Canadian Fuels
ASSOCIATION
canadienne des carburants

Water – A Precious Resource

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Canadian Fuels Association

Canada's Water Resources

Relative to other countries, Canada is blessed with an abundance of high quality fresh water and large water ecosystems that support a large and diverse array of plant and animal wildlife.

In some areas of Canada though, that resource is under severe stress – both the available quantity due to increasing demand from all sectors and the quality of the water ecosystem.

Governments are actively engaged in developing sound policies to dramatically improve the management and protection of Canada's water resources.

The petroleum refining industry has been a leader in responsibly managing its use of water and supports the broad policy undertakings currently underway by Canadian governments.

This paper describes the role of water in today's petroleum refining industry in Canada against a backdrop of a history of Canadian leadership by the industry in managing its use of water responsibly over the past century.

Section II

How is Fresh Water used in Petroleum Refining?

Water and energy systems constitute the foundation for modern infrastructures and quality of life around the world. All of the major energy production systems in North America from primary fuel sources (coal, natural gas, petroleum), to power generation (hydroelectric, fossil fuelled thermoelectric, nuclear) to biofuels require water as a critical input. The need for water varies from steam production to cooling. Water and energy infrastructure are interdependent.

Section II is about fresh water and its importance to petroleum refining. It is intended to provide a background level of understanding to readers unfamiliar with the petroleum refining industry and the key role that water plays in the operation of an oil refinery. It also focuses on the path ahead and what Canadian Fuels refiners are doing to improve the quality of their water effluents and minimize their consumption of water.

A discussion on water must start with distinguishing between water use and water consumption. *Water use* is a measure of the amount of water that is withdrawn from a source body of water (lakes, streams, rivers), passes through an energy production process and is then ultimately cleaned and discharged back into the source body of water. *Water consumption* refers to water intake into an energy production operation and not returned back to the source body of water.

Water is used in the refinery in many different ways. In many cases, the water withdrawn from the source is used, treated and returned. Only a portion of the water withdrawn is consumed as a chemical feedstock or lost to evaporation in a cooling tower. In fact, in some areas of the country, the amount of water collected and treated at the site from crude and rainwater actually exceeds the refinery water consumption. At these sites, the refinery returns more water to the source than it removes! In more arid regions of the country, where there is a shortage of large water bodies and cooling towers are more prevalent, the water use is lower and the water consumption is higher. Typically, 6 litres of water are consumed to produce a litre of gasoline (source: Argonne National Laboratory). To put this into perspective it takes around 6814 litres of water to grow enough cotton to produce just one pair of regular blue jeans; it takes 7 litres of water to manufacture the plastic for the bottle in the average commercial bottle of water (source: treehugger.com). Each person consumes 45 litres of water taking a bath or shower (source: Orange County Water District).

The members of the Canadian Fuels Association currently operate fourteen refineries across Canada.

Water used to remove salt from crude oil

All conventional crude oils (except synthetic or bitumen) contain salt. This salt must be removed from the crude oil as a first step in processing. This occurs in a desalter where crude and fresh water are intimately mixed at about 105 degrees Celsius (C). The salt dissolves in the water phase and the brine is removed from the crude. Typically, the treatment rate is 7% by volume of fresh water.

Water used as a process fluid

In the form of steam
There are many refining process units where water, in the form of steam, is required to come into contact with hydrocarbons to facilitate processing. All the water is recovered and either reused or returned after treatment to the water source, or disposed into deep underground wells.

In the form of condensate
Wash water is used primarily for corrosion control.

Water used as a heating fluid
All refineries need water in the form of steam for heating purposes. For this use, the steam does not come in direct contact with the hydrocarbon. Most refineries will use the pressure energy in the steam to drive the motors of rotating equipment (pumps, compressors, air blowers) instead of using electricity, prior to then using the steam as a heating medium. Most of the steam (60 – 90%) will be recovered as hot liquid condensate (hot water) and recycled for reuse. In addition to the steam plant, all refineries recover waste heat from refinery furnace and boiler stacks to boil water and convert to steam for use as a heating medium.

Water used as chemical feedstock
Most refineries use treated fresh water as a chemical feedstock for the synthesis of hydrogen – which is needed in the refinery to remove sulphur from fuel products and to upgrade heavy oil to transportation fuels.

