June 7, 2021

To: Mr. Francis Scarpaleggia, Chair of the Standing Committee on Environment and Sustainable Development

From: Dr. Kim Gilbride (gilbride@ryerson.ca), Dr. Rania Hamza (rhamza@ryerson.ca), Dr. Patricia Hania (phania@ryerson.ca), Ryerson University and Ryerson Urban Water

Re: Freshwater in Canada Study: A Pressure Point on Canada's Freshwater Resources: *Chemicals of Emerging Concern & Wastewater Treatment Plant Processes*:

**1.0 The respondents:**

The respondents are faculty members at Ryerson University in Toronto, and active members of Urban Water Research Centre. In response to recent scientific research along with growing public and industry concerns over 'contaminants of emerging concern' (CEC), Drs. Gilbride, Hamza, and Hania received a Knowledge Synthesis Grant through SSHRC's *Imaging Canada's Future Initiative* to critically assess the state of knowledge of wastewater pollution and CECs. This research project identified knowledge gaps in water legislation and wastewater treatment plant technologies with the aim of protecting human and ecological health, and with a particular focus on CECs entering Canada's freshwaters.

Dr. Gilbride is a microbiologist, who has studied biological wastewater treatment (WWT) for more than two decades. Her research has examined the microbial removal of ammonia and nitrogen, the ecological niches of ammonia-oxidizing bacteria and ammonia-oxidizing Archaea within the secondary treatment system, the role of wastewater treatment in the incidence of antibiotic resistant genes, the global concern with increased antibiotic resistant bacteria and CEC's in wastewater and most recently the development of a wastewater surveillance tool for Sars-CoV-2, the causative agent of Covid-19.

Dr. Hamza is a chemical engineer, who has for more than ten years has worked in the field of environmental engineering and sustainable development. Her research is focused on municipal and industrial wastewater treatment, fate and treatment of emerging contaminants, advanced biological and integrated physicochemical treatment technologies for the removal of nutrients and emerging contaminants along with wastewater reclamation and reuse.

Dr. Hania's is an interdisciplinary legal scholar, who has over her 15 years of academic and industry policy reform work. Her expertise is in sustainable water governance. Her research has examined the shift in the Canadian water management sector to a participatory model of governance, including how to strengthen Indigenous women's participation in natural resources regulatory regimes, and has worked in collaboration on such issues as climate change, adaptive management, antimicrobial resistance phenomenon, and gendered impacts of CECs.

Collectively, the expertise of this team of researchers spans microbial biology, molecular biology, civil engineering, environmental engineering, climate change, sustainable water governance, and sustainable environmental policy reform.

**2.0 Key Recommendations:**

- Research is required to establish the links between CEC in wastewater effluent discharge (i.e., water and sludge streams) and the risks to human and ecological health. These studies should target both chronic, low-dose and acute impacts, and be based on a longitudinal time frame.

- Integrated source regulation must be introduced to prevent CECs from entering the municipal wastewater system from industrial and public health (e.g., hospitals) sectors to reduce contaminants from entering the WWTP. Industrial economic incentives could be introduced to assist industries in establishing and operating on-site wastewater treatment to reduce the CEC load entering municipal sewer systems, WWTPs and the environment.

- Standardization of analytical methods to detect and monitor CECs in WWTP is required. These methods are needed to understand the shifts in CEC quantities both at the source and in the WWTP processes to determine trends in quantity and risk. Although many methods currently exist, the logistics to collect, analysis and share such data is non-existent.

- More funding for research and development is essential to develop innovative engineering techniques to remove CECs from wastewater and prevent CEC pollution from being released into freshwater sources. Existing wastewater treatment plants (WWTP) were not designed to eliminate present-day man-made pollutants and recalcitrant compounds generated by industries, hospitals and households.

- A review of the funding arrangements for WWTPs is warranted to establish an equitable funding program. The innovation gap is complicated by the financing of wastewater treatment plants where municipal taxpayers fund the operation of a WWTP, which places the financial burden of new technologies on the municipal tax base,

- An assessment of the social-ecological-health-economic-gendered impacts of CEC release from wastewater effluent upon vulnerable communities, such as those in rural and remote areas, far north locations and First Nation communities is needed.

