borne diseases in Canada. However, many cases still go unrecorded.[30,261] To improve our understanding of the scope and extent of microbe-related illness associated with contaminated water, Health Canada has established a National Advisory Committee on Foodborne, Waterborne and Enteric Disease Surveillance as the first step towards launching a national surveillance network.

What You Can Do

- If you rely on well water, have it tested at least once a year for microbial contamination. Water that does not meet the Canadian drinking water quality guidelines should be treated and retested prior to use.[272] For advice on water purification methods, contact the nearest Health Canada office or local public health unit.
- During cottage or camping trips, never assume that water drawn directly from a lake or river is free of contamination. On short trips, use water from home or another safe source. On long trips, choose your water source carefully and purify it before use. Chlorination and boiling are both effective methods for removing most disease-causing micro-organisms from drinking water. For more information, obtain a copy of *Wilderness Water: A Guide to Wilderness Drinking Water* from Health Canada.[273]
- Before heading to the beach for recreational water activities, call the municipal health authority to determine the status of water bodies in your area. Treat with suspicion any waters that contain algae with a distinctive blue-green or turquoise colour. Do not swim or wade in bloom-infested areas.[256]

Water Disinfection By-products

In Canada, chlorination is the principal method for disinfecting drinking water. Chlorine is a simple, effective, yet relatively inexpensive agent for destroying harmful micro-organisms and suppressing the growth of algae.[239] Moreover, following its use, small amounts of chlorine remain and continue to prevent microbial contamination throughout the water distribution system.[240]

However, chlorination (and other water disinfection processes) can create potentially harmful chemicals in our water supplies. The most common by-products of chlorination are called THMs, whereas other disinfectants such as ozone can generate bromate, formaldehyde and other potentially harmful compounds.[274,275]

Trihalomethanes (THMs)

THMs are formed when organic matter naturally present in untreated water (e.g. decayed vegetation, human and animal wastes) is chlorinated.[276] THMs are the most frequently detected organic compounds in municipal drinking water. The most

Great Lakes Basin Cancer Risk Assessment Study[278,280]

The Great Lakes Basin Cancer Risk Assessment Study was launched in 1992 by Health Canada to investigate the relationship between exposure to drinking water in the Great Lakes basin and the risk of bladder, colon and rectal cancers. Approximately 5000 Ontario residents—half of whom had been diagnosed with bladder, colon or rectal cancer between 1992 and 1994—were questioned about where they had lived in the past, the source of drinking water at these locations, their eating, drinking and fish consumption habits, recreational activities and other factors. The study also collected information dating back to 1940 regarding water sources and treatment methods in different municipalities. These data were used to estimate THM levels in drinking water supplies by geographic area and time.

The study, which supports the findings of previous research, showed that long-term consumption of chlorinated surface water with elevated levels of THMs is associated with an increased risk of bladder cancer and possibly colon cancer, but not rectal cancer. People who were exposed to THM levels of 50 µg/L or higher for at least 35 years had a significantly greater risk of bladder and colon cancer compared with those who were exposed for less than 10 years. As well, people who were exposed to THM levels of 75 µg/L or more for at least 25 years had a greater risk of developing both types of cancer than those who were exposed to levels of less than 25 µg/L for the same length of time. Today, almost 50% of Ontario residents are served by water supplies containing THM levels below 25 µg/L.

The researchers estimated that between 10 and 13% of all bladder and colon cancers in Ontario may be caused by long-term exposure to chlorinated water. (For comparison, over 50% of bladder cancers are likely due to smoking, and 40–60% of colon cancers may be caused by dietary factors.) The study was unable to determine, however, whether THMs or other substances present in chlorinated drinking water were responsible for the increased cancer risks. In 1995, there were an estimated 3500 new cases of colorectal (colon and rectal) cancer and 1000 new cases of bladder cancer in Ontario.[45]

common THMs are chloroform, bromodichloromethane, chlorodibromomethane and bromoform.[277,278]

Whereas all chlorinated water contains some THMs, the total concentrations present depend on when and where the water is chlorinated as well as the amount and type of organic matter in the water. For example, THM levels are generally lower in winter, because water supplies contain less organic matter and therefore require less chlorine to disinfect them. THM levels are also generally lower in water taken from deep wells and large lakes, in which organic matter tends to settle out. However, water drawn from sources such as rivers often contains higher levels of organic matter, which can result in higher THM levels after chlorination.[277,278]

Canadians may be exposed to THMs by drinking chlorinated water or beverages produced with chlorinated water, by inhaling airborne THMs released from tap water or by absorbing THMs directly through the skin, particularly during showers.[85,279] Studies have shown that elevated levels of chloroform (>50 µg/L) in water can cause cancer in animals. There is also evidence to suggest that exposure to THMs in tap water may increase the incidence of certain cancers in humans.[280] However, the health risks associated with drinking unchlorinated water are much higher than the risks posed by chlorination by-products, as is evident in developing countries with inadequate water treatment systems.[277] According to some experts, chlorine is the most effective public health measure ever implemented and "has saved more lives than any other single chemical"[250].

Protecting Our Health

In 1993, the Federal–Provincial Subcommittee on Drinking Water lowered the maximum acceptable concentration (MAC) of THMs, as defined in the *Guidelines for Canadian*

Alternative Disinfectants

Some municipalities control THM levels by using alternative chlorine-based disinfectants, such as chloramine and chlorine dioxide, at various stages of the treatment process.[278] Chloramine is a weaker disinfectant than chlorine, but it generates lower levels of THMs in treated water and is very effective at maintaining a residual level of disinfectant in drinking water distribution systems. Chlorine dioxide generates other by-products, including chlorate and chlorite, which are associated with a variety of adverse health effects. Health Canada scientists are currently assessing the health risks associated with some alternative disinfectants and their resulting disinfection by-products.

