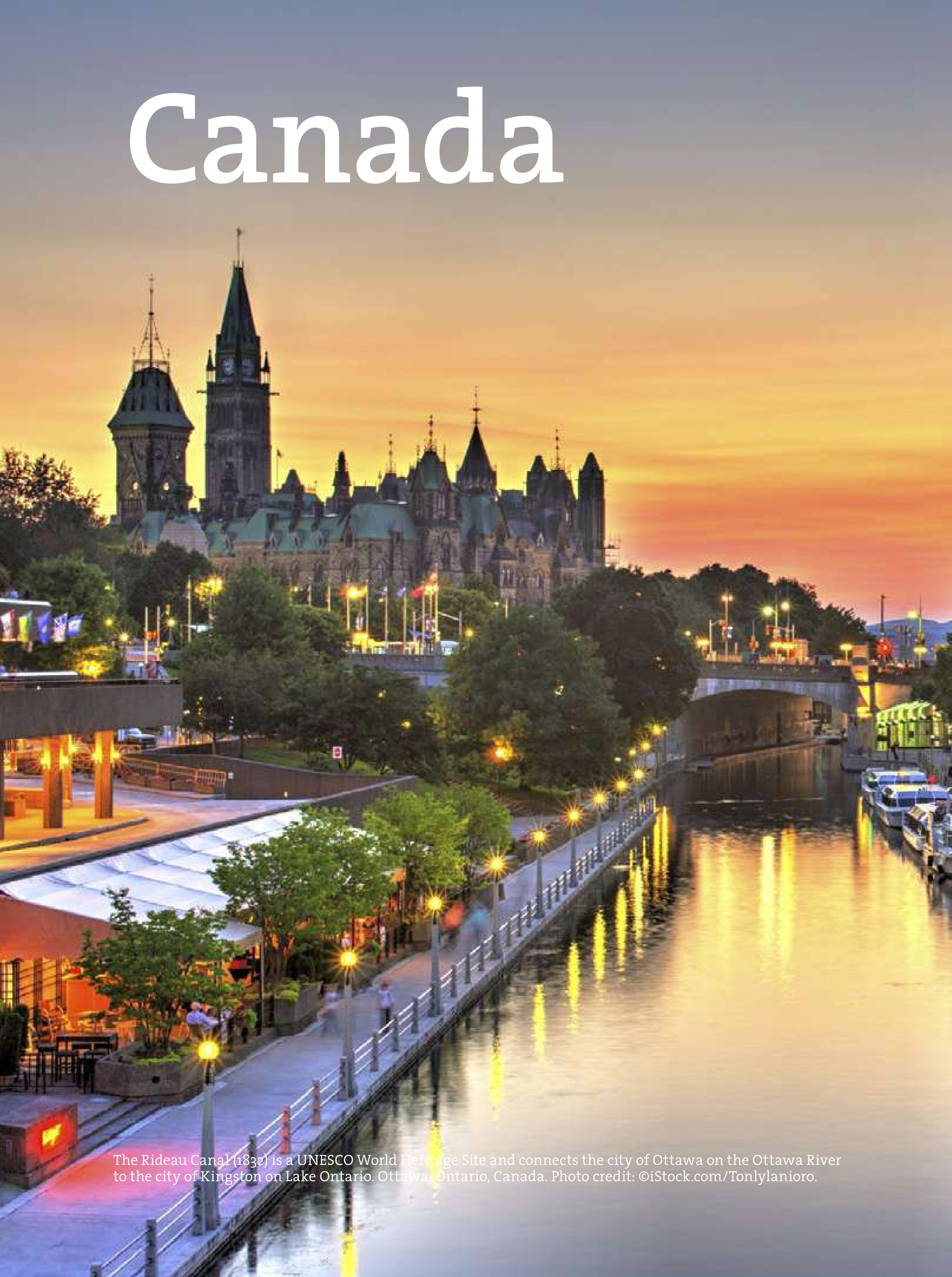
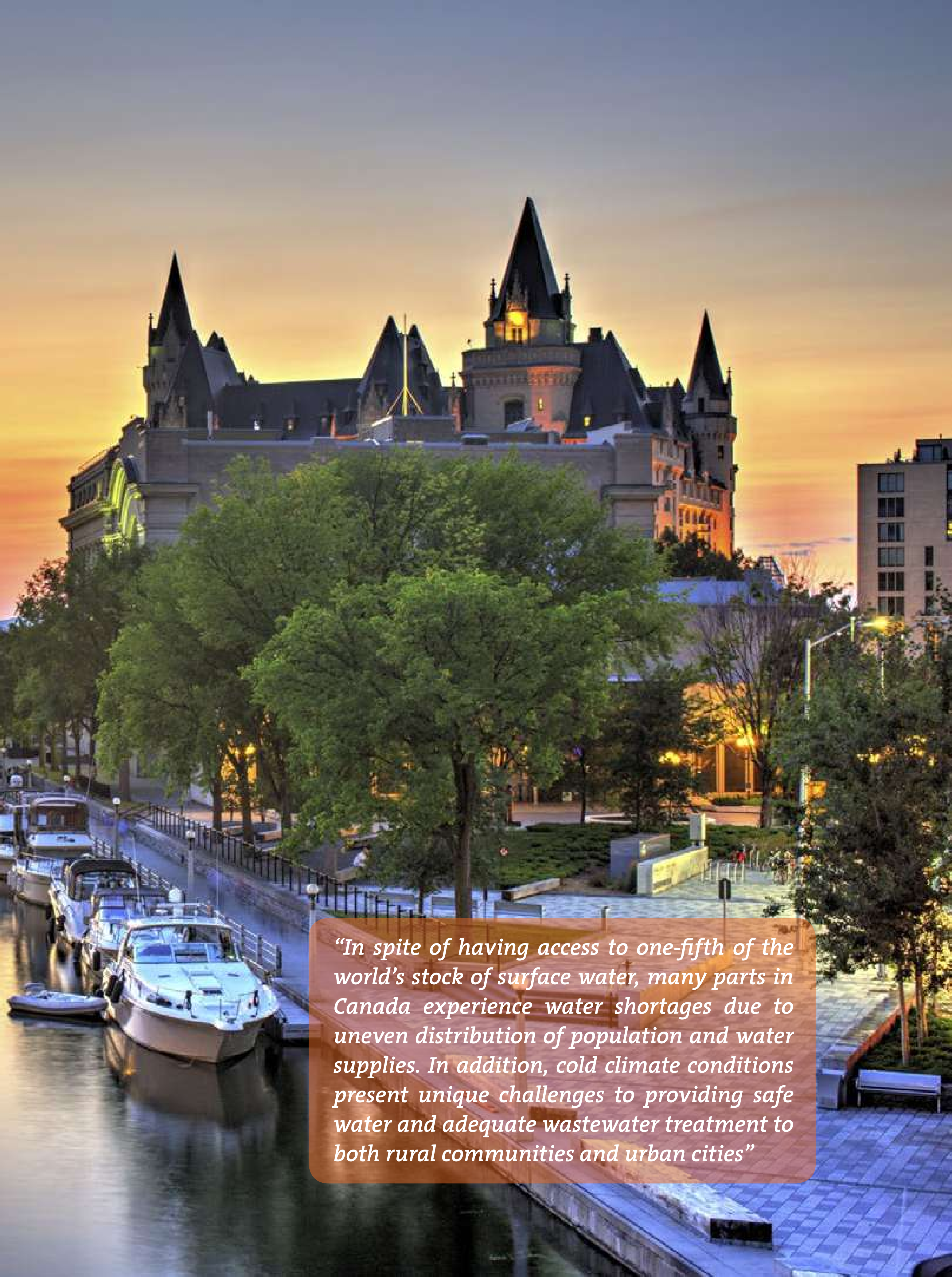
Canada