- Federal leadership on freshwater demands a responsive integrated regulatory framework to ensure a timely response to current and future CEC pollutants, and where cooperative federalism is upheld as expressed in the Canada Water Act. This integrative legislative response should be on multi-level governance scale and be directed at, and incentivize industry, municipalities, and regulators to response to CEC pollution while also promoting a citizen's right to know the risks of CEC pollution within their communities.

## 3.0 Executive Summary

The Government of Canada recognizes "[m]unicipal wastewater effluents [as] the largest single effluent discharge, by volume in the country." For example, everyday Toronto's sewer system collects over 1.5 billion litres of wastewater, which is treated and released into Lake Ontario. The wastewater treatment process is essential to removing solid debris, oils and grease, dissolved and suspended organic matter including bacterial pathogens and nutrients, such as nitrogen and phosphorus that can cause eutrophication of the receiving waters. However, the problem facing the wastewater sector is one of modernization. Wastewater treatment plants (WWTP) were not designed to eliminate present-day man-made pollutants and recalcitrant compounds generated by industries and households. The result — WWTPs have been transformed into a primary conveyor and producer of unregulated contaminants of emerging concern (CEC). Wastewater effluent is now recognized as a pressure point on freshwater resources, yet there is little understanding of how to protect freshwater sources with respect to WWTP processes and CECs. This freshwater issue affects all Canadians and can be attributed to three key factors: 1) a lack of regulation and importantly the need for a multi-level integrated responsive legal framework for CECs 2) the need for further research on the CEC impacts upon human and ecological health, and 3) an innovation gap where opportunities for technology innovation in the WWTP sector, and federal government's leadership role in advancing innovation in this sector is essential.

In its freshwater leadership role, the federal government could support a call for innovative research to understand not only the cumulative impacts but also the synergistic and mixture impacts of these chemical compounds where some CECs have been identified as 'forever chemicals' in the environment. The Committee's review of freshwater issues facing Canadians creates the opportunity to consider how to protect freshwater sources and support modernizing WWTPs processes to address 21st century freshwater challenges. Protecting freshwater requires scientific evidence based decision-making tools, resilient legal instruments, and should respect cultural values of water, Indigenous knowledge, and take into account freshwater ecosystems, the health of humans, fish, wildlife and the impact upon ocean waters, while expanding the capacity and expertise of municipalities and First Nations that are charged with operating WWTPs.

## 4.0 Background

This submission is directed at the Committee's freshwater study and, in particular, we would like to address two of the topics identified as under study: "1) pressure on the country's freshwater resources, and 2) present future freshwater-related research needs." Freshwater is a vital resource for life and the protection of such a resource is paramount to sustainable water governance. The growing presence of contaminants of emerging concern (CEC) in aquatic environments is a pressing issue that needs both scientific and legislative points of view. In our research, CEC is defined as: *all those contaminants recently identified as chemicals of concern that are not monitored or measured in wastewater treatment processes.* Overall, CEC includes a broad class of different types of chemical compounds found in personal care products, household cleaning solutions, pharmaceuticals including antibiotics, flame retardants, surfactants, pesticides and microplastics, to name a few.

Our knowledge gap synthesis research considered CECs lifecycle impacts, CEC transformation by-products, and their synergetic and cumulative effects that are currently documented in WWTP research, along with monitoring techniques in WWTPs and the receiving environment. Currently, more than 600 types of CECs have been identified and classified pointing to the pervasiveness of these compounds in the environment. While the scientific community is good at classifying CECs, the emerging nature of CECs has not yet allowed researchers to fully understand the impacts upon freshwater sources. These freshwater sources are often relied upon for drinking water, recreational uses, subsistence fishing, as an industry resource, and wildlife, fish and microbiota habitats. The issue of how wastewater effluents contribute to the pressure on the country's freshwater resource and the need for freshwater research to protect our resource will be demonstrated in each of our three case studies that are discussed below: Case study One: Microplastics (MP), Case study Two: Pharmaceuticals (PhACs), and Case Study Three: Per- and poly-fluoralkyl compounds (PFAS).

**4.1 Case Study 1: Microplastics**

Microplastics (MPs) are an emerging chemical of emerging concern (CEC) in freshwater sources. The increased global consumption of plastic products, synthetic textiles, inadequate disposal techniques and releases from consumer and industrial products has contributed to this threat to freshwater sources. Researchers have found that MPs are present in Lake Winnipeg and all five Great Lakes (i.e., Ontario, Erie, Michigan Superior and Huron). For example, Environment and Climate Change Canada researchers found that microbeads and fibres were the most abundant MP in Lake Erie, downstream from the Windsor/ Fort Erie region. It is estimated that 533 million microfibre pieces are discharged annually from Canadian households into municipal sewers.

