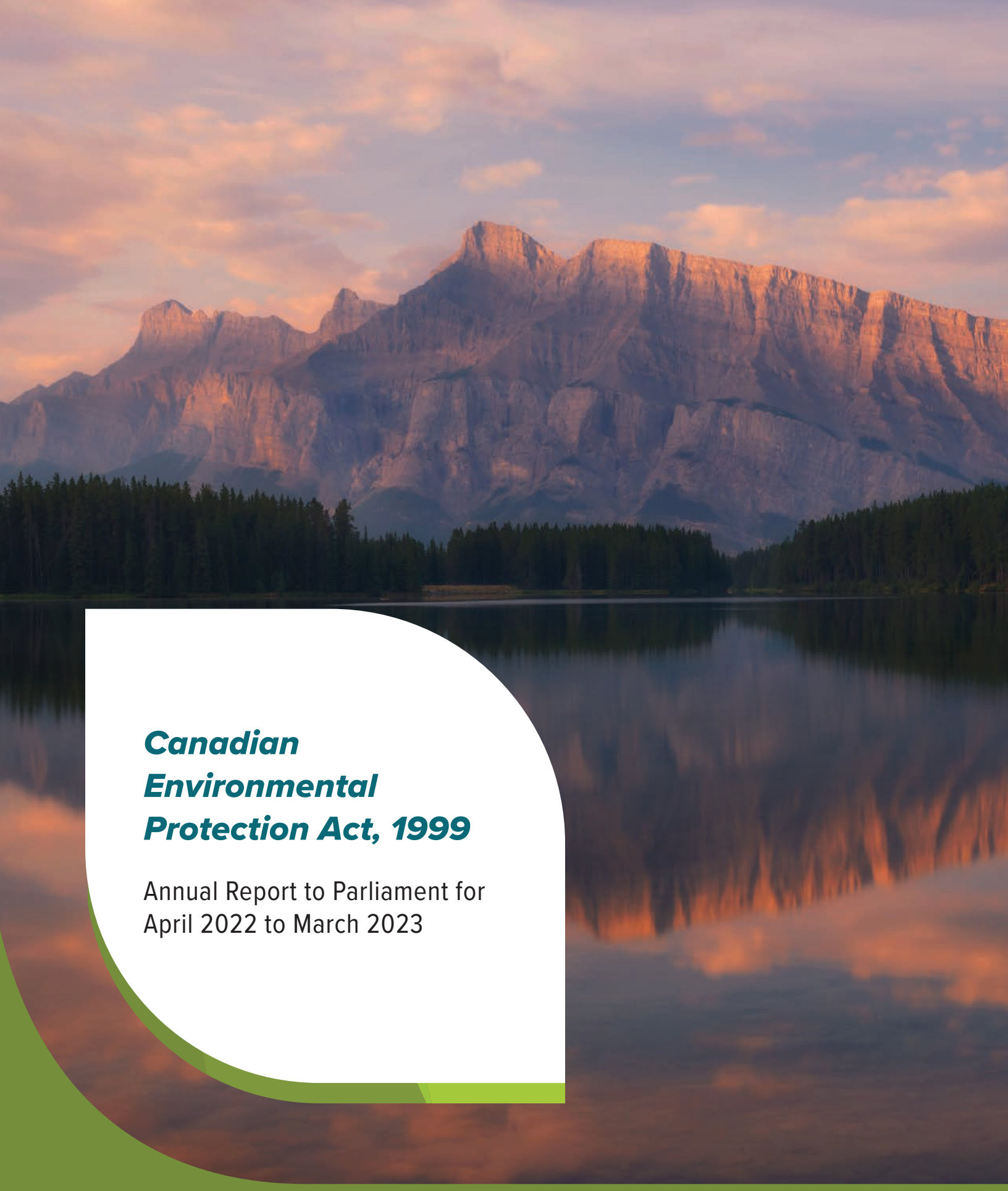

Canadian Environmental Protection Act, 1999

Annual Report to Parliament for
April 2022 to March 2023

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

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1. Introduction

Preventing pollution and protecting the environment and human health lies at the heart of the *Canadian Environmental Protection Act, 1999* (CEPA), (the Act). The Government delivers many of the environmental and health protection programs administered by Environment and Climate Change Canada (ECCC) and Health Canada (HC) through CEPA, such as the Chemicals Management Plan (CMP), the National Environmental Emergencies Center and the Air Quality Program. CEPA is also the legislative basis to implement several regulations and risk management instruments related to waste, disposals at sea, fuels, and emissions from vehicles, engines and equipment, as well as Canada's obligations under numerous international environmental agreements, such as the Basel Convention and the London Protocol.