Water used as a cooling fluid
The largest single use of water is as a fluid to cool most hydrocarbon streams to safe storage temperatures, which is about 5 to10 degrees C above ambient temperatures. All refineries are heavily heat integrated with heat exchangers to transfer heat from hot hydrocarbon streams to cooler ones. Water cooling represents typically the last cooling step to return the hydrocarbon close to ambient temperature. None of the cooling water comes into contact with the hydrocarbon and after use is either recycled or returned to the source body of fresh water.

Cooling Water Systems
There are two primary types of refining cooling water systems.

Once Through Cooling Water (OTCW) – These systems take water from the source and use it once only for cooling and then return the warmer water without any change in water quality to the water source.

Cooling Water Systems (CWS) (Recirculating) - These systems recover and reuse cooling water many times over. The heat picked up by the cooling water is released to atmosphere through evaporation in a cooling tower. About 10% of the water is lost to atmosphere as water vapour to cool the rest of the water. These systems build up contaminant levels and therefore, require purge rates of 2 to 5% of total flow. The purged water is routed to the water effluent treating system to keep these contaminants from being discharged into the environment. Water makeup rates therefore are approximately 15% of total flow. These systems typically return approximately 85% of the water intake. To prevent growth of algae, such systems need to be treated with algaecides.

Air Fin Coolers: Some refineries have moved away from water as the cooling medium to ambient air as the cooling medium. This requires much larger "air fin" (with forced air circulation) heat exchangers. The cooled hydrocarbon streams must still be cooled with water exchangers (called trim coolers) as in summer most air fins cannot meet the low final temperature requirements for the hydrocarbon streams. However, a refinery constructed with air fin coolers will typically require about 60 - 70% less cooling water than a refinery without air fin coolers.

Fire Water

All refineries need access to reliable and instant access to large amounts of water in the event of a refinery fire. The water is required to cool the fire and prevent the spread of the fire to other process units and petroleum storage tanks in the refinery. When water is put on a fire, it acts to exclude air (oxygen), which helps extinguish the fire.

Section III

Petroleum Refining and Water – A History of Continuous Improvement

Access to fresh clean water has always been a prerequisite for petroleum refining. In Canada, the industry recognized the importance of water and its management – with an on-going track record of continuous improvement.

1950's – Application of Biological Oxidation Process for treatment of refinery waste water effluents. This technology was an adaptation of living organisms used in municipal waste water treatment plants to virtually eliminate the traces of dissolved hydrocarbons and other contaminants (ammonia, nitrates, sulphides) in refinery waste water. The enzymes were tailored specifically to deliberately convert petroleum refinery water effluent contaminants to harmless by-products (water, carbon dioxide and nitrogen). This process is now used universally in every refinery in the world – with effluent quality, that in most cases, exceeds drinking water standards. It was the first and still remains one of the unique examples of the use of a living biological process to treat industrial waste water effluents.

1960's – Several Canadian refineries worked in concert with the federal government (PACE - Petroleum Association for Conservation of the Environment) to study the behaviour of live fish in treated refinery effluents. This was the first sector in Canada (and the world) to use and research the behaviour of live fish living in treated refinery effluents (prior to the discharge of the effluent back into the water source). Over the next 15 years, coarse fish (perch, carp) were replaced with more sensitive species (rainbow trout). Since the fish thrived and with no fish kills nor impairment, refiners worked cooperatively with the federal government to send live fish (after one month exposure to effluent) to determine uptake of residual contaminants in fish flesh (called tainting). Refineries were essentially living laboratories to research and development on Canadian fish species in regards to exposure to some classes of trace industrial contaminants.

1970's – Water conservation efforts led to the construction of more recycled cooling water systems for 60 to 80 percent reduction in water intake. In some cases, refineries also began a gradual process of displacing water cooling exchangers with air cooling exchangers.

1980's – Ontario refineries, working with the Ontario government, embarked on research into the most sensitive aquatic species (water fleas – Daphnia Pulex and Daphnia Magna) to test mortality, morbidity and ability to reproduce. This work led to the development of stringent water regulations, which were fully met by the petroleum refining sector.

1990's - Canadian refineries typically perform with water effluents at about 7-12 percent of maximum allowed concentration limits for trace contaminants, and usually return the water used back to the water source cleaner than the water intake from the water source to the refinery.

2000's – Some refineries are now using activated carbon filters to further lower contaminant levels.