The Rideau Canal (1832) is a UNESCO World Heritage Site and connects the city of Ottawa on the Ottawa River to the city of Kingston on Lake Ontario. Ottawa, Ontario, Canada. Photo credit: ©iStock.com/Tonlylanioro.



"In spite of having access to one-fifth of the world's stock of surface water, many parts in Canada experience water shortages due to uneven distribution of population and water supplies. In addition, cold climate conditions present unique challenges to providing safe water and adequate wastewater treatment to both rural communities and urban cities"

An Overview of Water Supply, Use and Treatment in Canada

Banu Örmeci

Summary

Canada is the world's second largest country by total area and spans over 9.98 million square kilometers from the Atlantic to the Pacific Oceans. It extends to the Arctic Ocean in the north and neighbours the United States in the south. Due to its sheer size, Canada encompasses a wide range of climate regions and ecosystems, which affect the supply, demand, use and treatment of water. Cold and remote regions present particularly difficult challenges in providing safe drinking water and adequate wastewater treatment to communities.

Canada is perceived to be a water-rich nation having access to approximately 20% of the world's stock of surface fresh water, which includes some of the largest lakes in the world as well as thousands of small lakes scattered across the land (Figure 1). Surface waters cover 12% of the total surface area and wetlands cover 14% of lands in Canada. In addition, glaciers cover an area of 200,000 km^2 (Statistics Canada, 2010). Canada has an average annual renewable freshwater supply (also known as water yield) of 3,472 km^3, which is higher than the water yield in many drier countries, but only 36% of the water yield in Brazil and 60% of the water yield in India (Statistics Canada, 2010).

Even though water is abundant at the national scale, there are strategic water problems and shortages at the regional scale due to the uneven distribution of population and water supplies. Simply put water is not always available where it is needed. For example, 98% of Canadians live in the warmer southern parts of the country where the renewable freshwater supply is only 38% (Statistics Canada, 2014). In addition, most of Canada's freshwater flows north where there is relatively little population. As a result, water intake can substantially exceed water yield in many parts including Southern Saskatchewan, Southern Manitoba and the Great Lakes region (Figure 2). Prairies are particularly dry and have experienced repeated and more prolonged droughts in recent decades.

Canada is a wealthy country and most Canadians are serviced with high-quality drinking water and wastewater infrastructure. However, there are also many small communities, particularly Aboriginal and rural communities, which suffer from continuous and persistent problems with the safety of their drinking water and the contamination of their water supplies due to inadequate wastewater treatment. As a result, waterborne disease outbreaks still occur in Canada. Water supplies are increasingly under pressure from intensification of urban areas, economic and industrial growth, expansion of agriculture, and impacts of climate change, and Canada needs a comprehensive plan for water governance to address these strategic water problems with an adaptive, integrative and participatory approach at all levels of government (Hipel et al., 2013).