This annual report provides an overview of the activities conducted and results achieved under CEPA from April 1, 2022 to March 31, 2023 by both ECCC and HC. It responds to the statutory requirement in Section 342 of the Act to provide an annual report to Parliament on its administration and enforcement.[1]

1.1 Bill S-5, *Strengthening Environmental Protection for a Healthier Canada Act*

Introduced in February 2022, Bill S-5, *Strengthening Environmental Protection for a Healthier Canada Act,* received Royal Assent on June 13, 2023. The Bill modernizes the *Canadian Environmental Protection Act, 1999* (CEPA) and represents the first set of comprehensive amendments to CEPA since it was enacted over 20 years ago and includes new requirements to report annually on certain CEPA activities.[2]

While Bill S-5 was not in effect during the fiscal year covering the activities included in this annual report, best efforts were made to include information in this report where available and possible. Where information was not available for this report, an implementation plan is in place and steps are being taken to collect the information for subsequent reports.

With this Bill, the Government of Canada delivered on its commitment to strengthen CEPA and recognize, for the first time in federal law, that every individual in Canada has a right to a healthy environment as provided under the Act. The Government will develop an implementation framework which will set out how the right will be considered in the administration of the Act and elaborate on principles such as environmental justice, intergenerational equity, and non-regression. It will also describe relevant factors to consider in interpreting and applying the right and determining its reasonable limits. The Government also confirmed its commitment to implement the *United Nations Declaration on the Rights of Indigenous Peoples* and incent action on reconciliation through a requirement to report annually on consultations, findings, recommendations, or measures taken in that regard (see section 6.3 of this report).

In addition to the recognition of the right to a healthy environment, other amendments introduced by Bill S-5 include:

- a new plan of Chemicals Management Priorities
  - With new chemicals being developed, new uses for existing chemicals, increasingly complex supply chains, and emerging science about risks including cumulative effects, the CEPA amendments require the Government to establish a new plan to prioritize the ongoing assessment of risks from chemicals. This plan will include timelines, a strategy to reduce reliance on vertebrate animal testing, consider class-based assessment approaches as a means of avoiding regrettable substitutions, as well as labelling and other means to provide meaningful information to the public. The amendments also require that this plan be reviewed at least every eight years.

1 CEPA requires the annual report to include the following mandatory information: s.342(s) report on research (found in section 7); s.8 activities of the National Advisory Committee (found in section 6.1); enforcement activities (found in section 4.2) and activities under administrative and equivalency agreements (found in section 6.2). The Act also requires the inclusion of activities under the international air pollution provisions, the international water pollution provisions and any committees established under section 7(1)(a) in the annual report. However, there were no activities under any of these sections during the reporting period.

2 Requirements include: s. 5.1(5) information for the right to a healthy environment framework; s. 74 progress of the Plan on Chemicals Management Priorities; s. 78(3),(4) progress made in developing subsequent instruments; s. 313(2) information on confidential business information requests and s. 317.3 disclosure of explicit names of masked substances or living organisms; s. 342.1 advancing Indigenous reconciliation.