Section IV

Examples of Current Continuous Improvement

There are several types of water actions that Canadian Fuels members are taking or planning. These kinds of improvements fall into a few groupings:

- Further Reduce the quantity of water used
- Further Protect the quality of returned water
- Provide education and involvement in working to address water challenges

Imperial and Shell – RiverWatch

Water management is a key environmental focus for our members and it's why they are happy to support a unique program at the RiverWatch Institute of Alberta. RiverWatch was started in 1995 by a group of three Calgary teachers who wanted to change the way students were able to learn about aquatic ecosystems. Students get to take part in an environmental monitoring program where they experience hands-on, real-world science. Students begin their five-hour day with RiverWatch by asking the question, how healthy is our river? They then follow a scientific process to form their hypothesis, gather and test water samples and analyze the data. Imperial and Shell through their refineries in Alberta, have been proud supporters of RiverWatch for many years.

Parkland Burnaby Refinery – Deep Shaft Wastewater Treatment System

Parkland is perhaps the first refinery in North America to use a deep shaft bio-remediation system for treating wastewater. The refinery, located adjacent to a residential neighbourhood, has a relatively small footprint that cannot accommodate a traditional water treatment facility. Instead, in the 1990s, Parkland installed the deep shaft to provide an extra layer of secondary treatment.

The Burnaby Refinery collects all water from steam generators and recirculating cooling systems. Every process unit in the entire refinery ties into an underground sewer system. From there, all the liquid is diverted into three retention ponds and pumped from there into a shaft. Once there, the water goes through a secondary treatment process in which aerobic bacteria "eat" the contaminants in the water. Oxygen is added to the water in the shaft which creates an environment to effectively treat and remove the contaminants. As the water is returned to the surface, it flows over gravel for yet another layer of cleaning.

The returned water is next tested to ensure it meets regulatory requirements and is then released into a municipal sewer system before moving on to Metro Vancouver's sewer system, where it is treated again.

The shaft is over 100 metres deep. The treatment plant covers 697 square metres and is powered by 56 kilowatts at peak load. However, a traditional aerobic water cleaning system would cover an area about five times as large and require twice the energy to operate.

It's Parkland's innovative, good neighbour solution to the challenge of being located where land is in short supply and where the only real direction they could expand was down.

Co-op Refinery Complex (CRC) – Wastewater Improvement Project

It was a colossal, $200 million project that took more than seven years to build. When the Wastewater Improvement Project becomes fully operational, in the Fall of 2016, CRC will be the only North American refinery recycling all of its daily 2 million gallons of wastewater, with two-thirds of it going into steam production. Water is critical to the operations of the CRC, because it uses steam to refine crude oil.

The refinery has a lot of well water that it uses from the aquifer below it. When CRC completed their expansion, they didn't have enough well water from the City of Regina, which was not a sustainable solution. The Water Security Agency left it to CRC to come up with a solution, and their solution was to recycle water. CRC came up with a "zero discharge" design, reducing the need to pull water out of the ground and eliminating the need to use the municipal water supply. The project has freed up enough water to serve the equivalent of 3,100 households in the City of Regina per year.

The CRC's system is a multi-pronged approach. For starters, the refinery uses every drop of water that falls on its 800-acre property. When there are heavy rain or snowfalls, the project allows CRC to draw less from the wells. There are storm water ponds all over the complex.

A special blend of live bacteria eats the impurities in the wastewater ponds. Spaghetti-like, hollow strands of "Zee Weed" filter wastewater to remove suspended solids.
The system then employs high-efficiency reverse osmosis to clean wastewater for steam production, using GE technology. Sixty-five per cent of the recycled water goes into steam production, with the remaining recycled water being reused in other processes such as cooling and hydrogen production. After being recycled multiple times, water that can no longer be recycled is disposed of in deep wells, including any excess brine.

CRC has reduced their water footprint and their air emission footprint.
The overall result is a significant reduction in both water usage and emissions from volatile organic compounds, which has the added benefit of reducing odours.

Suncor - Strathcona, Alberta Refinery

A recycled water line from the City of Edmonton's Gold Bar Wastewater Treatment Plant reduces the amount of water drawn directly from the North Saskatchewan River and provides water for Suncor's Strathcona County refinery. The 5.5-kilometre pipeline, the first of its kind in Canada, sets a new standard for environmental best practices. The award-winning project meets Suncor's water needs for new processes and provides surplus water for other users along the river valley, including the Sunridge and Nordic ski clubs for snowmaking and the parks system for irrigation and pond recharging. The public-private partnership between the City of Edmonton, Suncor and Strathcona County was funded by Suncor for approximately $25 million.

