Brief

Canadian Water Network

Microplastics in Water Systems

Challenges, Considerations and Opportunities for Water Managers

What to watch for

The federal government is addressing microplastics directly and indirectly, by taking steps to reduce all types of plastic waste entering the environment **by 2030**, and by supporting research.

1. New regulations to prohibit several kinds of harmful single-use plastics came into effect at the end of **2022**; they follow the four-year-old regulations to ban microbeads in toiletries in Canada.
2. Within the **next three or four years**, results are expected from numerous scientific studies that are examining all aspects of microplastics across Canada, including their presence in water systems, impacts and potential treatment processes.
3. By **2030**, the government aims to develop a circular economy for plastics (Government of Canada, 2020): plastic materials would stay in a "closed-loop" system of use, reuse, recycling and recovery, instead of being used once and then discarded (The SustainAbility Institute, 2022).
4. Ontario **municipalities** are required to work with the province to divert more materials containing Tier I and II chemicals from the waste stream, under the most recent Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health (Annex 2), signed in 2021. Annex 2 also targets pathogens in wastewater effluent, combined sewer overflows, and stormwater (Government of Canada, 2019).

The issue

In recent years, concerns have arisen about microplastics in the environment, particularly in water, and the harm they may cause to ecosystems, animals and people.

Microplastics—small plastic particles and fibres, many invisible to the naked eye—are a "forever, everywhere" contaminant that perseveres in the environment and can travel long distances by water and air. They have been detected in oceans, freshwater, lake sediments, air, and even in remote, sparsely populated regions (Anderson et al., 2017). Microplastics have been found in municipal source water and in some places, in drinking water.

Their wide distribution is of particular concern because we know relatively little about microplastics. Science does not yet understand the full extent to which microplastics harm aquatic fauna and the environment, and whether they may also harm humans (Government of Canada). Also unclear is the extent to which microplastics are removed by drinking water and wastewater treatment, because there are gaps in our knowledge about how to detect and measure these pollutants.

Canadian municipalities should benefit from recent federal initiatives to regulate plastics, reduce waste, and fund research for answers to critical questions about health risks and water management.

Background

Microplastics are tiny plastic particles that are less than or equal to five mm in size. They can be many orders of magnitude smaller, and visible only with a microscope.

There are two types of microplastics. Primary microplastics result from items that are commercially manufactured, such as microbeads used in toiletries, or synthetic textiles that shed plastic microfibres (less than or equal to five mm in length). Secondary microplastics result from the gradual breakdown of larger plastics into smaller and smaller pieces.

Primary sources of microplastics include antifouling boat paint, asphalt sealants, abrasives used in air blasting, microbeads, microfibres from laundry and industrial losses. Secondary sources include litter; inefficiencies and losses from recycling and waste management; fishing gear; personal care products; tires, and applications of biosolids, which receive microplastics from wastewater streams, to land (Burton, 2017; Canadian Water Network, 2018; Crossman et al., 2020; Eriksen et al., 2013; Global Water Research Coalition (GWRC), 2017; Government of Canada, 2020; Grbić et al., 2020; Kohut, 2017; Li et al., 2020; Rochman, 2018; Ross et al., 2021; Storck et al., 2015; Vassilenko et al., 2019; Wardlaw & Prosser, 2020; World Health Organization (WHO), 2019).

Microplastics may also be produced from per- and polyfluoroalkyl substances (PFAS), in addition to appearing as an independent co-contaminant (Cook & Steinle-Darling, 2021).

History

Microplastic pollution is a growing concern worldwide.

With an exponential increase in the manufacture and use of consumer plastics since the Second World War, plastic litter and garbage are now ubiquitous around the globe. Along shorelines, single-use plastic items are among the common types of macroplastics found. In Canada, about one per cent of plastic waste, or 29 kilotons, was released to the environment in 2016 alone (Lemieux, 2020).

As plastics slowly break down, the resulting microplastics can be transported all over the world by wind and precipitation (Brahney et al., 2020). Microplastics are abundant in lakes and oceans, on shorelines, in sediments and soils, and have been detected in indoor and outdoor air. (Lemieux, 2020). They are found in animals, especially freshwater and marine life, and the human body. Microplastics have been detected in some bottled water and tap water outside of Canada (Lemieux, 2020).

Microplastics persist for decades and accumulate in the environment, earning them the title "forever, everywhere" contaminant.