1. Water Resources and Problems Caused by Development

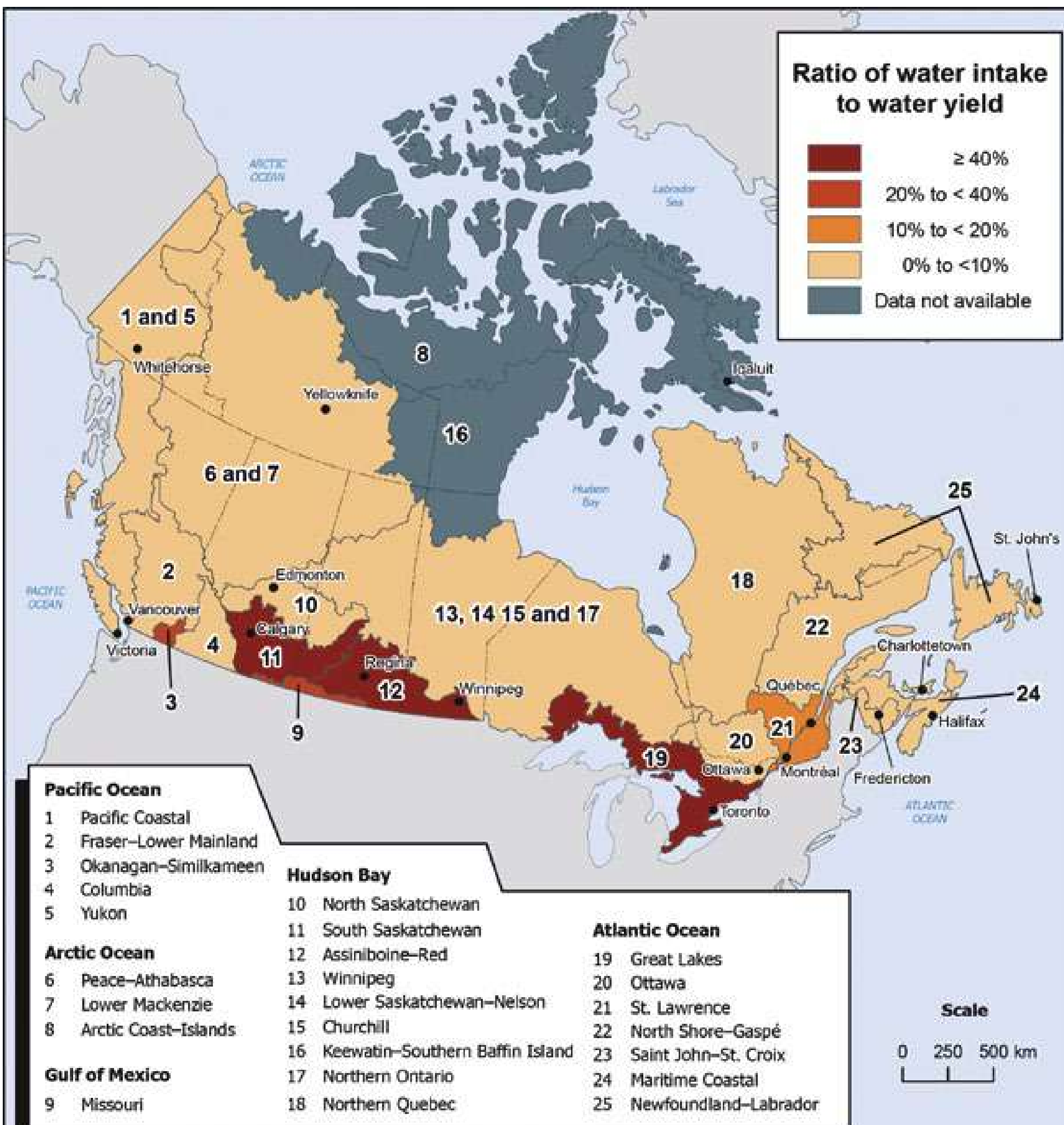
Canada used more than 42 km^3 of water for domestic and industrial use in 2005, and close to 90% of this water was used to support mainly thermal-electric power generation as well as economic activities (Statistics Canada, 2010). Pulp and paper, mining operations, and the oil and gas industries represent the three main industries in Canada. According to 2005 data, manufacturing sector, including the pulp and paper industry, used 14% of the withdrawn water, and petroleum and coal industries used another 12%. Agricultural sector was responsible for 5% of the water. Among all sectors, petroleum and coal industries had the highest reuse and recirculation of process water reaching 140% (Statistics Canada, 2010).

Economic growth coupled with urbanization play a major role in determining the water demands and withdrawals. Increasing water

Figure 1. Lake Moraine (Banff National Park, Alberta) is one of the many thousands of lakes in Canada. Photo credit: ©iStock.com/estivillml

withdrawals can put a stress on water resources and pose a threat to aquatic ecosystems and fish. In addition, anthropogenic activities are likely to cause the contamination of water bodies and may significantly decrease the overall quality of water. Eutrophication of Great Lakes, industrial activities in Southern Ontario and Southern Quebec, oil sands mining operations in Alberta (Figure 3), hydroelectric power developments in northern Quebec and Labrador, agricultural activities in Prairies, and overexploitation of groundwater are some of the main stresses on water resources in Canada (Hipel et al., 2013). In the near future, rapidly growing oil sands mining operations in Alberta and Saskatchewan, which require massive quantities of water to extract and process bitumen from oil sands, and the emerging hydraulic fracturing of shale gas, particularly in Alberta and British Columbia, are expected to increase the demand and threat to both surface waters and groundwater.

Figure 2. Ratio of August 2005 water intake to the August median water yield for 1971 to 2004



Source: Statistics Canada, 2010

Figure 3. An oil refinery located alongside the Athabasca River that processes the bitumen from oilsands. Fort McMurray, Alberta, Canada. Photo credit: ©iStock.com/Dan Barnes

Canada shares a long border with the United States and some of the water pollution originates from the US. Draining of the contaminated Devils Lake in North Dakota which empties into the Red River Basin in Manitoba and flows to downstream lakes and rivers such as Lake Winnipeg, has caused controversy between the two countries (Hipel et al., 2013). Concerns include the transfer of a wide range of chemical pollutants, sulphate compounds as well as unknown foreign aquatic species.

The Great Lakes basin is shared between Canada and the US, and is a major source of fresh water for both countries. Sewage, industrial discharges, fertilizers, and pesticides have caused adverse effects on the lakes decreasing the water quality and damaging the ecosystem. The Great Lakes Water Quality Agreement signed in 1972 between Canada and the US aims to restore and protect the water quality and wildlife in Great Lakes and was amended in 2012 to better address new and emerging issues such as climate change, invasive species, and habitat degradation.

2. Water Supply Services

Likely due to the availability and low price of water, Canadians are one of the highest per capita water users in the world. The water consumption in households was 298 litres per person per day in 2009 (Statistics Canada, 2011), which was twice as much water as compared to used in France and was slightly less than the per capita water use in the US. However, a decreasing trend in residential water use has been observed in Canada since 2006 (Environment Canada, 2011), which indicates a change in consumer behaviour towards a more sustainable approach to water use. In addition, increasing use of residential (72%) and commercial (87%) water metering over the past decade has helped to decrease the water consumption. The data from nationwide surveys indicate that non-metered households that pay a flat water rate use 65% more water compared to metered households that pay on a volume-based water rate (Environment Canada, 2011).

The 2011 Municipal Water Use Report (Environment Canada, 2011), provides the most recent results from a nationwide survey on municipal water and wastewater systems. The information obtained from the survey helps to make well-informed decisions on the efficient management of water and wastewater systems and identifying gaps where improvements and investments are needed. However, the survey does not include First Nations communities where the highest deficiency and need for water and wastewater treatment exists.

According to the survey results, 89% of Canadians are served by a water distribution system and 94% of them receive treated water. However, in smaller communities, the percent of people who are connected to a distribution system drop substantially. In communities with less than 1000 people, only 50% of the population is served by a water distribution system, while 47% rely on public wells and 2.5% use hauled water. 75% of the municipally supplied water is treated in these communities. In cities with a population more than 500,000, almost everyone (>98%) receive treated water from a water distribution system (Environment Canada, 2011).