Drinking Water Quality. Many municipalities across Canada have taken steps to reduce THM levels in drinking water supplies.[278] Treatment options include reducing the chlorine dose or using alternative disinfectants, removing organic matter from untreated water so that it cannot react with chlorine and using activated carbon beds to remove THMs.[276,278]

To clarify the potential risks associated with exposure to THMs, Health Canada's Laboratory Centre for Disease Control has launched a national study on the relationship between consumption of municipally treated water and cancer incidence. In a related initiative, the Department is studying the effect of temperature on chlorination by-products to find out which compounds remain in treated water after it is boiled.[278]

Ozonation By-products

Some Canadian municipalities now use a disinfection process called ozonation for their water treatment process, which helps to minimize the formation of chlorination by-products. Ozone is a highly effective treatment for disinfecting raw water, but it is generally more expensive to implement than chlorine, and its effectiveness is short-lived, requiring the addition of another disinfectant, usually chlorine, to prevent the growth of bacteria in water after it leaves the treatment plant.[277] As a result, drinking water treated with ozone may still contain some chlorination by-products, such as THMs.

Ozone-treated water also contains low levels of other by-products, such as bromate and formaldehyde. Bromate is an animal carcinogen and may also have the potential to cause cancer in humans, but probably at much higher levels than those found in drinking water, which is a relatively insignificant source of exposure to this chemical.[281,282] However, bromate levels in drinking water could increase as water utilities choose ozonation as an alternative to chlorination in areas where source water contains elevated levels of bromide. Formaldehyde is also an animal carcinogen via the inhalation route, but it is unlikely to cause cancer in humans via the ingestion of drinking water.[282,283]

Volatile Organic Compounds

Some of the most frequently detected organic contaminants found in groundwater are volatile organic compounds (VOCs)—chemicals that readily evaporate—such as trichloroethylene and tetrachloroethylene.[191,193] Trichloroethylene and tetrachloroethylene are commercial solvents used by the metal-degreasing and dry-cleaning industries and in a range of household products. Both substances are often present at high levels in the leachate from municipal landfills, from which they may enter surface water or groundwater[284]—and may ultimately degrade into more toxic substances.

Did you know?

Household products that contain organic solvents such as trichloroethylene and tetrachloroethylene, such as paint removers and strippers, should not be poured down drains or toilets or sent to landfill sites, but instead should be taken to the municipal hazardous waste collection depot for disposal. Upon entering sewage treatment plants, many of these chemicals can destroy the beneficial bacteria used to purify waste water and may end up polluting our drinking water supplies.[285]

In a national survey conducted in 1995, trichloroethylene and tetrachloroethylene were found in 56 out of 481 (12%) municipal and communal groundwater supplies tested.[131] Both chemicals typically occur in water bodies at concentrations below 1 µg/L, although higher levels have been detected in contaminated groundwater in several provinces.[191,193]

Trichloroethylene and tetrachloroethylene pose a potential health risk when inhaled at high concentrations. Health Canada has classified trichloroethylene as a probable human carcinogen. Tetrachloroethylene can cause cancer in laboratory animals, although it is unclear whether it has the potential to cause cancer in humans.[191,193] Exposure to groundwater contaminated with trichloroethylene or tetrachloroethylene at levels exceeding the current Canadian drinking water quality guidelines could pose a significant health risk.

However, at the levels typically found in drinking water, the risks associated with exposure to these compounds are very low.

Pesticides

Pesticides are chemical and biological agents that are used to control pests, such as weeds, insects, rodents, fungi, bacteria and viruses. Pesticides may enter water bodies during the spraying of farmland or crops, as a result of accidental spills or improper disposal procedures or in runoff from fields and lawns. In addition, pesticides may filter through the soil into groundwater supplies after being applied on crops or lawns or via the leachate from landfill sites.[30] A variety of factors influence whether a pesticide will reach surface water or groundwater, including the soil composition and texture, characteristics of the pesticide, precipitation, depth to the water table, terrain and method of application.

Atrazine

In the 1980s, atrazine was widely used in Canada due to the limited availability of other herbicide (weed-destroying) products. As well, the use rates at that time were considerably higher than is the case today. Groundwater testing conducted during that time period frequently detected the presence of atrazine, thereby raising public awareness of the issue of pesticides in groundwater.

Atrazine is used in Canada as a weed control agent in corn and blueberries, with the latter representing only marginal use of the product. Atrazine has been detected in surface and well water supplies in several provinces owing to its rapid movement with surface runoff and through soil into groundwater. In response to these concerns, a reevaluation of the regulatory status of this compound was initiated in 1988 by the Pesticides Directorate, Agriculture and Agri-Food Canada, now the Pest Management Regulatory Agency (PMRA).

Volatile Organic Compounds and Our Health

To help clarify the health risks associated with organic solvents, such as trichloroethylene and tetrachloroethylene, present in groundwater, Health Canada's Laboratory Centre for Disease Control has launched a national study to examine the relationship between cancer incidence and proximity to landfill sites. Scientists have identified about 260 communities in Canada with a total population of 2.25 million that may be exposed to contaminated groundwater via landfill leachate.[284]

In conjunction with the reevaluation and in an effort to address the groundwater contamination issue, all registered atrazine products have been the focus of a label improvement program, initiated by the basic manufacturers, in which both the use pattern (the types of sites on which it can be used) and registered rates (the amount that can be used per hectare) for this compound have been reduced. In addition, buffer zones (for both mixing and spraying) were established for wells and water sources. The (interim) Canadian drinking water quality guideline for atrazine and its metabolites has been reduced to the current level of 5 µg/L.

As a result of these initiatives, atrazine use in the province of Ontario (a major corn production area) declined by 66% over the 10-year period from 1983 to 1993. Accordingly, more than 99% of well water samples tested contain atrazine at levels below the established drinking water quality guideline. The situation is continuing to be monitored to ensure the protection of our water resources.

What You Can Do

Some of the pesticides used on our lawns and gardens can end up in groundwater or surface water supplies. One way to reduce pesticide levels in the environment is to replace your lawn grass with a lower-maintenance landscape, such as trees and shrubs.[285]

Use of cultural practices that keep turfgrass healthy and vigorous will reduce the need for pesticides on your lawn. Here are some suggestions[286]:

- Let your grass grow to a height of four inches before cutting it. Taller grass is more resistant to weeds and disease and requires less water.
- Use insecticidal or household soaps to flush insects off garden plants and vegetables.
- Spray non-toxic oils on trees and shrubs to smother pests.
- Add compost to your lawn to discourage lawn pests.