In the environment, MPs are persistent and accumulative due to their stable carbon-hydrogen bonds that make them resistant to degradation. Microplastics can also contain other compounds such as lubricants, dyes, plasticizers, fillers and stabilizers as additives hindering the degradation and removal from environments. MPs are also known to be hydrophobic, which means they can adsorb to toxic pollutants like flame retardants, polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls, heavy metals, pathogenic microorganisms, polycyclic aromatic hydrocarbons, pesticides, carcinogenic and endocrine-disrupting substances, and petroleum hydrocarbons. These MPs are found in many everyday products, for example, industrial products (e.g., abrasives, scrubbers), commercial products (e.g., synthetic textiles, plastic powders, plastic pellets like nurdles) and personal care products (e.g., toothpaste, body wash, detergents, and facial cleansers). Today, the quantity of microplastics in the environment continues to increase each year. This increase in consumption and use of plastics in society points to the risk of the continued contamination of freshwaters from WWTPs, which are not equipped to remove MPs.

The range of sizes, combined with the vast quantities of MPs that pass through the treatment plant every day creates design removal challenges. Research has shown that microplastic fibers (MPF), microbeads and fragments are the most common MP in WWTPs. The problem is these fibers are continuously released from synthetic textiles (e.g., polyester - stretchy jeans) every time our clothes are washed and dried in household laundry machines. In 2018, researchers reported the release of 6,000,000 to 17,700,000 fibres from a single 5kg washing machine. These researchers estimated that 80% of these fibers travel through WWTP and are released into receiving waters. Currently, microfibre filters on washing machines are regulated in Canada nor do regulations exist that prevent release of fibres into sewer nor from WWTP into freshwaters.

Despite the ubiquity of microplastics and microfibers in wastewater and the inevitable release into freshwater sources, little is known about the direct health effects of MPs on humans. A few studies have demonstrated the potentiality of metabolic disturbances, neurotoxicity, and increased cancer risk in humans but the effect of microplastics is much more complex due to their ability to produce flocculating particles in freshwater that can both sink and float. Without the modernization of WWTPs, industry incentives to innovate and directed research on the removal and impacts of MP/MPFs upon freshwater sources, the discharge problem will continue.

**4.2 Case Study 2: Pharmaceuticals**

Pharmaceuticals (PhACs) are prescription, veterinary, and over-the-counter therapeutic drugs used to treat human and animal diseases. They can include nonsteroidal anti-inflammatory drugs (NSAIDs), psychiatric drugs, hormones, lipid regulators, β-blockers, and antibiotics. When PhACs are consumed they are not completely metabolized in the human body, and once excreted are carried in sewage to wastewater treatment plants (WWTPs) and discharged in the effluent. WWPTs were not designed to remove PhACs. This discharge of PhACs into freshwater explains, in part, why receiving waters have been found to contain varying concentrations of PhACs downstream of WWTPs. Many scholars have suggested that WWTPs are the hotspots for PhACs residues that enter the aquatic environment. Even though the presence, persistence, and potential ecological impacts of these chemical compounds in the environment have been studied for many decades, PhACs continue to gain increasing attention as CECs. Numerous researchers have linked the presence of PhACs in source waters to the disruption of endocrine system pathways in vertebrates, increased oxidative stress, reduced reproductive capacity and are known to bioaccumulate in fish and modify their sexual characteristics.

Within a WWTP, PhACs are not monitored because a comprehensive CEC regulatory framework does not exist. Complicating the absence of a CEC monitoring process in WWTPs, is the problem of a lack of transparency with respect to the types and concentrations of pharmaceutical compounds that are present in the effluents discharged by industries and healthcare facilities. This monitoring gap complicated by a lack of regulation may explain why pharmaceutical compounds are found to be present, and persist in drinking water sources at low concentrations. Further research is needed to understand the long-term impacts of PhACs on freshwater ecosystems, including the synergistic and possible additive effects of combinations of pharmaceuticals, or combinations of pharmaceuticals with other compounds upon ecological and human health.