The membrane-treated water is cleaner than the wastewater formerly returned to the river at Gold Bar. The recycled water will help Suncor meet new federal standards in the manufacture of fuels to reduce vehicle emissions. Suncor will use the water to produce hydrogen and for general refining purposes, such as steam production and cooling.

Under the water line arrangement, Strathcona County will purchase the recycled water, operate and maintain the pipeline on behalf of Suncor, and deliver the water to the refinery. About 30% of the water used for refining processes will be returned to the river through the Alberta Capital Region Wastewater Treatment Plant.

The Recycled Water Line project has been singled out by the Alberta Government for going beyond expectations in protecting water resources and exemplifying the province's Water for Life strategy.

Suncor

In 2009, with an investment of nearly $2 million, Suncor launched three new water partnerships created jointly with Canadian Parks and Wilderness Society, Centre for Affordable Water and Sanitation Technology and Alberta Ecotrust Foundation. The programs created through these partnerships will educate and empower youth to make socially responsible decisions when it comes to water and to be role models for others in their water stewardship. Protecting water and water-related ecosystems is important to Suncor, which is why the company is focusing its Community Partnerships environmental funding in these areas. These new partnerships support the corporate-wide water principles that guide business operations around the world and help consistently manage the water footprint.

Imperial Oil - Sarnia Site

Upgraded cooling water treatment means less freshwater use. Improvements to plant operations, is a continuous focus at Imperial Oil. In 2006, Imperial upgraded one of the cooling water systems at the Sarnia site. Cooling water is now able to be recycled for longer periods of time, which resulted in 66% less water being used (from 318 m3 per day to 95 m3 per day). In addition, the reduced water stream from the cooling tower directionally improved the effectiveness of the water treatment facility and hence, clean-up of the water stream before it was returned to the river.

Imperial Oil - Youth Education on Water Management in 2008

The Society for Environment and Energy Studies Development (SEEDS) introduced the Water Systems and Habitats educational module to Grade 7 to 12 students across Canada. The module instructs students in making informed decisions about the responsible allocation of water. It presents a case study based on a real-life development project outside Calgary. In this case study, there is not enough available water in the immediate area to support the project and to make it work would require negotiation of water rights from surrounding regions.

Students assume the point of view of one of 12 stakeholders, playing roles such as the developer, mayor, environmental activist, rancher, or farmer. They then work through water allocation issues by looking at the project’s rationale and options. In the end, each decides, based on what they’ve learned, their perspective and their own thought processes, whether they would give the project the green light or not. Their results are presented in a final statement to their classmates and teacher. This module is part of the SEEDS Habitat in the Balance series which Imperial Oil is funding with $500,000 over five years.

Shell – Scotford Refinery

Beginning operation in 1983, Shell Scotford refinery is one of North America's most modern refineries utilizing energy efficient processing technologies and an environmental design basis including water conservation features. Included in the design basis is air cooling of process streams eliminating the need for cooling water systems thus avoiding water use and the need for water treatment. Process water from hydrocracking/hydrotreating processes is segregated and until recently was injected in deep well, leaving storm water and utility blowdowns as streams being returned to the North Saskatchewan River. Effective 2003 as part of the integration of processes with the Shell Scotford upgrader, refinery process water is treated at the upgrader, a portion of which is recycled back to the refinery as process make up water, and the balance is treated and returned to the river. Effectively more than 50% of the previously injected water in deep well is now recovered.

Shell – Sarnia Refinery

The Shell refinery is participating in ongoing pilot work led by the Council of Great Lakes Industries to assess water stewardship tools and their applicability in the Great Lakes Region. The Council represents industries and businesses with significant investments, facilities, products, or services in the Great Lakes region. Members are drawn from manufacturing, utilities, transportation, natural resources, financial, services, and trade.

Valero – Refinery Wastewater Treatment Plant Upgrade

In September 2019, Valero completed upgrades to their refinery wastewater treatment plant which aimed to increase nitrification capacity to minimize free ammonia discharge. The new WWTP design included:

- Two American Petroleum Institute separators for optimum oil separation
- A two-train moving bed biofilm reactor with two processing stages
- Two dissolved air flotation biological sludge separators

and offers complete redundancy of the process to facilitate maintenance activities without impacting production or the environment.
Discharge of treated wastewater directly to the St. Lawrence River began in May 2020, and although the previous system was fully compliant, the new one has demonstrated significantly improved results including 75 percent reduction of ammoniacal nitrogen.