Concerns

Microplastics have been shown to harm animals and ecosystems, but the potential risks to human health are not yet clear. Information is limited, leaving many uncertainties (Lemieux, 2021). A sample of research to date highlights some key concerns and questions:

1. Microplastics are known to bind with other contaminants of concern, including PFAS and pharmaceuticals, and can attract pathogens such as bacteria and viruses.

2. Microplastics have also been found to carry, and leach, endocrine-disrupting chemicals, especially estrogen; smaller microplastic particles yield higher concentrations than larger ones (Qiqiang, et al., 2019).
3. In marine fish, the ingestion of plastic particles carrying endocrine disruptors has been found to alter endocrine-system function (Rochman, et al., 2014).
4. Microplastic particles < 20 µm are a particular concern because of their ability to accumulate in tissues, and even move through and between tissues (Ross et al., 2021).
5. In Canada, research has found that both freshwater and marine fish ingest microfibres; one Saskatchewan study found they damaged the stomachs of nearly all fish examined (Kohut, 2017).

There is a particular concern about Indigenous communities that rely on fish and other aquatic fauna for their food, such as Inuit communities in northern Canada (Ross et al., 2021). Researchers are also concerned about the smallest microplastics in drinking water systems.

Knowledge gaps

Decision-makers would benefit from knowing how microplastics affect health, how they behave in municipal water systems and the routes of human exposure. However, science has not caught up with this issue. Research on microplastics is in its infancy worldwide. As a result, there are significant gaps in our understanding of the scope of the problem and how to manage it. Areas of scientific uncertainty include:

1. The ecotoxicological effects of microplastics (Government of Canada, 2020).
2. The health impact of human consumption of microplastics. The World Health Organization (2019) has deemed ingestion safe at the moment until research indicates otherwise.
3. Whether nanoplastics (the tiniest microplastic particles, less than 100 nanometres long, or smaller than 1 µm) (Gigault et al., 2018) can bypass water treatment and harm people and ecosystems in ways that we do not yet understand (Allan et al., 2021; GWRC, 2017; Gouin et al., 2021)
4. The combined effect of microplastics and other common environmental pollutants (Liu et al., 2020).
5. The processes that degrade microplastics into smaller and smaller particles, and processes that could prevent this breakdown (Li et al., 2020).
6. To what extent microplastics are present in different environments, including soil (Government of Canada, 2020).

In addition to these unknowns, Canadian researchers lack standardized methodologies or protocols for sampling, characterizing and quantifying microplastics, or for evaluating the health effects of macro- and microplastics. This disharmony in research procedures may thwart comparisons between studies and findings.

Microplastics in municipal water systems

Recent research indicates that microplastics are present in stormwater, wastewater, municipal source water and possibly drinking water. Municipal water systems are also a significant source of microplastics entering the wider environment.

Drinking water

1. Research generally indicates that drinking-water treatment can remove most microplastics (Government of Canada, 2020; WHO, 2019). One study that tested drinking water for microplastics from five Canadian facilities (bottled water and treatment plants) found a 91-to-92-per-cent removal efficiency for particles > 20 µm. (Lemieux, C., 2020).
2. Disease-causing agents (such as viruses, bacteria, fungi and others) that may live in the biofilms on microplastics are probably inactivated by drinking-water treatment (Government of Canada, 2020).
3. Other pollutants that may be absorbed by microplastics (such as pharmaceutical products) are not considered a significant toxicological concern (Burton, 2017; Government of Canada, 2020).

Wastewater

Wastewater treatment plants (WWTPs) have been identified as a major recipient of microplastics, and therefore, an important point source of microplastics entering the environment, in spite of their capacity to remove most of this waste from the liquid stream (Canadian Water Network, 2018; Cook & Steinle-Darling, 2021; GWRC, 2017).