Metals

Metals can enter Canadian water supplies as a result of natural processes, such as weathering and erosion, and from human activities, such as mining and manufacturing. For most Canadians, drinking water is a relatively minor source of exposure to metals compared with food and air. However, in some areas of Canada, water bodies contain naturally elevated levels of metals, such as uranium and arsenic. Moreover, water treatment processes and water distribution networks are both potential sources of metallic contaminants, such as aluminum.[30] Canadians are also exposed to lead, antimony and organotins from various sources in their drinking water.

Aluminum

Aluminum is one of the most common metals found in nature, comprising more than 8% of the Earth's crust. Aluminum enters water bodies primarily as a result of natural weathering and erosion. Aluminum levels tend to be highest in surface waters in regions where acid rain is a serious problem, because acid helps to dissolve aluminum found in soil and rock.[30,85]

One of the main sources of aluminum in tap water, however, is the water treatment process. Most municipalities add aluminum compounds, such as alum (aluminum sulphate), to water supplies to help remove harmful micro-organisms and the suspended particles to which they adhere. Aluminum compounds are also used to remove naturally occurring organic matter. This reduces the formation of THMs and other chlorination by-products. The amount of aluminum in treated water depends on aluminum levels in the water source, the amount of alum used, frequency of addition, acidity, temperature, efficiency of the filtration process and other factors.[85,287]

Canadians are exposed to aluminum primarily through food and some medications that contain aluminum salts, such as antacids. Drinking water accounts for less than 5% of our total exposure to aluminum, although recent research suggests that our bodies absorb a higher proportion of aluminum from drinking water than from food, particularly when water is consumed on an empty stomach.[287]

Kidney dialysis patients who are exposed to high levels of aluminum in dialysis fluids and medications can develop dialysis encephalopathy, a form of dementia characterized by speech and behavioural changes, tremors, convulsions and psychosis.[287] The health effects of low levels of aluminum, such as those typically found in treated tap water, are unknown, although the metal has been linked with Parkinson's disease, amyotrophic lateral sclerosis (Lou Gehrig's disease) and Alzheimer's disease. Patients with Alzheimer's disease appear to have elevated levels of aluminum in some areas of their brains. Moreover, several studies have found a small increased risk of Alzheimer's disease in areas where aluminum levels in drinking water were high. This does not prove, however, that aluminum is the cause, because all of these studies have methodological weaknesses. So far, all attempts to induce Alzheimer's disease-like changes in the brains of laboratory animals exposed to aluminum have failed.[287]

Arsenic

Arsenic is found throughout the Earth's crust and usually occurs as arsenic sulphate or in other inorganic forms. Arsenic enters water bodies from smelting operations, the combustion of coal and municipal wastes and industrial waste water; via the deposition of airborne particles; and through natural processes, such as weathering and erosion.[288,289]

In Canada, arsenic levels in water bodies are generally quite low, ranging from 1 to 2 µg/L, although higher concentrations have been found near gold-mining and ore-roasting operations and in regions with naturally high levels of arsenic in bedrock, including parts of Ontario, Quebec and the Maritime provinces. For example, in a 1984 survey, levels of over 500 µg/L were detected in 10% of the wells from seven Nova Scotia communities.[288,289] Studies in other countries have shown that exposure to elevated arsenic levels is associated with an increased risk of skin cancer as well as bladder, kidney, liver and lung cancers.[85,288–290]

Lead

Canadians are exposed to lead primarily in food, soil and airborne dust. With some exceptions, tap water is a minor source of exposure to lead, because the levels found in untreated water are generally below 1 µg/L. However, tap water may pick up significant amounts of lead after leaving the water treatment plant as a result of leaching from plumbing components that contain the metal.[203,291] Potential sources of contamination include the underground water distribution system, holding tanks and lead pipes and fixtures inside old buildings, particularly homes built before the 1950s. Lead may also be present in brass fittings, solder that connects copper tubing and some plastic pipes.[30,292]

Studies conducted in the 1980s suggest that even small amounts of lead may have some impact, however small, on human health. Prolonged exposure even to relatively low levels of lead may affect the intellectual and neurological development of the fetus, infants and young children and may cause blood pressure and reproductive effects in adults.[200,201,291]

Did you know?

The Canadian plumbing code prevents the use of lead solder in new plumbing and in plumbing repairs to water distribution systems. In addition, several provinces have passed legislation limiting the amount of lead in solder for drinking water supply lines.[200]

Uranium

Uranium is a metal found in granites and other mineral deposits. Uranium can enter water bodies as a result of natural erosion and weathering or from human activities, such as mining and the use of phosphate fertilizers, which can contain small amounts of the metal. In Canada, uranium levels found in drinking water are usually fairly low, below 1 µg/L, but significantly higher concentrations have been detected in some parts of Saskatchewan, Manitoba, Quebec and Nova Scotia. For example, concentrations of up to 700 µg/L were found in private wells in Nova Scotia during the 1980s.[293]

Did you know?

Although uranium is radioactive, the primary hazard of uranium in drinking water is its chemical toxicity.[293]

In both animals and humans, the kidney is the organ most vulnerable to uranium exposure. However, studies conducted in the 1980s involving Nova Scotians who used contaminated well water found no overt pattern of kidney disease in the exposed population.[293] To gain a better understanding of the health effects of uranium, Health Canada recently completed an investigation of three communities in Saskatchewan and Nova Scotia where the uranium levels exceed 20 µg/L in tap water. The studies found some minor changes in the kidney function of participants who were exposed to uranium in the water supply over a prolonged period of time. However, there was no evidence that the uranium had caused any kidney damage.[294]

Antimony

Antimony is a metal used in a wide range of products, such as semiconductors, infrared detectors and plumbing components. Antimony enters water bodies through natural processes such as weathering and erosion and in waste waters from mining operations and industrial and municipal discharges. Household piping and non-lead solders are potential sources of antimony in tap water, although levels are often undetectable. For Canadians, food and drinking water are likely the main sources of exposure to antimony.[295] Studies involving workers in occupational settings suggest that elevated levels of airborne antimony can cause an increase in blood pressure, heart problems and ulcers. Chronic exposure to antimony has also been linked with an increased incidence of menstrual disorders and spontaneous abortions in female smelter workers.[282]

Did you know?