Alberta Water Conservation Efficiency Productivity Plan (2012)

The Alberta Water Council (AWC), established in 2004, is a multi-stakeholder partnership with representation from governments, industry, and non-government organizations. The primary task of the AWC is to monitor and steward implementation of the Alberta's *Water for Life* strategy and to champion achievement of the strategy's three goals:

1) Safe, secure drinking water supply
2) Healthy aquatic ecosystems, and
3) Reliable, quality water supplies for a sustainable economy

The Alberta Government's *Water for Life s*trategy (2003) has set an aspirational target for Albertans to achieve a 30 per cent improvement in water-use efficiency and productivity. The AWC recommended that seven major water-using sectors in the province prepare a voluntary Water Conservation Efficiency Productivity (CEP) plan to guide their sector towards achieving the *Water for Life* goals.

Canadian Fuels established a task force, representative of Alberta downstream petroleum operations, to develop the Alberta CEP plan. The plan was completed in 2012 and covers refining, marketing and distribution operations in Alberta and provides details on the current state of water use and progress that has, and is being made, toward more efficient use of this resource. It also identifies potential opportunities to enhance CEP efforts. The downstream petroleum industry has significantly improved water use efficiency over the past decade through continuous improvement (operating and technological), in spite of regulatory changes requiring more use of energy and water. The sector has been a leader in responsibly managing its use of water and supports the broad policy undertakings currently underway by Canadian governments.

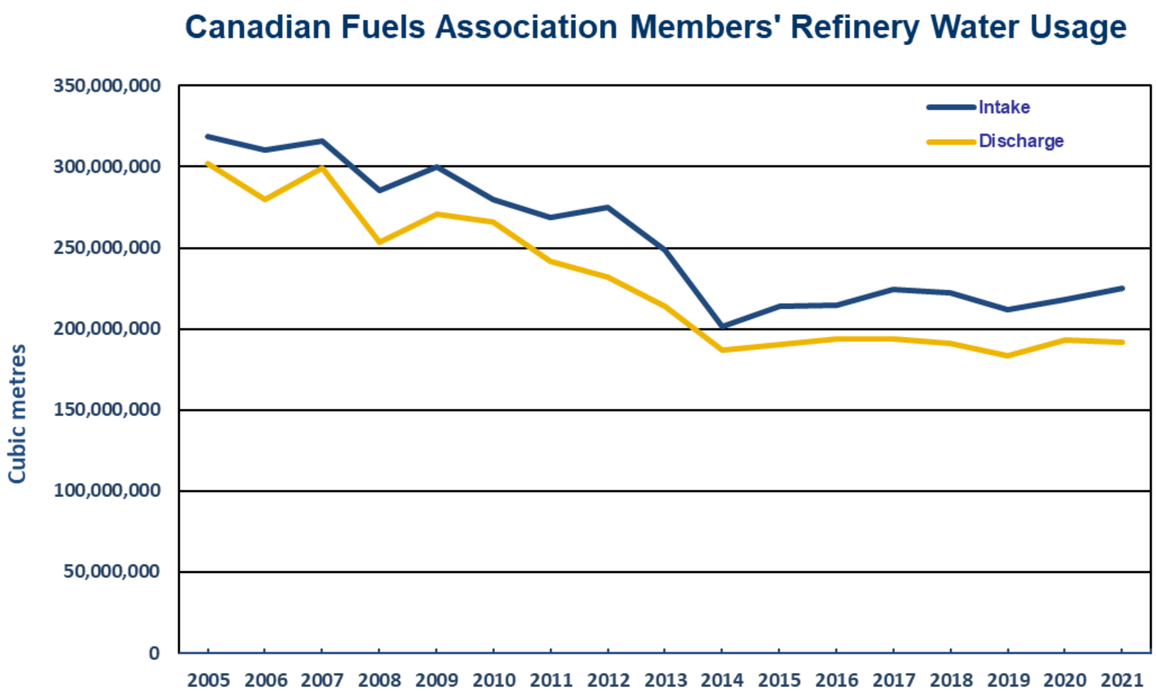
In 2015, the seven major water-using sectors, including Canadian Fuels, provided an update to the AWC on their CEP plans. The update confirmed that the seven sectors collectively had achieved the 30 percent improvement target. The petroleum refining sector achieved a 15 percent improvement in efficiency when measuring the period 2005 – 2015 against the 2005 baseline year.