Canadian municipalities mostly rely on surface water to provide water to their residents. In 2009, 90% of the municipal water was sourced from surface water and the remaining 10% was sourced from groundwater. The groundwater use was much higher in smaller municipalities reaching 50% for those with a population less than 1000. There was also a regional variation in ground water use. In Prince Edward Island, 100% of municipal water came from groundwater and in Territories groundwater constituted 70% of the municipal water supply (Environment Canada, 2011). It should also be noted that in Canada the entire water supply of more than 80% of the rural population come from groundwater (Environment Canada, 2014).

More than two-thirds of Canadians (68%) drank tap water regardless of whether the source was municipal or non-municipal water. In spite of a very good water treatment and distribution infrastructure, 22% of Canadians still preferred to use bottled water as their drinking water in 2011 but the bottled water use is slowly decreasing partly due to the education of the public on the safety of their drinking water. Additionally, 50% of Canadian households treated their water further at home mainly by using jug filters (33%) or using on-tap (20%) or main-pipe (11%) treatment systems. The main reasons cited for in-home water treatment units were the consumer desire to improve taste, odour, and appearance of water, and remove hardness, minerals and metals (Statistics Canada, 2011).

3. Treatment of Wastewater

Wastewater treatment is important for the protection of public health and environment. In general, Canada benefits from high-quality wastewater infrastructure and treatment in many of the provinces, but there are also places where no or little wastewater treatment is used. In rural areas, remoteness of communities and cold climatic conditions present unique challenges to the treatment of wastewater. Over 150 billion litres of untreated or undertreated sewage is dumped into to waterways every year in Canada (Environment Canada, 2012) which poses a threat to the quality of water supplies and consequently human health.

The responsibility of wastewater collection, treatment, and discharge is shared among the federal, provincial, and territorial governments and municipalities in Canada. In provinces and territories, the majority of wastewater collection and treatment infrastructures are owned and operated by municipalities. First Nations are the owners and operators of community infrastructures on reserves. Until recently, Canada did not have a national policy on wastewater treatment, which resulted in large differences among provinces and territories with respect to the level of wastewater treatment and effluent quality. In order to remedy this, the federal government established Canada's first national standards for wastewater treatment in July 2012. *The Wastewater Systems Effluent Regulations* created the basic treatment standards for wastewater treatment across Canada, requiring the use of secondary (biological) or equivalent treatment. The regulations also put in place additional requirements for monitoring, reporting and toxicity testing. The new standards apply to wastewater systems with an average daily influent volume of 100 m^3 or more, to which smaller systems do not have to comply. Wastewater systems in the far North, such as Nunavut, Newfoundland, Labrador, the Northwest Territories and Northern Quebec are exempt as well.

The new regulations do not allow wastewater systems to exceed 25 mg/L average carbonaceous biochemical oxygen demand (CBOD), 25 mg/L average concentration of suspended solids, 0.02 mg/L average concentration of total residual chlorine, and 1.25 mg/L maximum concentration of unionized ammonia expressed as nitrogen (N) at 15 °C ±1 °C. All owners and operators of wastewater treatment systems are required to monitor and report effluent quality and quantity. In addition, owners and operators of combined sewer systems are required to monitor, record and report the frequency and quantity of combined overflow discharges of untreated sewage to surface waters.

The regulations also provide timelines for treatment systems to achieve compliance based on a points system which takes into consideration the size of the community, risk factors and the sensitivity of the area. It was estimated that approximately 850 wastewater systems, which constituted to 25% of existing treatment facilities in Canada, needed to be upgraded to secondary or equivalent treatment (Environment Canada, 2012). These systems will be gradually phased in where high risk systems are given until 2020, medium risk systems until 2030, and low risk systems until 2040; and this is criticized for the long rollout time. During this period, wastewater treatment facilities can obtain "transitional authorizations" to allow them stay in operation until they are in compliance. The cost of these changes to the treatment systems, including the capital and operational costs, were estimated as $5.5 billion, and the expected benefits to Canada were estimated as $16.5 billion (Environment Canada, 2012).

According to the 2011 Municipal Water Use Report (Environment Canada, 2011), 43% of Canadians live in municipalities with a population less than 1,000 residents. On the level of wastewater treatment and connection to sewer system, 1524 municipalities with a combined population of 28.1 million responded to the survey. The results revealed that 87% of people in these municipalities were connected to sanitary sewer system whereas 12% were using septic tanks and 0.5% were using holding tanks and sewage haulage. From large municipalities with a population of 500,000 people or more, 98% had sewer access, but municipalities containing less than 1,000 people had only 47% sewer coverage. All provinces except Nova Scotia had higher than 86% of the population served with sanitary sewers. In Nova Scotia, 68% of the population was connected to sewers and 32% used private septic tanks. In three territories (Northwest Territories, Nunavut and Yukon), 76% of the population was served with sewers and private septic tank use was relatively low at 8%. Instead, 15% of population stored sewage in holding tanks, where sewage is removed and transported from homes to a central treatment or disposal facilities. Holding tanks are rarely used in other parts of Canada.

Figure 4 shows the level of wastewater treatment employed across Canada based on the population size of municipalities. The level of wastewater treatment varied from no treatment to preliminary treatment, primary treatment, secondary treatment and tertiary treatment depending on the size and location of the communities. In this context, no treatment means raw sewage as is, preliminary treatment is the removal of grit and large objects, primary treatment is the removal of solids using settling tanks, secondary treatment is the biological removal of organic matter using lagoons, secondary-mechanical treatment is the biological removal of organic matter at treatment plants, and tertiary treatment is the removal of mainly nutrients such as nitrogen and phosphorus. Of approximately 24.5 million people connected to the sewer system, 55% received secondary-mechanical treatment, 7% had secondary treatment in sewage lagoons and 17% received tertiary treatment. However, 3% received no treatment or only preliminary treatment and 18% received primary treatment. It should also be noted the percent of people with no treatment, preliminary treatment or primary treatment would be substantially higher in rural areas where there is no sewer system, which was not included in the data used for this figure.