- supporting the shift to safer chemicals
  - In addition to changes to risk assessment and risk management activities, CEPA amendments require the Minister of Environment and Climate Change[3] to maintain a Watch List—a list of substances that can pose a risk and thereby meet the criteria in Section 64 of CEPA if, for example, uses change or exposure increases.
- increased transparency in decision-making
  - Individuals in Canada may request that a chemical be assessed and require the Minister of Environment and Climate Change and the Minister of Health (the Ministers) to consider and respond to any such requests. The amendments also require that the Government communicate anticipated timelines for completing risk assessments and for proposing subsequent risk management actions when a substance is found to meet the criteria to require risk management. Industry will also be required to provide a rationale to support requests for the confidentiality of business information, and the Ministers will be required to review and validate a statistically representative sample of these requests and report on the results. In addition, the amendments establish the circumstances under which the Ministers may disclose the explicit names of masked substances or living organisms.
- a stronger regime for toxic substances that pose the highest risk
  - For substances that are determined to be toxic under CEPA and that meet criteria for posing the highest risk, the amendments to CEPA require that the Ministers give priority to prohibiting activities involving these substances. The criteria for these substances will include the existing regulations on persistence and bioaccumulation, as well as new criteria that will be set out in regulations on carcinogenicity, mutagenicity, reproductive toxicity, and substances that pose the highest risk. These regulations will be developed in consultation with stakeholders.
- risk assessments of new living organisms under Part 6 of the Act
  - Amendments to CEPA require the Ministers to consult interested persons when assessing new living organisms that are vertebrate animals or otherwise prescribed by regulation.
- reducing reliance on vertebrate animal testing
  - Amendments to CEPA recognize the need to reduce reliance on the use of vertebrate animal testing when assessing the risks that substances may pose to human health and the environment. These amendments require the Government to support the development and use of scientifically justified alternative methods and strategies to replace, reduce, or refine the use of vertebrate animals in toxicity testing, as science permits.
- changes to the *Food and Drugs Act* to strengthen the environmental risk assessment and risk management of drugs
  - Amendments to the *Food and Drugs Act* expand the Minister of Health's ability to manage environmental risks resulting from drugs, and the ability to develop modernized environmental risk assessment and risk management regulations for drugs under the *Food and Drugs Act*.
- the ability to put in place geographically targeted regulations, as appropriate, including to help address pollution "hot spots"

1.2 CEPA management cycle

CEPA provides the authority for the Government of Canada to take action on a wide range of environmental and human health risks – from chemicals, to pollution, to wastes. The Act provides a suite of instruments and measures to identify, assess and address these risks.

3 Although CEPA refers to the "Minister of the Environment", this report will refer to the Minister using the current title of "Minister of the Environment and Climate Change."

The steps taken to address each risk constitute a **management cycle** (see Figure 1). At each stage of the cycle:

- industries, individuals, interest groups and others are invited to participate in the public consultations and decision-making processes
- the Government works closely with their partners in domestic and international jurisdictions and agencies

Figure 1. The CEPA management cycle

This report provides information on all stages of the management cycle:

- **Research and Monitoring** (sections 2 and 7) covers the monitoring and surveillance activities that allow experts to determine levels and trends of chemicals, air pollutants and waste disposal affecting the environment and human health
- **Risk Assessment** (section 3) covers information gathering and risk assessment for substances, air pollution and greenhouse gases, water quality, and waste
- **Risk Management** (section 3) covers risk management for substances, air pollution and greenhouse gases, water quality, and waste
- **Compliance promotion and enforcement** (section 4) provides information on the planned activities undertaken to increase awareness, understanding and compliance with the Act and regulations
- **Reporting programs and emission inventories** (section 5) covers information on releases of pollutants and greenhouse gases
- **Administration, public participation and engagement with Indigenous Peoples** (section 6) covers stakeholder engagement and inter-jurisdictional relationships

The CEPA Registry is an accessible online source of current information relating to the Act. It gives people in Canada the opportunity to learn how the federal government administers the Act and is a comprehensive source of information on a variety of CEPA-related tools, including proposed and existing policies, guidelines, codes of practice, government notices and orders, agreements, permits, and regulations. The Registry invites industries, individuals, interest groups and others to participate in the public consultations and decision-making processes that take place under the Act.

2. Monitoring the environment and human health

Monitoring changes in the environment and human health trends is essential for assessing the impact of toxic substances. It is also essential for assessing the effectiveness of measures put in place to minimize environmental harm and reduce current and potential threats to human life.

2.1 Canadian Environmental Sustainability Indicators

The Canadian Environmental Sustainability Indicators (CESI) program is a key mechanism whereby the Government of Canada monitors and publishes information on all aspects of environmental quality. CESI produces indicators on environmental sustainability issues including climate change, air quality, water quality and availability, wildlife, biodiversity, habitat, pollution, and toxic substances. The program works with partners to analyze and communicate the state of Canada's environment, including historical trends, in a straightforward and transparent manner. CESI provides citizens, Parliamentarians, policy makers and researchers with comprehensive, unbiased, and authoritative environmental information. CESI is the prime instrument used to measure progress of the Federal Sustainable Development Strategy and United Nations Sustainable Development Goals and responds to ECCC's commitments under CEPA and the *Department of the Environment Act* to report on the state of the environment.