In developing countries, antimony compounds are used in the treatment of parasitic diseases such as schistosomiasis, leishmaniasis and trypanosomiasis.[282]

Organotins

Organotins are a family of organic compounds that contain tin. In Canada, organotins are imported for use as chemical stabilizers in polyvinyl chloride (PVC) plastics, as ingredients in wood preservatives and as antifouling paints on boats. In a recent survey by Health Canada, no organotins were found in raw or treated water from five municipalities in Canada, although the tap water in 10 of 22 homes contained trace amounts of these compounds.[296] This suggests that organotins may enter water supplies as a result of leaching from PVC pipes.[297] Exposure to very high levels of certain organotin compounds can cause brain damage.[282]

Protecting Our Health

Scientists at Health Canada, in collaboration with provincial and territorial government agencies, have established drinking water quality guidelines for a variety of metals, including arsenic and lead, and are revising the current guideline for uranium. Additional guidelines for aluminum, antimony and organotins are at different stages of development. Most Canadian municipalities already monitor aluminum levels in treated tap water to keep concentrations as low as is reasonably possible.

Canadian municipalities use a variety of techniques to control concentrations of metals found in drinking water. For example, some municipalities use corrosion inhibitors to reduce leaching from water pipes after drinking water leaves the treatment plant.[203] Health Canada is also developing new legislation to establish national standards for chemicals used in water treatment processes, such as alum.

What You Can Do

If you rely on well water, you may wish to have it tested for metallic contaminants. If your water contains any metal in amounts that exceed its drinking water quality guideline, contact your local health authority for advice.[85] If your tap water contains elevated amounts of lead (above the Canadian drinking water guideline of 0.01 mg/L, or 10 µg/L), here are some simple steps you can take to reduce your and your family's exposure[200]:

- Flush your bathroom or kitchen taps every morning for at least 30 seconds to remove excess lead, which tends to accumulate overnight in water pipes.
- Use cold water for drinking, cooking or making baby formula, because hot water tends to leach lead from plumbing components at a faster rate than cold water.
- If tests indicate that your water consistently exceeds the recommended limit for lead in tap water, you may need to replace lead-based plumbing components in your home or install an appropriate water treatment system.

Fluoride

Fluoride occurs naturally in the Earth's crust, in materials such as coal and clay and in volcanoes and oceans. Fluoride enters water as a result of natural processes, such as weathering and erosion, and from human activities, such as aluminum smelting, chemical production and fluoridation of drinking water. In Canada, approximately 40% of the population receives fluoridated water.[299]

Fluoridation was introduced in Canada during the 1940s and 1950s to improve our dental health. At optimum levels, fluoride increases the resistance of tooth enamel to acids that cause tooth decay. Numerous studies have found that fluoridated water can significantly reduce the number of cavities in children, without endangering their health. Despite claims to the contrary, there is no evidence that fluoridation can

cause heart disease, cancer, thyroid problems, birth defects, miscarriages or hearing or vision problems.[300]

At levels in water as low as 0.7 mg/L, fluoride can cause dental fluorosis in some children, a generally mild condition involving tooth mottling or discoloration. If children are exposed to much higher levels during the period of tooth formation, from birth to about 12 years of age, moderate to severe dental fluorosis can result.[300]

Chronic exposure to very high levels of fluoride can be associated with skeletal fluorosis, a progressive disorder in which the bones increase in density and become more brittle. Mild cases of skeletal fluorosis generally involve pain and stiffness of the joints. In more severe cases, symptoms may include complete rigidity of the spine, skeletal deformities and an increased risk of bone fractures.[300]

Symptoms of skeletal fluorosis are unlikely to occur in people who routinely ingest less than 200 µg of fluoride per kilogram of body weight per day. For comparison, Health Canada estimates that the average levels of fluoride to which Canadians are exposed on a daily basis are at least 20% lower than the levels at which adverse effects on the skeleton are anticipated (see Figure 16).[301]

Protecting Our Health

Following an extensive review of the available data concerning the risks and benefits of fluoridating water supplies, the Federal–Provincial Subcommittee on Drinking Water has reaffirmed the Canadian drinking water quality guideline for fluoride of 1.5 mg/L. Health Canada has recommended that exposure of Canadians to fluoride be closely monitored to ensure that the average person continues to take in less than the lowest level at which mild health effects may occur.[259,302]

Figure 16
Estimated Total Daily Intake of Inorganic Fluoride by the General Population of Canada

	Estimated Intake of Inorganic Fluoride by Various Age Groups (µg/kg-bw per day)				
Route of Exposure	0–6 months	7 months – 4 years	5–11 years	12–19 years	20 + years
Breast-fed infants	0.51–2.61	–	–	–	–
Formula-fed infants	13.64–93.06	–	–	–	–
"Fluoridated" water	–	87.25–160.42	48.94–78.52	32.76–44.73	46.87–58.11
"Non-fluoridated" water	–	45.41–96.42	26.28–43.85	17.25–21.01	32.30–35.82

Source: Adapted from ***Priority Substances List Assessment Report. Inorganic Fluorides. Canadian Environmental Protection Act,*** *Environment Canada and Health Canada, Ottawa, 1993, p. 43.*

What You Can Do

Here are some steps you can follow to help you and your family enjoy the benefits of fluoridation while ensuring that your exposure levels remain within the range considered safe by Health Canada[300]:

- Do not give fluoridated mouthwash to children under six years of age, because they may swallow the liquid after use.
- Do not give children under six years of age more than a pea-sized amount of toothpaste per day.
- Consult a dentist before using fluoridated mouthwash or fluoride supplements if you already use a fluoride toothpaste.
- Avoid the use of fluoride supplements if the drinking water in your municipality is fluoridated.