The data also showed that municipalities with less than 5,000 people had higher percentages of no treatment, preliminary treatment and primary treatment. For municipalities with less than 1,000 people, approximately 25% of wastewater was either not treated or minimally treated, but the remaining portion received secondary treatment in lagoons. For municipalities with less than 5,000 people, lagoon based wastewater systems were prevalent (approximately 50%). Percentage of secondary-mechanical treatment increased with increasing population, and constituted for 60% of treatment for municipalities with populations greater than 500,000.

Figure 4. Wastewater treatment level by municipal size group (Source: Environment Canada, 2011).

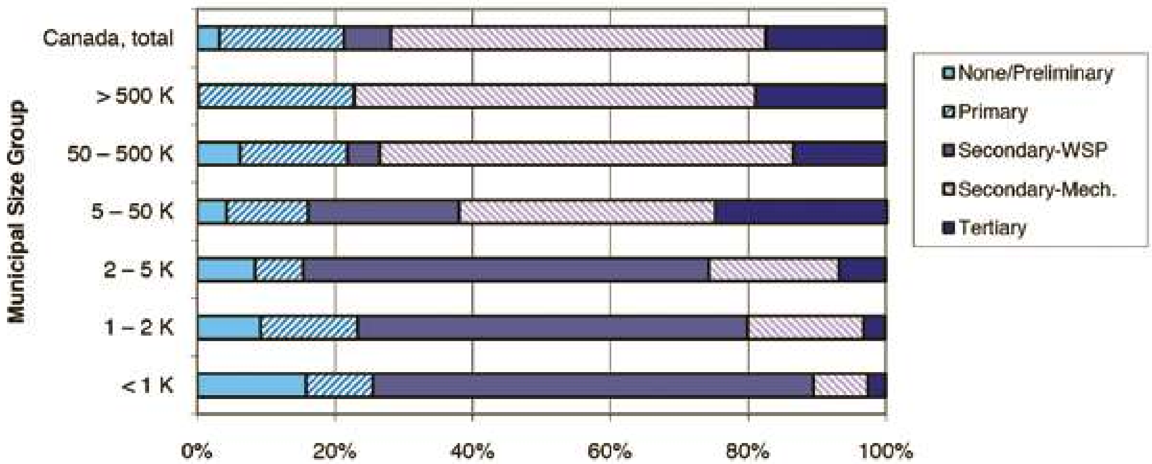


Figure 5. Wastewater treatment levels by province and territory (Source: Environment Canada, 2011).

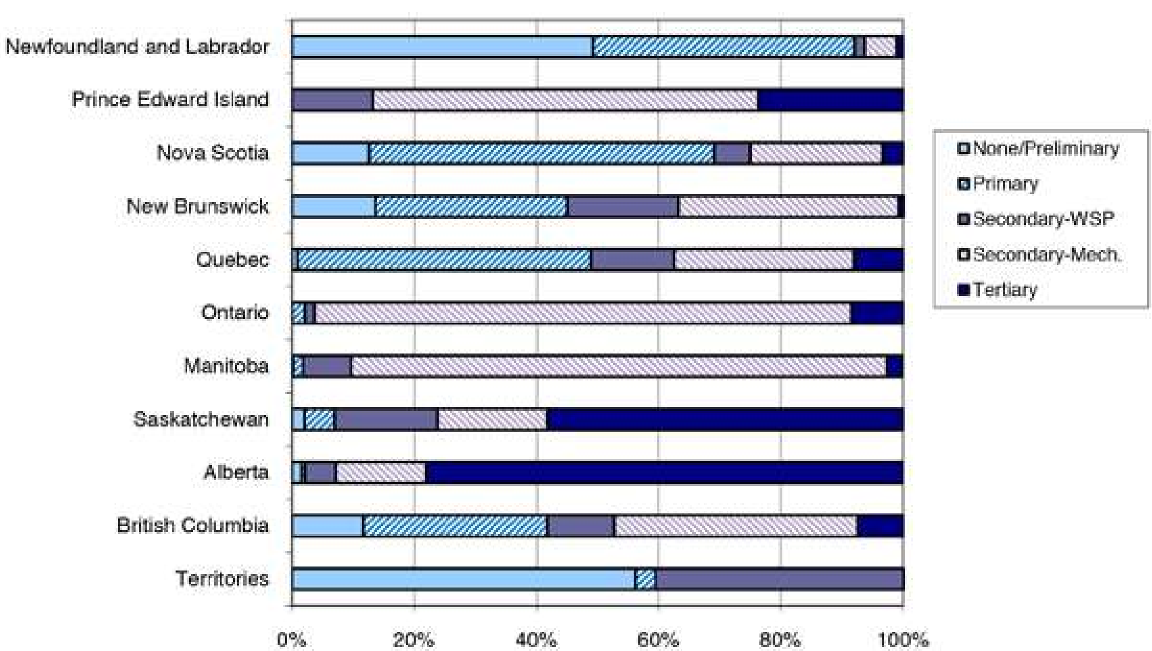
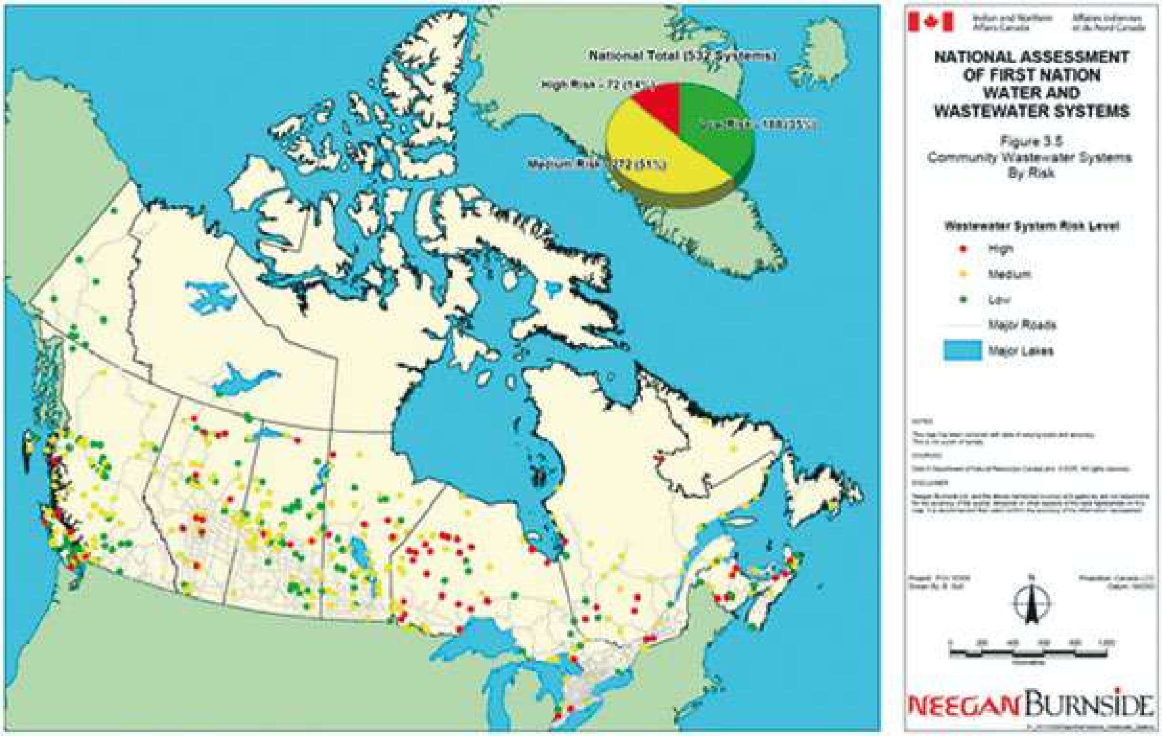