The Indicators published on the CESI website show national and regional data along with contextual analysis and the methodologies explaining each indicator. CESI makes understanding the data easier through interactive tools such as Power BI dashboards and interactive maps that enable the user to quickly explore Canada's local and regional environmental indicators. The corresponding datasets are also published in the Government of Canada Open Data Portal (see Table 1 for CESI updates and new releases in 2022-2023).

2.2 Chemicals

2.2.1 Chemicals in our environment

Monitoring programs contribute to efforts both domestically and abroad. The following programs contribute to national monitoring activities:

- the Chemicals Management Plan (CMP) Environmental Monitoring and Surveillance Program
- the Northern Contaminants Program (NCP)
- the Freshwater Quality Monitoring Program
- the St. Lawrence Action Plan
- the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health (COA)
- the Great Lakes Basin (GLB) Monitoring and Surveillance Program
- the Global Atmospheric Passive Sampling network (GAPS)
- the Whales Initiative
- Canada's Plastics Science Agenda

Monitoring activities which support Canada's contribution to international efforts, include:

- the Canada-United States Great Lakes Water Quality Agreement
- the Great Lakes Herring Gull Contaminants Monitoring Program
- the Canada-United States Air Quality Agreement
- the Arctic Council's Arctic Monitoring and Assessment Programme and the Arctic Contaminants Action Program
- the United Nations Economic Commission for Europe's Convention on Long-range Transboundary Air Pollution
- the United Nations Environment Programme's Stockholm Convention on Persistent Organic Pollutants and the Minamata Convention on Mercury

In particular, the CMP Environmental Monitoring and Surveillance Program involves the collection of data on the concentration of chemical substances in various environmental media across Canada. Environmental media include surface water, sediment, air, aquatic biota and wildlife. Wastewater system influent, effluent and biosolids are also monitored across a range of input and treatment system types. These activities provide data to inform the assessment and management of chemical substances in the environment.

A selection of the numerous papers on the presence of chemicals in the environment published by ECCC scientists in 2022-2023 are highlighted below.

Examples of priority substances monitored in 2022-2023 as part of the CMP Environmental Monitoring and Surveillance Program

- Per- and polyfluorinated alkyl substances (PFASs)
- Polychlorinated biphenyls (PCBs)
- Polycyclic aromatic hydrocarbons (PAHs)
- Polybrominated diphenyl ethers (PBDEs)
- Other flame retardants
- Organochlorine pesticides
- Chlorinated alkanes
- Bisphenols
- Metals, including mercury
- Organotins
- Triclocarban
- Quaternary Ammonium Compounds

Prediction of bisphenol A contamination in Canadian municipal wastewater	
Abstract	Bisphenol A (BPA) is one of the most common contaminants of emerging concerns (CECs), which pose a threat to human health. Conventional wastewater treatment plants (WWTPs) are considered as the major pathway of BPA entering the aqueous environment. To control and mitigate BPA contamination in the aquatic environment, predicting BPAs fate at WWTPs is critical. In this study, three machine learning models, including shared layer multi-task neural network (MLT-NN), genetic programming (GP), and extra trees (ET) are used to predict the effluent BPA concentration at 12 municipal WWTPs across Canada. Additionally, the theory of networks is adopted to analyze the interdependencies among the influencing factors of BPA removal. It is found that the proposed models can provide reasonable BPA effluent concentration predictions. They have advantages in alleviating data sparsity and imbalance, improving model interpretability, and measuring predictor importance, which is valuable for the modeling of BPA and many other CECs. The network analysis results imply there are moderate interdependencies among various influencing factors of BPA removal. Factors that significantly affect BPA effluent concentration and are thus important for BPA removal are identified. The results also show that BPA is unlikely to be removed at primary treatment plants, while BPA removal could be achieved through secondary or tertiary treatment. This study presents an integrated framework for the modeling and analysis of BPA at WWTPs, which can provide direct and robust decision support for the management of BPA as well as other emerging contaminants in municipal wastewater.
Highlights	• a framework for Bisphenol A (BPA) modeling at wastewater plants is proposed • data from 12 plants are used to develop data-driven models for BPA prediction • influencing factors of BPA removal are studied using network theory • the results imply that BPA can hardly be removed through primary treatment • important factors for BPA removal at wastewater treatment plants are identified
Publication	Zhou, P., Li, Z., El-Dakhakhni, W., Smyth, S.A., 2022. *Prediction of bisphenol A contamination in Canadian municipal wastewater*. Journal of Water Process Engineering 50, 103304. DOI:10.1016/j.jwpe.2022.103304