The antibiotic resistance global health phenomenon is an example of pharmaceutical contamination of freshwaters that is attributed to the overuse of antibiotics in human and veterinary medicines. WWTP processes do not eliminate all of the antibiotic residues resulting in a release into freshwater environments. According to the World Health Organization (WHO), the death toll due to antibiotic resistance is expected to rise to ten million deaths by the year 2050, which raises questions on how WWTPs contribute to this global health problem. The accumulation of antibiotic resistant bacteria (ARB) and antibiotic resistant bacteria genes (ARGs) in wastewaters of WWTPs is a known contributor to this particular problem. For example, the train of WWTP treatment processes includes a biological process (e.g., activated sludge) which can facilitate the accumulation of ARBs by establishing a suitable environment to support resistance development and spread from bacteria to bacteria. Currently, WWTP treatment methods fail to effectively eliminate ARB and ARGs, therefore releasing them into the environment. More research into the impacts upon receiving freshwater sources and their ecosystems is needed. It is expected that since antibiotic and pharmaceuticals, in general, are vital medicinal compounds, their residues will continue to contaminate wastewater, therefore research is needed to design and implement new innovative wastewater processes to remove these compounds at the WWTP level.

### 4.3 Case Study 3: PFAS

Per- and polyfluoroalkyl substances (PFAS) are human-made organic compounds. Since the 1950s PFAS have been used in the manufacturing of a variety of commercial and industrial goods (for example, printing, textile, laundry and cleaning, paper, cosmetics, electrical and metal industries, firefighting foams, Teflon, Scotchgard and Gore-Tex coatings). The PFAS chemical compound (i.e., Carbon-Fluorine bond) is one of the strongest organic bonds resulting in a substance that is resistant to degradation. The PFAS compound is considered toxic, bioaccumulative, and persistent in the environment leading to the compound being named a 'forever' chemical.

To date, in Canada, four types (or groups) of PFAS have been named and listed as toxic under the *Canadian Environmental Protection Act's* (CEPA) - List of Toxic Substances (toxic list). Currently, CEPA's toxic list does not include short-chain PFAS nor the replacement chemicals nor the alternative chemistry substances nor poly-fluorinated PFAS. In effect, this regulatory gap has opened the door for some manufacturers to switch to short-chain PFAS. Many of these short-chain PFASs still offer the chemical and thermal stable features sought after by manufacturers. However, from a chemical compound perspective, these short-chain PFAS are known to be just as environmentally persistent, bio-accumulative, and long-lasting in the human body, fish and the environment and water-soluble. Interestingly, PFAS can also adsorb or adhere to other CECs, such as microplastics in the environment, then possibly desorb in aquatic species. In effect, a sticky PFAS becomes mobile in a freshwater ecosystem as the plastic's pathway creates a corridor for the sticky PFAS to move beyond its point of entry into the receiving waters. These features of short-chain PFAS are a significant threat to drinking water and ecosystem safety, and perhaps, with further innovative research we can have a better understanding of the functioning of PFAS in wastewater treatment plant (WWTP) processes.

PFAS in freshwater can partly be attributed to WWTPs because a WWTP is both a conveyor and producer of PFAS. As a conveyor, WWTPs receive raw sewage from industrial, residential, commercial, and firefighting foam waste streams. Some studies have shown that over 85% of PFOA and 50% of PFOS compounds in the sewage are being discharged with the wastewater effluent, and into the receiving water bodies. As a producer, some precursor PFAS in the WWTP process can biotransform into PFCAs and PFSAs, which is then discharged in the effluent and released into lakes, rivers or oceans further spreading the PFAS contaminants to wildlife, fish and microbiota habitat, and humans.

The sheer numbers of PFAS also raises the problem of quantification, which when taken on is a complex, labour-intensive and expensive task. Several established methods exist for the measurement of targeted PFAS molecules exist (e.g., Isotope dilution anion exchange solid phase extraction (SEE) and liquid chromatography-mass spectroscopy (LC-MS/MS)). But, these methods lack standardization. Complicating this quantification problem is that the chemical structure of many PFAS compounds have yet to be determined, which creates a detection problem in the WWTP when relying on current detection methods and standards. There is a need for additional methods combining fast preparation and analyzing complex matrices with minimal sample pre-treatment. The reported concentrations of PFAS in the environment is extremely high emphasizing the need for innovative wastewater removal technologies and regulations directed at the PFAS producer that should also include disclosure requirements under securities regulations.