Nitrates

Nitrates are essential plant nutrients that are formed during electrical storms and by soil bacteria. Nitrates occur naturally in the aquatic environment as a result of the decay of organic matter.[303] They are also a key ingredient of commercial fertilizers and can enter water bodies via the runoff from farmers' fields, from septic systems and in the leachate from industrial and municipal landfills.[85]

Did you know?

Up to 50% of the nitrogen content of commercial fertilizers used on residential lawns ends up in nearby water bodies. To help reduce nitrate levels in the environment, consider using natural fertilizers, such as compost, or switching to a lower-maintenance landscape, such as trees and shrubs.[285]

From 1960 to 1985, the annual consumption of fertilizers in Canada increased from one million tonnes to four million tonnes, although fertilizer use remained steady for the rest of the 1980s. In the same period, the nitrogen content of fertilizers increased from about 10% to 30%.[238] As a result of such trends, the amount of nitrates present in Canadian water bodies has risen, particularly in rural areas that rely on groundwater. In a 1993 survey of Ontario groundwater, 15% of 1300 rural wells contained nitrates at potentially harmful levels.[254] Nitrate levels in treated surface water are well below those associated with adverse health effects.

Among adults, food is the principal source of exposure to nitrates, followed by drinking water. However, water is the primary source for bottle-fed infants. Exposure to elevated levels of nitrates (above 45 mg/L) has been linked to methemoglobinemia in infants, a life-threatening condition in which body tissues are deprived of oxygen.[304] Symptoms may include shock, heart arrhythmia and severe skin discoloration. Babies under three months of age are particularly at risk, as are the fetuses of pregnant women in their last trimester.[305,306] The incidence of methemoglobinemia in Canada is unknown.

Did you know?

The average bottle-fed infant, weighing 7 kg, consumes about 750 mL of tap water in formula per day, which is the equivalent of a 70-kg adult drinking over 20 355-mL cans of soda pop per day.[291,307]

What You Can Do

The Canadian drinking water quality guideline for nitrate is 45 mg/L; the corresponding guideline for nitrite, which is formed from nitrate in the body and which causes methemoglobinemia, is 3.2 mg/L.[259] If you rely on well water, you may wish to have it tested for nitrates on a regular basis. Water that contains higher levels of nitrates should be avoided, particularly if it is used by infants.

Radiation

Water may become contaminated with radionuclides from a variety of natural and human sources. The main health effects associated with the ingestion of radionuclides in drinking water are the same as those resulting from exposure to radionuclides through other pathways—specifically, a small increase in the risk of cancer and genetic disorders. The contribution of drinking water to our total radiation exposure is very small and results primarily from naturally occurring radionuclides produced from the decay of uranium and thorium. The contribution from human-made sources, such as normal releases from nuclear power facilities, is very low compared with the contribution from natural background sources.[30,308,309] The bulk of artificial radionuclides released into the global environment have come from nuclear weapons tests, especially those conducted in the 1950s and 1960s. Since then, however, concentrations of these radionuclides have decreased to barely detectable levels.

In Canada, the potential risks associated with radionuclides in drinking water are extremely low. The largest contributors to the total dose from Great Lakes waters are tritium (^{3}H) and strontium-90 (^{90}Sr) from atmospheric weapons tests conducted before 1962 and naturally occurring radium and uranium.[309] However, the dose associated with these radionuclides is approximately 1000 times less than the Canadian drinking water quality guidelines for radionuclides, or about 0.001 mSv from one year's consumption of water. This would result in a risk estimate for cancers and hereditary effects of about 50 per billion, based on the linear no-threshold risk model. Substantially higher levels of radium and uranium have been found in some well waters across Canada.

Monitoring Radionuclides in Water

In Canada, provinces and/or municipalities are responsible for monitoring radionuclide levels in drinking water. Until recently, Health Canada's Radiation Protection Bureau routinely monitored untreated water from drinking water intake pipes near nuclear facilities and research stations. This activity was discontinued at the end of 1993 as a result of continually low levels of radionuclides. However, the Department's monitoring capability has been maintained in case of future needs.

Nuclear power reactor operators are responsible for monitoring radionuclides in the local environment and reporting levels to the Atomic Energy Control Board. Small increases in tritium (^{3}H) are often detected in water, but at levels well below the Canadian drinking water quality guideline. In several studies conducted to date, scientists have not found any health effects attributable to tritium or other radionuclides in populations living near nuclear power facilities.[85,310]

Did you know?

The Health Canada publication ***Guidelines for Canadian Drinking Water Quality*** *specifies maximum acceptable concentrations (MACs) for natural and artificial radionuclides. Radionuclide levels in open waters are usually very low; however, if you rely on well water, you may wish to have it tested for natural radionuclides. If your water does not meet the guidelines, it does not necessarily mean that the water is unsuitable for consumption. However, further investigation is recommended.*

Emerging Issues

Dermal Exposure to Chemical Contaminants

In large water bodies such as the Great Lakes, particularly in the vicinity of heavily populated areas, recreational users may come in contact with chemical contaminants present in the water or sediments, such as polycyclic aromatic hydrocarbons (PAHs) and organochlorine compounds.[308] Based on recent laboratory data, scientists at Health Canada have concluded that, under certain conditions, recreational water users may absorb significant amounts of some chemical contaminants, particularly if they are sunburned.[244,311]

What You Can Do

To reduce the risk of dermal exposure to chemical contaminants found in recreational waters, you should:

- confine your activities to public beaches;
- avoid going in the water if you have a sunburn; and
- wash thoroughly with soap and water as soon as possible after swimming.[244]

Investigating Exposure to Polycyclic Aromatic Hydrocarbons (PAHs) Among Recreational Users of the St. Marys River, Sault Ste. Marie[312,313]