1. Microplastics are released from WWTPs in effluent, sludge and biosolids.
2. In **wastewater effluent**, the dominant microplastics may be microfibres from laundered clothing (Grbić et al., 2020; Vassilenko et al., 2019).
3. The average North American household sheds 135 grams of microplastics (533 million microfibres) in laundry wastewater each year, according to a study by Ocean Wise in Vancouver (Vassilenko et al., 2019). This amounts to 22,000 tonnes (22 kilotonnes) of microfibres entering treatment plants.
4. About 98 per cent of these microfibres are removed by tertiary and even secondary wastewater treatment. However, the two per cent that evade treatment and are released in effluent persist and accumulate in the environment, affecting marine and freshwater systems (Li et al., 2020). This represents about 440 tonnes in North America every year.
5. The microfibres removed during wastewater treatment will end up in **sludge or biosolids** (Burton, 2017; Vassilenko et al., 2019). These may be applied to agricultural fields and other locations, including mines, landfill sites (as topsoil) and urban land (as landscaping soil) (Metro Vancouver, pers. comms.).
6. As much as 300,000 tonnes of microplastics may be spread on agricultural fields in biosolids each year in North America. It is unclear to what extent soils retain microplastics; however, this agricultural practice may result in microplastics entering fresh water (Crossman et al., 2020).
7. Liquid biosolids that are stored for extended periods contain fewer microplastics; longer storage and settling serves to separate the components by density. Since microplastics are less dense than water, they may be skimmed off the top and sent to landfills, while the liquid fraction may be siphoned for retreatment (Crossman et al., 2020).

Stormwater

Stormwater is an important sink for microplastics and pathway for microplastics to enter water systems. Although research on this subject is limited, studies so far have found:

The amount of plastic in stormwater, in particular, is significantly influenced by land use (Liu et al., 2019). Urban areas have more litter and other kinds of plastic waste than do rural areas.

Concentrations of microplastics in stormwater may exceed the concentrations found in effluent from WWTPs.

Regulation

No legislation or regulations specifically address microplastics in drinking water, wastewater or stormwater in Canada. Research studies now underway may close some of the knowledge gaps about microplastics, and inform future regulations.

However, the federal government has prohibited certain microbeads and single-use plastics with recent regulations:

1. As of July **2018**, most toiletries containing plastic microbeads cannot be manufactured or imported into Canada; the objective is to reduce the number of microbeads entering freshwater and marine systems. In **2019**, these regulations extended to remaining toiletries, and the sale of such toiletries. (Canadian Environmental Protection Act (CEPA): Microbeads in Toiletries Regulations, 2018)
2. A lab test to identify microbeads in toiletries was developed by Environment and Climate Change Canada for use in **determining compliance** with the regulations. (Government of Canada, 2018).
3. As of December 20, 2022, the manufacture and import of five types of single-use plastics are prohibited, including most grocery checkout bags, plastic straws, stir-sticks, cutlery, and food takeout containers. In December **2023** the sale of these items will also be prohibited, and two years after that, it will be illegal to export these items from Canada. (CEPA: Single-use Plastics Prohibition Regulations, 2022).
4. In June **2023,** the ban on single-use plastics will extend to six-pack and other ring carriers (which hold together groups of cans or jars).

One exception to the ban is flexible plastic straws, which will remain available for sale under certain conditions for people who need them.

Current status

Regulatory environment

Canada has no regulations or guidelines that specifically govern microplastics in municipal water systems. The lack of standardized protocols for identifying, sampling and measuring microplastics, and for evaluating their effects, currently prevents the establishment of guidelines.

However, recent federal regulations have prohibited a variety of single-use plastics, as well as plastic microbeads in toiletries. These actions are part of Ottawa's multifaceted "Zero Plastic Waste" agenda to eliminate domestic plastic waste by 2030. Over time, this should reduce the amount of microplastics entering Canada's water systems.

Emerging research

A wide variety of research into all aspects of microplastics in Canada is currently underway across Canada by universities and private groups, with the support of federal, provincial and municipal governments.

As part of its Zero Plastic Waste initiative, the federal government is financing more than two dozen major studies of microplastics through the National Sciences and Engineering Research Council of Canada (NSERC), Environment and Climate Change Canada and Health Canada:

1. In 2021 NSERC invested nearly $7-million (Cdn.) in seven major microplastics research projects across the country. With an average $1-million in funding each, they will address a wide range of microplastics issues over four years.
2. One of the NSERC projects, led by Dr. Philippe Van Cappellen of the University of Waterloo, is studying microplastics at the watershed scale in the Lower Great Lakes in partnership with Environment and Climate Change Canada and a host of municipalities and agencies.
3. A two-year study by the University of Regina is examining the ecotoxicological effects of microplastics in Saskatchewan watersheds. Led by Dr. Gordon Huang of the Faculty of Engineering and Applied Science, it is financed by Environment and Climate Change Canada.
4. Carleton University's Global Water Institute is collaborating with three companies to develop technologies to monitor microplastics in water, air, and on land. It is one of more than a dozen projects financed in 2020 Environment and Climate Change Canada's Zero Plastic Waste initiative.
5. Environment and Climate Change Canada and Health Canada contributed $2.2-million in financing for more than a dozen projects related to the potential human health effects and ecotoxicology of plastics. The Increasing Knowledge on Plastic Pollution initiative has a particular focus on research gaps identified by the federal government as part of its broader plastics action plan. The two-year studies were to be completed in 2022.
6. Dr. Chelsea Rochman, a prominent microplastics researcher at the University of Toronto, leads the U of T Trash Team, a science-based community outreach group that delivers evidence-based solutions with the goal of reducing solid waste locally while promoting a circular plastics economy globally.

Key considerations

Many factors influence the management of microplastics in Canada, including a lack of answers to important questions. There is significant uncertainty about:

1. The extent of macroplastic pollution.
2. The identification and quantification of microplastics.
3. The degree of risk that microplastics pose to human health.

Challenges

A fundamental challenge for water managers is that **drinking water** may contain microplastics that can harm people and other life forms.

There is concern that nanoplastics—particles that are less than 100 nanometres long, or smaller than 1 µm—(Gigault et al., 2018) could evade water treatment processes and harm humans and ecosystems in ways that we have yet to understand (Allan et al., 2021; GWRC, 2017).

Microplastics in **wastewater** and **stormwater** also present significant challenges and unknowns.

Compounding these concerns is that researchers and technicians employ diverse methodologies to sample, identify, and quantify microplastics in water and soil, as well as to evaluate their effects. Canada lacks a nationally standardized methodology for sampling, quantifying and identifying microplastics (Government of Canada, 2020).

There is an urgent need for **harmonized protocols** in Canada and internationally; this would enable correct comparisons between research studies.

Opportunities

Even with imperfect knowledge, there are opportunities to advance the management of microplastics at the municipal level. Prevention, monitoring, and treatment each present possibilities.

Prevention

As with other contaminants of concern, it is easier and less expensive to treat microplastic pollution in both drinking water and wastewater if the volume of pollution can be reduced at the source. Engineering solutions may include:

1. Reduce the flow of plastic in **stormwater** with more efficient filters and capturing systems (Raven Magazine, 2020).
2. Install permeable pavements and bioretention cells (also called rain gardens) in urban areas to filter, trap and remove pollutants in runoff that would otherwise be carried downstream (Grbić et al., 2020; Smyth et al., 2021).
3. Reduce microplastics in **wastewater** by supporting the installation of microfibre-capturing equipment in washing machines (Grbić et al., 2020), through a program for consumers similar to rebates that encourage the purchase of water-saving toilets.
4. Offer public education about ways that individuals can reduce their plastic pollution, such as: washing clothes less often (spot-cleaning more often), using a front-loading washer and installing a microfibre lint trap, and buying less "fast fashion" (in favour of natural fibres) (Vassilenko et al., 2019).

The Metro Vancouver website has additional recommendations.

Monitoring

Microplastics can be monitored in **stormwater**, **wastewater** and **receiving environments** (aquatic and terrestrial). A municipality may:

1. Standardize internal procedures to quantify microplastics more reliably.
2. Use the classification key developed by Lusher et al. (2020) to characterize microplastics based on optical properties, physical behaviour/density, and morphology.
3. Monitor all water sources, including **drinking water**:
    a. Using harmonized sampling protocols and analytic methods (Burton, 2017; Storck et al., 2015; WHO, 2019).
    b. Specifically for microplastic particles smaller than 0.3 millimetres (< 300 µm) (Burton, 2017).

Treatment

Emerging water-treatment technologies offer some key considerations for municipalities. These include:

1. Supporting incentives for water-treatment innovations that would remove microplastics and other contaminants of emerging concern (Vassilenko et al., 2019).
2. Retrofitting wastewater treatment plants with new or upgraded technology to further improve the removal of microplastics (Canadian Water Network, 2018).
3. Storing liquid biosolids for extended periods, in order to separate their components by density. Microplastics may then be skimmed off the top and sent to landfills while the liquid fraction may be siphoned for retreatment. Achieving this workflow is not without its challenges, Crossman and others (2020) have noted.

Table 1 highlights five recent technological developments in the field of microplastics removal from **wastewater**.