Figure 6. First Nations Community Wastewater Systems categorized by high, medium, and low risk (Source: Neegan Burnside, 2011).



The level of wastewater treatment employed in provinces and territories varies widely (Figure 5). Approximately 50% of wastewater did not receive any treatment in Newfoundland and Labrador, and 40% received only preliminary treatment. Similarly, close to 60% of wastewater did not receive treatment in territories, but the remaining 40% received secondary treatment in lagoon based treatment systems. Even in Quebec, British Columbia, New Brunswick and Nova Scotia, 40-65% of wastewater did not receive any biological treatment and was limited to preliminary and primary treatment. In Ontario, Manitoba, Saskatchewan and Alberta, more than 90% of wastewater received biological or superior treatment but tertiary treatment was minimal in Ontario and Manitoba. The best municipal wastewater treatment in Canada was employed in Alberta and Saskatchewan, where approximately 40-60% of wastewater received tertiary treatment.

The status of water and wastewater infrastructure is of particular concern in aboriginal communities and requires substantial investment to meet acceptable effluent quality standards. The federal government undertook the National Assessment of First Nations Water and Wastewater Systems between 2009 and 2010 to assess the water and wastewater infrastructure on First Nations lands, evaluate the risk factors associated with their management, and identify the needs for upgrades (Neegan Burnside, 2011). Such a comprehensive and independent survey was carried out for the first time in Canada and 97% of First Nation communities participated in the survey. The study reported that 153 First Nation communities were exclusively serviced by septic tanks and 418 First Nation communities employed 532 wastewater systems which mainly consisted of wastewater treatment lagoons. Overall, 54% of homes were connected to sewers, 36% had septic tanks and other individual treatment systems, 8% were on truck haul, and 2% had no service. The overall management risk for the wastewater systems was also evaluated where factors such as operation and maintenance, operator training and qualification, and record keeping were conjointly considered. Figure 6 shows the distribution of the low, medium, and high risk systems across Canada. For the 532 wastewater systems that were evaluated, 14% were identified as high-risk, 51% as medium risk, and 35% as low risk. Ontario had the highest percentage (36%) of wastewater systems that were categorized as high risk compared to other provinces. As predicted, least accessible First Nations due to their remoteness had higher percentages of high-risk wastewater systems. The report also identified the cost for the necessary upgrades of water and wastewater systems on First Nations lands as $1.2 billion.

4. Water and Health

Canada has a well-established network of water systems, and overall Canadians enjoy safe and high-quality drinking water. Waterborne outbreaks are rare, but they continue to occur particularly in rural regions and aboriginal communities where operation and maintenance of water treatment and distribution systems are difficult. Cold climate conditions also present unique challenges for the design and installation of water systems. Additionally, a large percentage of the population rely on groundwater systems and individual wells, which are more susceptible to contamination and increase the risk of waterborne diseases. According to an Environment Canada report, 30% of Canadians and 80% of rural population rely on groundwater for their water use (Nowlan, 2005).

There is no national surveillance system to track the occurrence and frequency of waterborne diseases and outbreaks in Canada, and it is likely that a large percentage of incidents are not recognized or reported in the first place. Canada has experienced a number of waterborne outbreaks in recent past, the Walkerton outbreak in 2000 where 7 people died and approximately 2,500 people got sick being the most important one. In Walkerton, the groundwater supply was contaminated with the O157:H7 strain of E. coli from farm runoff, and several factors including the lack of formal training and improper operating practices of the water treatment personnel contributed to the tragedy. The total cost of the Walkerton outbreak, including the tangible and intangible costs amounted to $155 million (Livernois, 2002). The tragedy led to many changes in provincial policies and legislation across Canada on the safety and quality of drinking water and resulted in improvements in the source water protection, training and certification of operators, and management and operation of water systems. More importantly, the Walkerton outbreak led to the establishment of effective programs and centres (e.g., Walkerton Clean Water Centre, Ontario Clean Water Agency) that target the training of treatment personnel and the proper operation of treatment and distribution systems with a focus on smaller, remote and older systems. Other high-profile waterborne outbreaks in Canada include the cryptosporidiosis outbreak in North Battleford, Saskatchewan in 2001 where 2,000 people got sick, and the Kashechewan outbreak in Northern Ontario in 2005 where 2,000 aboriginal people got infected due to a mechanical malfunction at the water treatment plant. Almost everyone on the Kashechewan reserve had to be airlifted to Ontario communities for the necessary treatment and living arrangements.