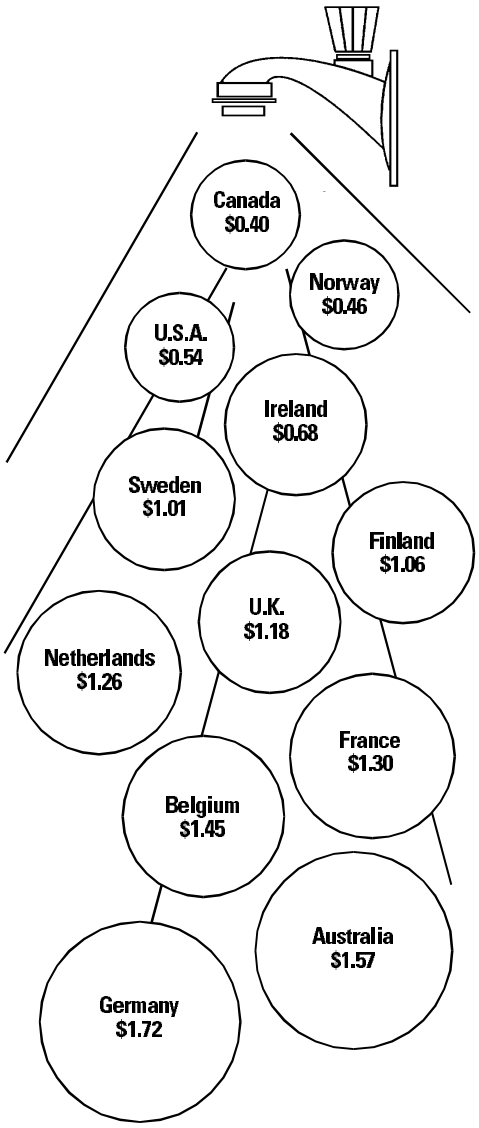
A variety of contaminants flow into the St. Marys River at Sault Ste. Marie, Ontario, including polycyclic aromatic hydrocarbons (PAHs) that are released by a steel mill in the area. PAHs are complex organic compounds formed during incomplete combustion processes. Some of these compounds are suspected human carcinogens. In response to the concerns of local residents, a study was launched early in 1992 by Health Canada and the Ontario Ministry of Environment and Energy to determine the potential health risks associated with the recreational use of the St. Marys River.

That summer, the Ontario Ministry of Environment and Energy sampled water and river sediments at five beach sites near Sault Ste. Marie. Residents were also surveyed to assess the most likely routes of exposure to river water. The survey found that direct skin contact with PAHs present in river water or sediments is probably the most relevant route of exposure. Scientists at the Ontario Ministry of Environment and Energy and Great Lakes Health Effects Program of Health Canada then estimated the likely intake of PAHs resulting from a single swim by a 70-kg adult. By assuming that the typical adult swims 30 minutes a day for a maximum of 30 days per year over a 30-year span, the scientists calculated the average lifetime exposure to PAHs associated with recreational use of the river, at five locations.

The results showed that the lifetime risk of developing skin cancer for swimmers at four inshore locations is very small—less than 1 in 1 million. However, the risk may exceed 1 in 10 000 at two offshore locations used less often by swimmers. After completing this study, Health Canada explained the results to community members. Local residents were informed that the risks of dermal exposure to PAHs at most locations are essentially negligible and that the risk of swimming farther from shore (in the more heavily polluted water) could be lowered by swimming less often and taking a shower immediately after each swim.

As a follow-up, different areas of the St. Marys River were ranked in order of priority for clean-up. In 1995, thousands of tonnes of contaminated sediments were removed from the boat access area of the local steel mill as well as from the government dock in Sault Ste. Marie. In addition, the steel mill has reduced its output of PAHs.

Figure 17
Typical Municipal Water Prices
($/1000 litres*)



* All amounts are in 1992 Canadian dollars. These figures do not include the cost of waste treatment.

Source: ***Water Works! Freshwater Series A-4,*** *Environment Canada, 1993. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 1997.*

Water Conservation

Many Canadians take water for granted because of its abundance and comparatively low cost (see Figures 17 and 18). The average Canadian household of four people uses more than 500 000 L of water per year, but could easily cope with 30–50% less water with no reduction in lifestyle. For example, only 5% of the water consumed at home is used for drinking and cooking. The remainder is used for toilets (45%), bathing and showering (30%) and laundry (20%).[298,314]

In 1991, we withdrew a grand total of 45 billion cubic metres of water, 88% more than in 1972, or roughly 45 L per person per day, of which 34 L went towards residential uses. This makes us the world's second largest water consumers on a per capita basis.

The more water we use, the more waste water we generate, and the harder our sewage treatment systems must work to keep up. Experience has shown that overburdened sewage systems often release untreated water directly into the aquatic environment. Looking towards the future, one of the keys to maintaining the quality of our water supply is to control our rate of consumption.[131,238,298]

Figure 18
Typical Prices of Popular Beverages

Beverage	Cost* ($/1000 L)
Tap water**	0.82
Cola	850.00
Milk	985.00
Bottled water/mineral water	1,500.00
Beer	2,500.00
Wine	9,000.00
Whiskey, gin...	26,700.00

* All amounts are in 1992 Canadian dollars.

** Only tap water includes automatic delivery to the user. This figure includes the cost of waste treatment.

Source: ***Water Works! Freshwater Series A-4,*** *Environment Canada, 1993. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 1997.*

Promoting Water Conservation

To promote water conservation across Canada, the Canadian Council of Ministers of the Environment adopted a National Action Plan to Encourage Municipal Water Use Efficiency in June 1994. The plan calls on federal, provincial, territorial and municipal government agencies to demonstrate water efficiency in their operations, harmonize existing regulations, adopt more realistic water and sewage rate structures and educate the public about the benefits of water conservation.[315]

The Federation of Canadian Municipalities' (FCM) Policy Statement on Municipal Infrastructure (adopted at FCM's annual conference in 1997) has a section devoted to water efficiency.[316] FCM has worked with other stakeholders in organizing national conferences on water efficiency and in preparing and promoting tools to encourage and support municipal water efficiency.[317]

In a related initiative, the federal government has started to implement water efficiency measures at federal facilities across Canada. Under the Greening Government Operations program, federal departments and agencies are conducting water audits, optimizing water conservation using flow meters and preventive maintenance, installing water-saving equipment and devices and retrofitting existing equipment to reduce water use. For example, at Health Canada's Banting Research Centre in Ottawa, almost $8000 in annual savings were realized by installing low-volume shower heads, low-flow faucets and other water conservation devices.[315,318]

What You Can Do

Here are some ways to reduce the amount of water you use in your home[239,314]:

- Repair leaking taps and faucets promptly.
- Never run water continuously when washing dishes by hand. Use your dishwasher on the shortest cycle possible.
- Install low-flush toilets to reduce water usage by up to 50% per flush. Low-flow shower heads can reduce flow rates by at least 25%.
- Wash only full loads of clothing in your washing machine.
- Do not water green grass. Replace your sprinklers with drip irrigation systems. Clean sidewalks with a broom and not a hose. Capture and store rainwater for outdoor use in rain barrels.