Table 1. Recent technological developments for wastewater treatment

The Practice	Description	Source
Electro-oxidation (EO) to break down microplastics in wastewater	Microplastics are broken down into gases (water and CO2) without producing smaller microplastic fibres, particles or additional chemicals. More research is needed on anode-fouling and mutual contaminant interactions.	Kiendrebeogo et al., 2021
Retrofit secondary wastewater treatment plants	Additional microplastics are removed from the liquid stream by retrofitting secondary plants with primary clarifiers. Co-benefits of this technology include the removal of other contaminants of concern.	Canadian Water Network, 2018; Conley et al., 2019
Coagulant removal of microplastics	An advanced coagulant removes microplastics early in the water treatment process, causing them to sink right away in settling tanks.	McGill Reporter staff, 2020
Ferrofluid removal of microplastics	Ferrofluid may be used to remove microplastics (particularly microfibres) with up to 88-per-cent efficiency.	Bendix, 2019
Ozofractionative Catalysed Reagent Addition (OCRA)	Microplastic particles and other contaminants such as metal and PFAS attach to large microbubbles and float to the top of treatment tanks, where they can be skimmed off and removed.	Evocra, 2020

Curated resource list

Vassilenko, K., Watkins, M., Chastain, S., Posacka, A., & Ross, P.S. (2019). Me, my clothes and the ocean: The role of textiles in microfiber pollution. Ocean Wise. https://assets.ctfassets.net/fsquhe7zbn68/4MQ9y89yx4KeyHv9Svynyq/8434de64585e9d2cfbcd3c46627c7a4a/Research_MicrofibersReport_191004-e.pdf

The study lead by Ocean Wise represents a collaborative effort between industry, researchers and government to quantify microplastic loads in wastewater effluent and identify solutions. The partnership is growing and includes Mountain Equipment Company (MEC); Patagonia Inc., Arc'teryx Equipment Inc., Recreational Equipment Inc. (REI), Aritzia Inc., Gap Inc., Environment and Climate Change Canada, and Metro Vancouver. The study identified microfibres from laundered textiles as a significant source of microplastics in wastewater systems, and concluded that 878 tonnes of microplastics are released from wastewater effluent annually across North America. In addition, it identified some possible solutions, including sustainable textile design, improved wastewater engineering and informed consumer choices. The study spurred a public education campaign to increase awareness of consumer habits in Vancouver.

Grbić, J., Helm, P., Athey, S., & Rochman, C.M. (2020). Microplastics entering northwestern Lake Ontario are diverse and linked to urban sources. Water Research, 174, 115623. https://doi.org/10.1016/j.watres.2020.115623

This study, by the University of Toronto and the Ontario Ministry of the Environment, Conservation and Parks, highlights common point sources and non-point sources of microplastic contamination and offers solutions such as permeable pavements and bioretention cells to intercept stormwater. It is an up-to-date, Canadian source of information about non-point sources.

Bujaczek, T., Kolter, S., Locky, D., & Ross, M.S. (2021). Characterization of microplastics and anthropogenic fibers in surface waters of the North Saskatchewan River, Alberta, Canada. FACETS, 6(1), 26–43. https://doi.org/10.1139/facets-2020-0057

This represents the first characterization of microplastics in a river in Western Canada, the North Saskatchewan River. It contributes to the Canadian context of microplastic knowledge and highlights the importance of increased monitoring in Canadian waterways. The study identified non-point sources as the main contributor of microplastics, including stormwater outfalls and runoff from biosolid application on agricultural fields. Its conclusions emphasize the need to understand how different methods of sampling, extraction and analysis may influence results.

Global Water Research Coalition. (2017). Microplastic fact sheet. http://www.globalwaterresearchcoalition.net/_r2715/media/system/attrib/file/719/GWRC_Microplastic_Fact_Sheet_2017.pdf

Burton, G. A. (2017). Microplastics in aquatic systems: An assessment of risk [White paper]. Global Water Research Coalition. http://www.globalwaterresearchcoalition.net/_r2619/media/system/attrib/file/706/Microplastics%20White%20Paper%20CEC7R17%20web%20%28002%29.pdf

The Global Water Research Coalition has been curating insights from microplastics research in summary documents, including fact sheets and a white paper. These documents capture the progress of microplastics research up to 2017, providing baseline information as well as highlighting knowledge gaps, some of which persist today.

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