Technology-critical elements in fishes from the Great Lakes	
Focus of Research	Technology-critical elements are increasingly extracted and used in electronics. The aim of this study is to assess the levels of these lesser-known elements in fishes of the Great Lakes.
Results	Concentrations of ten technology-critical elements (Ce, Gd, Hf, Ir, Os, Re, Ru, Ta, W, Y) were measured in the muscle of six fish species collected from Lakes Erie and Ontario, as well as their relationships to body size and condition to understand whether biological factors affect their bioaccumulation. The highest concentrations detected were for Ce in the muscle of trout-perch (*Percopsis omiscomaycus*) from Lake Erie, and in the muscle of round goby (*Neogobius melanostomus*) from Lake Ontario. There were negative relationships for W and Y with length in *S. namaycush* and deepwater sculpin (*Myoxocephalus thompsonii*), respectively. Also, there was a negative relationship for Gd with weight in *M. thompsonii*. The regressions showed that Ta showed positive relationship with both length and weight of yellow perch (*Perca flavescens*) from Lake Erie, whereas this element showed a negative correlation ($p < 0.05$) with the Fulton factor in *S. namaycush* from Lake Ontario. These first results suggest that technology-critical elements vary within and among species from two of the Great Lakes, with some decreasing with increasing fish size, and that these data could serve as baseline information to assess trends in fish populations in these systems. This study was conducted in collaboration the Unversidad de Concepción, McMaster University, and Toyo University.
Publication	Celis, J.E., W. Espejo, K. Kidd, D. McGoldrick, M. Clark, D. Kitamura, S. Kashiwada. 2022. *Technology-critical elements in fishes from two of the Laurentian Great Lakes*. Int. Aquat. Res. 14:285-292. DOI:10.22034/IAR.2022.1966270.1325

2.2.2 Chemicals in humans

HC human biomonitoring efforts continued in 2022-2023 with the national biomonitoring program conducted under the Canadian Health Measures Survey (CHMS), measuring environmental chemical exposures in a nationally representative sample of Canadians aged 3 to 79 years. Collection of data for cycle 7 of the CHMS experienced delays due to modernization efforts at Statistics Canada and subsequently the COVID-19 outbreak. Biomonitoring data collection for cycle 7 of the CHMS survey started in January 2023 and is planned for completion in late 2024. Cycle 7 includes emerging chemicals such as BPA substitutes, glyphosate, DEET and neonicotinoid pesticides, as well as the first samples collected from children aged 1 to 2 for metals in blood.

In order to generate timely baseline data for certain priority chemicals impacted by the delay in CHMS cycle 7, and to collect additional data points necessary to calculate time trends for certain priority chemicals measured in previous CHMS cycles, a CHMS biobank analysis was initiated in 2020. At year-end 2022-2023, the biobank analysis for a number of priority pesticides (including glyphosate and DEET), flame retardants, and self-care and consumer product chemicals had been completed, and the data were being validated. The data will be released online via the Canadian Biomonitoring Dashboard through PHAC's Health Infobase. The release of the dashboard with the existing CHMS (cycle 1 to 6) dataset alongside initial biobank data is planned for fiscal year 2023-2024.

Internal and external consultations for drafting the chemical list for Cycle 8 were completed and input has been consolidated.

Activities of the CHMS in 2022-2023 included:

- publication of two peer-reviewed scientific articles:
  - *Introducing the international human biomonitoring health-based guidance value (HB2GV) dashboard*
  - *Characterizing variability in total mercury hair:blood ratio in the general Canadian population*
- development of the Canadian Biomonitoring Dashboard on the Health Infobase platform, with the goal of launching the dashboard and releasing initial results from the CHMS biobank project in the 2023-2024 fiscal year
- CHMS biomonitoring data continues to inform Health Canada's risk assessment and management activities. For example, CHMS cycle 1, 3, 4, and 5 data were used in a dioxins and furans performance evaluation report

published in July 2022, which demonstrated that concentrations have remained stable since 2007 in the Canadian population.