The sector will continue to advance opportunities identified in the CEP plan to improve water use, while balancing social, economic, and environmental priorities.

Section V

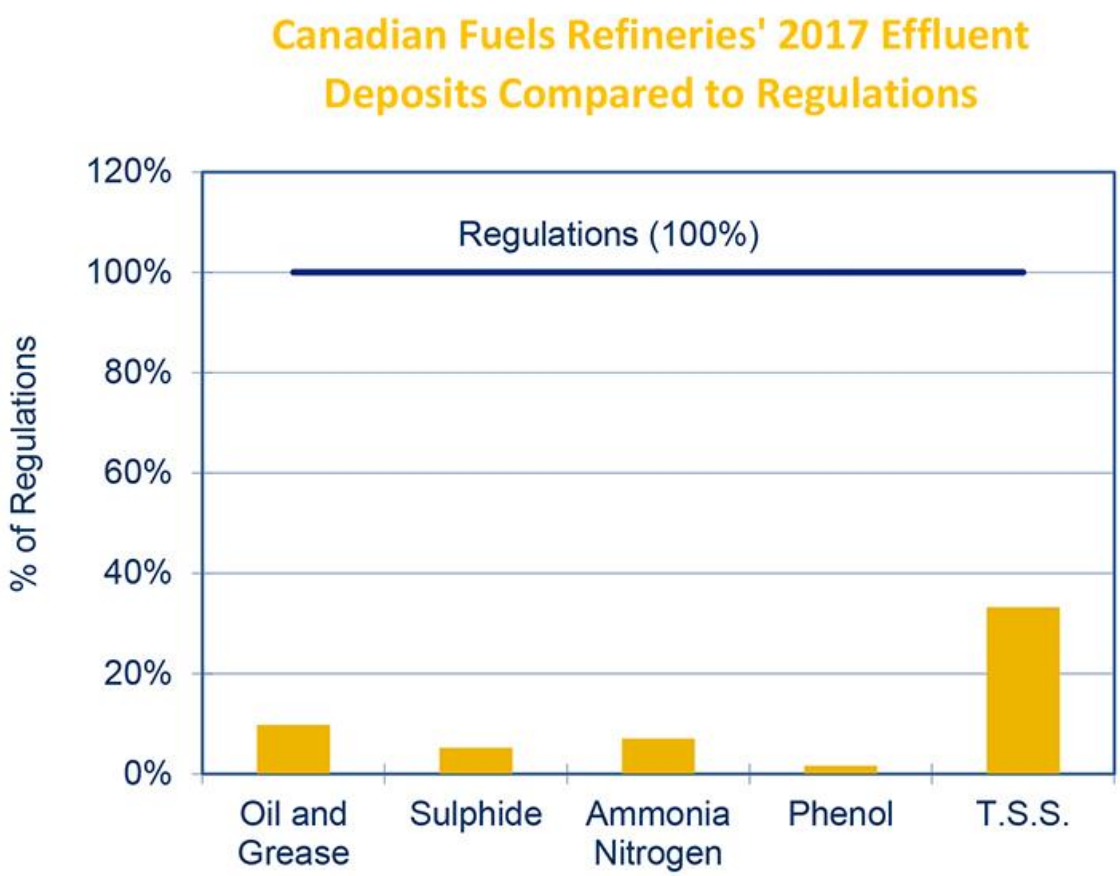
Quantity of Intake Water & Quality Discharged Water for Member Refineries

Canadian Fuels Association members are continually looking for ways to improve their water stewardship by using less water and by protecting the quality of the water they return to the ecosystem.



Source: Intake and discharge volumes reported are based on Canadian Fuels member companies' submissions to the Statistics Canada Industrial Water Survey.
Canadian Fuels membership has changed over the past several years.

Since 1992, environmental upgrades have resulted in water effluents with lower concentrations of five regulated substances: oil and grease, sulphide, ammonia nitrogen, phenol and total suspended solids.



*Total suspended solids
Source: Canadian Fuels Association members
Canadian Fuels membership changed in 2012, 2013, 2014 and 2016