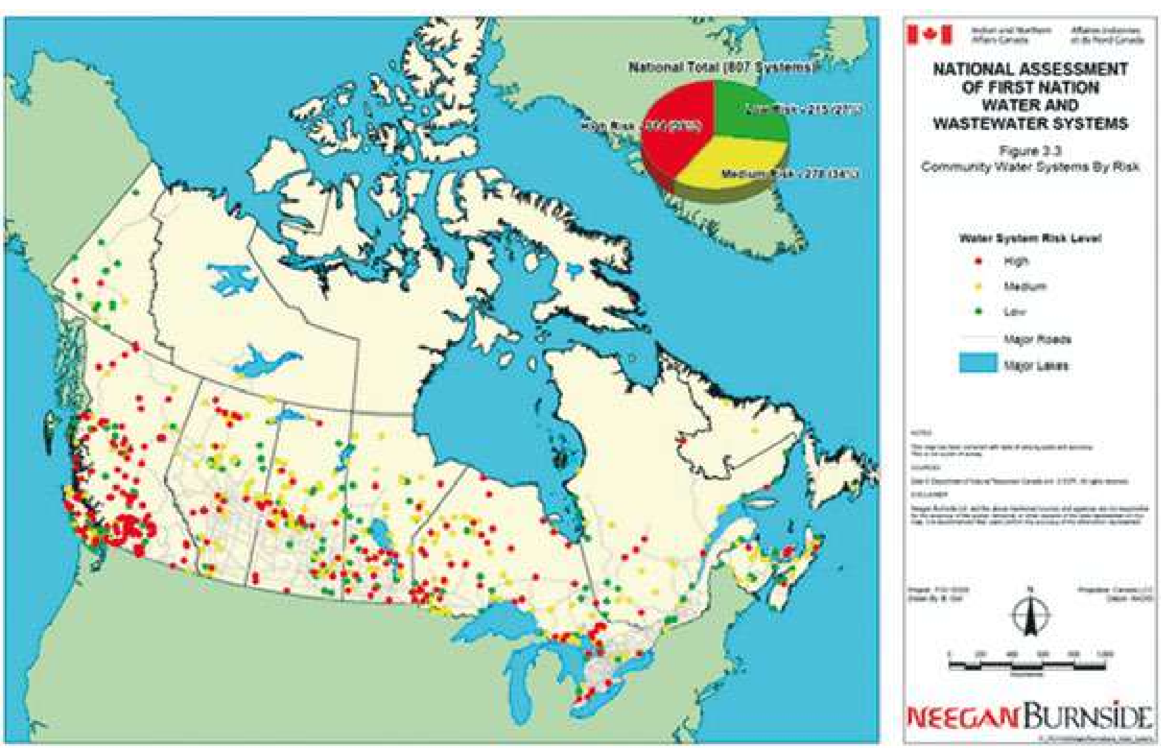
A comprehensive surveillance for the occurrence of drinking water related illnesses in Canada between 1993 and 2008 was carried out and published in a report in 2009 (Wilson et al., 2009). Based on the responses to questionnaires and interviews, 47 waterborne disease events (WBE) were identified in this time frame. On average 5-6 WBE's per year occurred before 2001, and after 2001 there was a substantial drop to 1-2 WBEs per year, which was likely due to the measures taken after Walkerton and North Battleford. *Giardia* and *Cryptosporidium* were the etiologic agents behind 40% of the WBEs. Infections due to *Giardia* and *Cryptosporidium* were most common when surface water was used as the water source and infections due to bacteria and viruses (*E. coli, Salmonella, S. aureus, Norovirus, Hepatitis A*) were most common in groundwater. In 50, 39 and 11 percent of the WBEs, the water source that caused the outbreak came from surface water, ground water, and mixed surface and groundwater respectively, indicating that half of the outbreaks were caused by source water from rivers and lakes that are more vulnerable to contamination. Interestingly, *Giardia*, bacteria and viruses were the predominant causative agents when no treatment or only disinfection was used, whereas *Cryptosporidium* was the main cause of the outbreaks in water systems that used filtration and disinfection. Frequency of the WBE's was 6 times higher in communities with less than 1,000 people compared to communities with more than 100,000 people.

The level and quality of water treatment plays a major role in preventing waterborne diseases. In 2007, 55% of treated water came from conventional treatment and direct filtration plants, serving half of the Canadian population (Statistics Canada, 2009). Approximately 8.7% of Canadians living in communities of 300 or more people received their water from a water system without any treatment. For private systems such as wells, only 35% of owners reported testing their water (Statistics Canada, 2007) and 21% reported having never tested their water (Jones et al., 2007).

Small drinking water systems are of particular concern for waterborne diseases since they often face a wide range of challenges. The factors contributing to waterborne disease outbreaks in Canada, particularly in small systems, were found to be related to lack of source water protection; precipitation, high turbidity, spring thaw and run off; inadequate or malfunctioning water treatment systems; malfunctioning water distribution systems; and other factors such as human error (Moffatt and Struck, 2011). Changes in water infrastructure, treatment operations and practices, and extreme weather events were strongly associated with the occurrence of outbreaks and it was suggested to take these changes as a warning sign for potential outbreaks and to take the necessary precautions (Hrudey and Hrudey, 2004). It was also noted that monitoring of water quality such as indicator bacteria, pathogens, turbidity and residual chlorine can be very effective in preventing waterborne disease outbreaks if implemented and maintained by government bodies rather than private owners or operators (Moffatt and Struck, 2011).

The inadequacy of drinking water and wastewater systems in First Nation communities has been well-known and well-documented. In spite of substantial investment for water and wastewater systems in First Nation communities, problems persist and there are still a staggering number of boil and drinking water advisories in these communities. In Canada, the Aboriginal Affairs and Northern Development Canada (AANDC) provides funding and advice to assist with the design, construction, operation, maintenance of water and

Figure 7. First Nations Community Water Systems categorized by high, medium, and low risk (Source: Neegan Burnside, 2011).



wastewater systems and training and certification of operators. However, First Nations are responsible for the daily operation and management of their water and wastewater systems.

The results of the National Assessment of First Nations Water and Wastewater Systems (Neegan Burnside, 2011) revealed that from the 807 drinking water systems inspected 39% were found high-risk, 34% medium risk, and 27% as low risk. Figure 7 shows that high, medium, and low risk water systems were distributed throughout Canada and were not localized to particular First Nation communities. British Columbia (53%) and Ontario (46%) had the greatest percentage of high-risk water systems. The majority of high-risk systems were found in small communities and only 30% of the risk in these high-risk systems was attributed to the design and infrastructure of the water systems. This emphasizes the importance and need for operator training in First Nations communities. The Circuit Rider Training Program aims to address the gaps in this area. The program provides on-going and hands on training to the First Nation operators on their own systems and aims to achieve the safe operation and maintenance of the water systems. The program also runs a 24-hour hotline to assist the operators with their questions and emergencies.