- successfully integrated Canadian national biomonitoring data in the European Commission's 'Information Platform for Chemical Monitoring' (IPCHEM) databases, greatly enhancing access to the CHMS data and facilitating comparison of CHMS data with other international/European datasets by policy and research communities.
- launch of the Human Biomonitoring Health-Based Guidance Value (HB2GV) Dashboard, a HC initiative, under the auspices of International Human Biomonitoring Guidance Values Working Group and International Society of Exposure Science (ISES). The database allows search of health-based guidance values for priority chemical substances, and comparison of population concentrations against guidance values. This also aids prioritization of chemicals for monitoring, assessment and research.
- The National Biomonitoring Program organized, co-chaired and provided secretariat support for the annual International Human Biomonitoring (i-HBM) Working Group meeting at the ISES conference in Portugal.

The Maternal-Infant Research on Environmental Chemicals (MIREC) Study was established in 2007 to obtain national biomonitoring data for pregnant women and their infants, and to examine possible adverse health effects of prenatal exposure to environmental chemicals on pregnancy and infant health. There are several follow-up studies under the MIREC Research Platform, including:

- the MIREC-ID (Infant Development) study
- the MIREC-CD3 (Child Development at 3 years) and MIREC-CD Plus (Early Childhood Biomonitoring and Neurodevelopment) studies
- the MIREC-ENDO (Pubertal Timing, Endocrine and Metabolic Function) study

HC continued analysis and publication of biomonitoring and research results from the MIREC Research Platform. These included novel assessments of prenatal and early-childhood exposure to chemicals and the establishment of national estimates of maternal and fetal exposures (see section 7.1.2.1 for publications).

Phase 2 of the MIREC ENDO study started in-person recruitment in Q1 of 2022-2023 and by year-end 2022-2023 was recruiting participants from eight sites, with two more to come online. By the end of 2022-2023, 63% of participants contacted were interested in participating in Phase 2.

The MIREC Biobank, created at the beginning of the MIREC study in 2008, has grown with each follow-up study. The Biobank stores all the data and biological specimens collected since the inception of MIREC. Novel measures added to the Biobank in 2022-2023 include immune system biomarkers. At year-end 2022-2023, the MIREC biobank had six preliminary Biobank access requests under review, and five full Biobank access requests had been approved.

During the 2022-2023 fiscal year, 13 MIREC Research Platform papers were published, including the MIREC Research Platform's 100th publication. Nine of 13 publications were co-authored by Health Canada, using biomonitoring and research data from the MIREC cohort. These studies investigated prenatal and lactational exposure to multiple chemicals and associations with child health and neurodevelopment outcomes.

Other MIREC knowledge transfer activities for 2022-2023 included:

- providing data from MIREC participants for silver, dioxins and furans in support of risk assessment and performance measurement activities within HC
- contributing data to the draft risk profile for Chlorpyrifos with the Persistent Organic Pollutants Review Committee (PORC-17)
- scientific presentations at International Conferences, including the International Society for Environmental Epidemiology and the U.S. National PFAS conference

Monitoring in the North

Both ECCC and HC contributed to the Northern Contaminants Program (NCP) led by Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC). HC partners with CIRNAC on the human health component of the NCP, which addresses concerns about human exposure to elevated levels of contaminants in wildlife species important to the traditional diets of northern Indigenous peoples. In 2022-2023, HC supported six human biomonitoring and health projects under the NCP in several Arctic regions including the Yukon, Inuvialuit Settlement Region, Northwest Territories, and in Nunavik. These projects addressed:

- exposure to contaminants and links to country foods
- understanding dietary decision-making and supporting the development of communication materials
- the integration of information on country foods, nutrition, food security and health messaging
- identifying sources and patterns of persistent organic pollutants (POPs)
- understanding the health impacts of elevated exposure to perfluoroalkyl acids (PFAAs)

This work forms the basis of Canada's contribution to the Arctic Monitoring and Assessment Program's (AMAP) Human Health Assessment Group (HHAG), co-chaired by HC. The AMAP human health assessment was released in 2022-2023.