For more advice on how to conserve water, contact the nearest Environment Canada office and request the *Water Wise* brochures. If you have Internet access, visit the Health Canada World Wide Web site (at http://www.hc-sc.gc.ca/dataehd/English/bch/water_quality.htm) and H_2O Links on the Green Lane, Environment Canada's World Wide Web site (which is located at http://www.doe.ca).

Major Initiatives to Protect Our Health

In Canada, there are a variety of programs and initiatives designed to maintain and improve the quality of drinking water and recreational waters across the country. For example, Health Canada and Environment Canada jointly administer the *Canadian Environmental Protection Act*, which deals with toxic substances in the environment. Other initiatives are briefly described below.

Guidelines for Canadian Drinking Water Quality

The *Guidelines for Canadian Drinking Water Quality* help provincial/territorial and municipal authorities and home-owners with individual supplies provide drinking water that is of sufficient purity to protect human health over an entire lifetime of consuming the water. The guidelines are intended to apply to both public and private drinking water supplies, but they are not legally enforceable, because provision of drinking water is a provincial/territorial responsibility. However, all provincial and territorial governments use them as a basis for setting drinking water objectives or standards.[240]

The guidelines are prepared by the Federal–Provincial Subcommittee on Drinking Water, which includes representatives from Health Canada, Environment Canada and each province and territory.[259] First published in 1968 as the *Canadian Drinking Water Standards and Objectives*, the *Guidelines for Canadian Drinking Water Quality* provide recommended limits for substances and conditions that affect the quality of drinking water.[259] Since 1986, the guidelines have been continually updated to reflect the accumulation of new data on the health impacts of drinking water contaminants and on water treatment technologies and to achieve progressive improvements in water quality.

Guidelines are developed for substances that have been detected in water supplies across Canada and are known or suspected to be harmful. For each contaminant, the Subcommittee establishes a MAC, based on the most current and reliable scientific literature from around the world as well as monitoring data collected by Canadian researchers. In the case of substances for which there are insufficient toxicological data to derive a MAC with reasonable certainty (or for which the MAC is difficult to achieve using available treatment methods), an interim MAC (IMAC) is recommended instead. In addition, aesthetic objectives are defined for certain substances to ensure that drinking water supplies do not have an unpleasant appearance, taste or odour.[240] The guideline reference dose for radionuclides is based on the total radioactivity in a water sample, whether the radionuclides appear singly or in combination.

To ensure the safety of all Canadians and to account for uncertainties in the data, MAC values are typically set from 10 to 5000 times lower than the levels at which adverse health effects have been observed in animals or people during prolonged and repeated exposure. Thus, short-term ingestion of water that contains pollutants at levels that exceed the MAC is not necessarily hazardous to human health.[319] MAC values are also set low enough to allow for additional exposures from other sources, such as food, air and soil, because drinking water is not the only way in which contaminants can reach us.[240]

The sixth edition of the *Guidelines for Canadian Drinking Water Quality* lists MACs for more than 80 microbial, chemical and physical contaminants and 78 natural and artificial radioactive contaminants. Copies of the guidelines can be purchased from book stores that carry government publications. For more information about the guidelines, contact the nearest Health Canada office in your area or visit the Bureau of Chemical Hazards' website (which is located at http://www.hc-sc.gc.ca/dataehd/English/bch/). To find out whether your tap water meets the guidelines, contact the local water department or public health department and ask what measures are in place to ensure that your water is safe to drink.

Did you know?

Many Canadians believe that bottled water is safer to drink than municipal tap water, although this is not necessarily the case.

Drinking Water Materials Safety Legislation

In Canada, it is the responsibility of municipal water authorities to decide how to adapt treatment processes in order to implement provincial/territorial drinking water limits. To assist municipalities—and individuals who rely on private water supplies—the Minister of Health introduced the *Drinking Water Materials Safety Act* in December 1996. The purpose of the Act would be to protect the health of Canadians by preventing unsafe drinking water materials from being sold in or imported into Canada. The Act would provide for the certification (by accredited third-party certification organizations) of water treatment devices, water treatment additives and water system components for which health-based performance standards have been established. For example, chemical additives such as chlorine-based disinfectants and fluoride would be regulated, as well as materials that come in contact with treated drinking water and household drinking water treatment devices.[287,320] In 1996 and 1997, Health Canada held a series of public consultations designed to elicit feedback on this proposed initiative.

Guidelines for Canadian Recreational Water Quality

In Canada, provincial and territorial governments are responsible for establishing regulations for recreational water quality. Health Canada, in collaboration with other health and safety experts from across the country, has developed recreational water quality guidelines, which are published in *Guidelines for Canadian Recreational Water Quality*. The recreational water quality guidelines suggest limits for organisms that act as indicators of water quality (but which are not necessarily harmful themselves) and address various hazards associated with recreational water activities.[30,256,257]

The recreational water quality guidelines are intended for use by municipal health authorities, who are responsible for monitoring the water quality of public beaches during the swimming season and investigating illnesses or injuries resulting from the use of recreational waters. If measurements indicate a potential water quality problem at a public beach, local authorities may increase the level of monitoring or close the beach to the public.[257] Copies of the guidelines can be purchased from book stores that carry government publications.

Drinking Water Safety Program for Native People

The incidence of water-borne diseases in First Nations communities is several times higher than the incidence in the general population, in part because of inadequate or non-existent water treatment systems.[238,321] For example, a recent survey conducted by Health Canada found that out of 863 community water systems, 171 were rated as having potential health and safety concerns.[322] In 1989, the Split Lake Band in Manitoba, with support from the International Development Research Centre and Environment Canada, started testing simple water quality methods developed for use in remote communities.[323] In 1991, the Medical Services Branch of Health Canada established the Drinking Water Safety Program for Native People to help First Nations communities identify and remedy potential water quality problems.