In Canada, drinking water advisories are issued as a preventive measure when there is suspicion that drinking water may pose a risk to the public. A boil-water advisory means that water should be brought to a rolling boil for one minute before consumption in order to kill pathogenic microorganisms. High coliform counts or high turbidity in water may trigger a boil-water advisory. According to a Health Canada report (2009), the length of the boil water advisories varied from 1 day to 13 years between 1995 and 2007. The average duration of the boil water advisories were 343 days and the median was 39 days, and the discrepancy was caused by the skewed average due to the years of ongoing boil water advisories in some communities. 35% of boil water advisories were resolved within two weeks, and 75% were resolved within one year. However, 25% of all boil water advisories lasted longer than one year and some extended for several years with no break. Data obtained on October 31, 2011 through Access to Information legislation showed that the average duration of a boil water advisory in First Nation communities continued to increase to 772.6 days, 38% of which were in place for more than 5 years and 70% for more than 2 years (Young, 2012).

5. Climate Change and Influence on Water Resources

Global climate models predict an increase in precipitation and evaporation between 3 and 15 percent when CO_2 is doubled in the atmosphere. According to a 2014 report by the Intergovernmental Panel on Climate Change, the annual greenhouse gas emissions (GHG) reached 49.5 billions of tons of carbon dioxide equivalent in 2010 and continue to increase (IPCC, 2014a). The climate models also predict severe weather events, such as major storms, hurricanes, floods, droughts, and ice melts in the near future. It is well-known that changes and variability in climate will lead to a shift in the availability and distribution of water, which are being noticed in many regions in Canada (Figure 8). Rising temperatures, increasing ice melt and evaporation will affect the seasonal variability of water and will further increase the competition among municipal, industrial and agricultural use of water in Canada in the near future (IPCC, 2014b). Water resources are already overused due to rapid economic and population growth in Southern Canada, and climate change will exert additional water stress.

One of the main climate change induced water problems in Canada is the melting glaciers of the Rocky Mountains of Western Canada (British Columbia, western edge of Alberta, and eastern Arctic) and the drought it is intensifying in Prairie provinces (Alberta, Saskatchewan, and Manitoba) (Hipel et al, 2013). Approximately 2% of Canada is covered by glaciers and after Antarctica and Greenland, Canada has the highest amount of glacial ice (CCME, 2003). Glaciers store water as ice in the winter and slowly release the melting water in the summer when it is needed most for municipal, agricultural and industrial use. Melting of glaciers has significantly changed the seasonal flow patterns of rivers that flow across the Prairie provinces, and 20-84% of reduction in summer flows were reported (Schindler and Donahue, 2006). Warmer temperatures, increasing precipitation and snow melt, and extreme weather events also impact the water quality by increasing the carriage of sediments, nutrients and a wide range of pollutants (e.g., fertilizers, pesticides, endocrine disrupting compounds) into surface waters and aquifers. In addition, the increased frequency and strength of rain and storm events will increase the sewer overflows and discharge of untreated sewage to surface waters, which is already a big problem in most Canadian cities. The negative impact of climate change on water quality is seen in many provinces, particularly in Ontario and Quebec, where nutrient-enriched lakes and warmer temperatures have resulted in toxic blue-green algae blooms making the water unsuitable for human consumption.

Other impacts of warmer temperatures on water systems include rising sea levels on the Pacific coast, potential flooding in low-lying areas and heavily populated deltas, pre-spawning mortality of the Pacific salmon, increased number of forest fires, more frequent droughts in Prairies, temperature increase in Great Lakes and decrease in water levels, disappearance of wetlands, gradual melting of permafrost, and contamination of aquifers with salt water and pollutants (Environment Canada, 2014).

Climate caused changes on water systems can have important consequences for the environment, economy and public health (TRCA and ESSA, 2012). The cost of flooding in southern Alberta in 2010 was $956 million and the impact of the 2001-2002 drought in Saskatchewan was the loss of $6 billion in GDP and 41,000 jobs. In 2005, a summer storm in southwestern Ontario and the flooding followed resulted in insurance claims of $500 million. Severe rain and storms have also played a role in the waterborne disease outbreaks in Walkerton, Ontario (2000) and North Battleford, Saskatchewan (2001), and numerous boil water advisories in remote regions and aboriginal communities.

Based on the increased severity and frequency of weather and water hazards that are seen globally, it is clear that countries need to rethink and revise their approach to water management (IPCC, 2014a; TRCA and ESSA, 2012). Canada is taking steps towards developing an adaptive, flexible, and risk-based approach to water management that requires an integrated analysis of water and wastewater infrastructure as well as adopting new policies and management practices for all water resources.

Figure 8. Melting iceberg and glacier at the Jasper National Park (Alberta, Canada). Photo credit: ©iStock.com/coryz.

6. Conclusions

Canada has access to approximately 20% of the world's stock of surface water. However, because of the uneven distribution of population and water supplies, many regions experience water shortages. In addition, water problems caused by population increase, urbanization, economic development, and climate change are on the rise, and have started to pose a threat to both the quality and quantity of surface waters and groundwater. Overall, Canada has a good network of water and wastewater infrastructure and can provide safe drinking water and good sanitation to its citizens. Nevertheless, there are also many small communities, particularly First Nations reserves, which suffer from continuous and persistent problems with the safety of drinking water and the contamination of water supplies due to inadequate wastewater treatment. Remoteness and cold climate conditions exert additional challenges to the design, construction and operation of water and wastewater infrastructure. As a result, waterborne outbreaks still occur in Canada but their frequency has substantially dropped in the past decade mainly due to the investments made to the water and wastewater infrastructure and training programs put in place for small system operators.

7. Acknowledgment

Figures 2, 4, 5, 6 and 7 are obtained with permission from reports published by the Government of Canada. The content of this chapter has not been produced in affiliation with or with the endorsement of the Government of Canada.

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