Under this program, Health Canada, in partnership with the Assembly of First Nations, is[30,70,322]:

- increasing the sampling and analysis of drinking water for chemical contaminants;
- establishing community-based water quality laboratories that enable First Nations communities to monitor the bacteriological quality of their drinking water supplies;
- developing and testing a training program for First Nations water treatment plant operators;
- providing advice on the design, operation and maintenance of water treatment facilities; and
- providing advice on the importance of having a potable water supply and the relationship between personal hygiene, drinking water quality and communicable diseases.

What You Can Do

Drinking Water

Many Canadians are concerned about the potential health risks associated with contaminants in tap water. As a result, water treatment devices (including both water purification systems and devices for removing chemicals) have become common household appliances, with about 100 000 units sold annually in Canada. Currently, there are no federal or provincial regulations mandating the safety of drinking water treatment devices; however, they would be covered under the proposed *Drinking Water Materials Safety Act*.

If you live in an area served by a municipal water treatment facility, you probably do not need a water treatment device. Here are some alternative ways to reduce your exposure to drinking water contaminants:

- Flush your household's pipes every morning by opening the kitchen or bathroom taps for about 30 seconds (taking a shower will do the trick) before using water for drinking or cooking. This will remove any excess chemicals and bacteria that have accumulated overnight.[30]
- If you do not like the taste of chlorinated tap water, simply refrigerate some water overnight in an open container, and the chlorine taste will dissipate.
- If you have any doubts about the quality of your municipal tap water, request a copy of the latest water analysis from your local utility. The test results will tell you the condition of water in the municipal distribution system, although it will not tell you the condition at your tap.

If you decide to purchase a water treatment device, it is important to understand what you are buying before installing a system in your home.[238] Figures 19 and 20 list the strengths and weaknesses of different water treatment devices. You should purchase a device whose manufacturer indicates that it meets the performance standards of the National Sanitation Foundation (NSF) International.[240,324]

Water Purification Systems

Chlorinators and ultraviolet (UV) light devices are the most practical systems available to disinfect water supplies for an entire household. Chlorination kills most disease-causing organisms. UV devices destroy most pathogens while leaving virtually no by-products, taste or odour. However, they are relatively ineffective against protozoa, such as *Giardia*, which can be removed using a prefiltration system containing filters with a pore size of no more than 1 µm.[272]

Other water purification methods include distillation and ozonation. Distillation removes both microbial and inorganic contaminants, such as heavy metals, but does not remove all organic compounds. Ozonators rapidly destroy microbial pathogens without leaving behind a taste or odour. However, the disinfection is temporary. Following treatment, water that is left to stand in pipes may become recontaminated. For best results, distillation systems and ozonators can be combined with carbon filtration systems.[272]

Figure 19
Water Purification Systems

Method	Strengths	Weaknesses
Chlorination	Effective against most micro-organisms.	Creates undesirable by-products, such as THMs. Not recommended for removal of protozoa.
UV devices	Fast-acting and leave few by-products.	Provides temporary disinfection only. Not effective against protozoa.
Distillation	Also removes many chemical compounds.	Cannot remove all organic compounds.
Ozonation	Fast-acting. Also removes unpleasant tastes and odours.	Effect is temporary and creates some undesirable by-products.

Devices for Removing Chemicals

Several water treatment products are available for removing chemical contaminants and improving the aesthetic qualities of drinking water. Many devices contain activated carbon filters, which are designed primarily to remove organic compounds. Activated carbon filters are often combined with other devices to provide a complete water treatment system.[324]

One of the drawbacks of activated carbon filters is that, if not used properly, they can become saturated with chemicals, causing the release of contaminants into filtered water. Moreover, the buildup of organic matter on the filter can promote bacterial growth in very short periods of time, such as overnight. Studies have shown that levels of bacteria present in water that has passed through an improperly maintained home filtration device may be up to 2000 times higher than levels in unfiltered water.[30,324]

Figure 20
Chemical Decontamination Systems

Method	Strengths	Weaknesses
Activated carbon filters	Remove a range of organic compounds, such as THMs.	Potential for buildup of bacteria.
Distillation	Removes a range of organic and inorganic compounds.	Cannot remove volatile organic compounds without additional treatment.
Reverse osmosis	Removes both organic and inorganic compounds.	Low water use efficiency and potential for scaling or buildup of bacteria.
Aluminum oxide filters	Remove lead and other metals.	Potential source of aluminum contamination.

Did you know?

Activated carbon filters should be replaced regularly, according to the manufacturer's instructions, to prevent the buildup of chemicals. In addition, filtration devices should be flushed until the water turns cold before using filtered water for drinking or cooking.[328]

Several other water treatment devices are available for reducing the levels of chemical contaminants found in tap water. For example, distillation systems are useful for removing both inorganic compounds, such as metals, and many organic compounds, with the exception of volatile chemicals such as THMs. Reverse osmosis systems are useful for removing metallic and organic contaminants. Activated aluminum oxide filters can also remove metals such as lead and arsenic from tap water.[324]

Recreational Waters

Here are some ways to help keep Canada's rivers, lakes and streams safe for recreational activities and to protect your own health[257]:

- Be aware of conditions in your area. Contact your local health authorities, who test water quality at public beaches, for up-to-date information.
- Do not go in the water if you have an infection (to protect other swimmers) or an open wound, because micro-organisms can enter the body more easily through broken skin.
- Do not use soap in recreational waters, because soap is a source of nutrients for potentially harmful algae and bacteria.
- Help organize or participate in a neighbourhood clean-up of beaches and waterways in your area.
- Do not feed animals or birds on public beaches, because they may leave droppings in the water.
- Pick up your pet's feces and dispose of them in a toilet.

- Avoid using fertilizers near recreational water.
- When boating, do not dump any wastes into or near the water.
- If you live in a rural area, make sure that your septic system works properly.
- Encourage municipalities and local industries to observe proper waste management practices by making your views known to elected representatives.

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