NCP knowledge transfer activities at year-end 2022-2023 included:

- data use from NCP funded projects to support several ongoing chemicals management activities in 2022-2023 (e.g., Performance Measurement Evaluation (PME) reports for cadmium and arsenic, the State of PFAS report, and the Preliminary Assessment of Chromium)
- publication of the Arctic Monitoring and Assessment Programme (AMAP)'s 2021 AMAP Assessment on Human Health in the Arctic (published April 13, 2022)

ECCC has been a major contributor in monitoring abiotic media, aquatic biota, and wildlife, as well as Arctic ecosystem health. ECCC monitors wildlife at numerous sites across the Canadian Arctic on a biennial or annual basis under the NCP, for a large suite of legacy and new Chemicals of Emerging Arctic Concern (CEACs), as well as metals, including mercury.

2.3 Air pollutants and greenhouse gases monitoring

Monitoring and reporting activities are important for identifying and tracking levels and trends of air pollutants that impact both the environment and human health, as well as greenhouse gases that impact climate change.

2.3.1 Air pollution

Ambient (outdoor) air quality monitoring informs air quality management in Canada. ECCC monitors ambient air quality across the country through two complementary networks.

- The National Air Pollution Surveillance (NAPS) program provides long-term air quality data from populated regions of Canada. This program is managed through a formal agreement between the provincial and territorial governments and ECCC.
- The Canadian Air and Precipitation Monitoring Network (CAPMoN) provides information on regional patterns and trends of atmospheric pollutants in both air and precipitation at rural and remote sites.

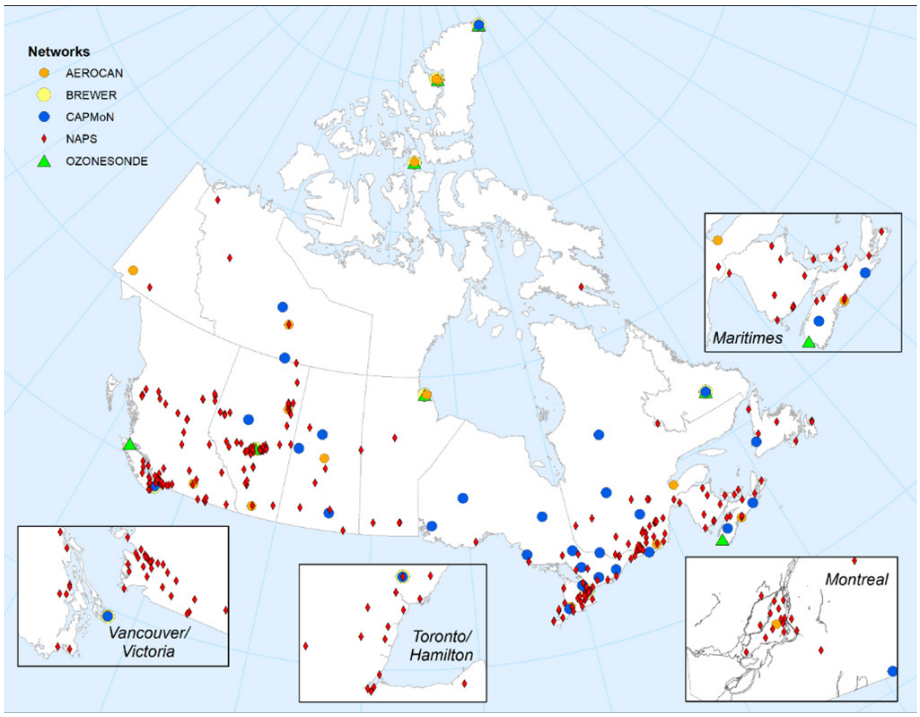
The data collected through the NAPS program and CAPMoN are used to assess the impact of air pollution on people in Canada and the environment, validate numerical air quality prediction models, evaluate the benefits and effectiveness of control measures, and report on Canada's progress under international air agreements. NAPS data are used to track progress relative to the Canadian Ambient Air Quality Standards (CAAQS). The CAAQS are

health- and environment-based air quality objectives for concentrations of fine particulate matter ($PM_{2.5}$), ground-level ozone (O_3), sulphur dioxide (SO_2), and nitrogen dioxide (NO_2) in outdoor air. Data collected through the NAPS program, CAPMoN, and other provincial, territorial, and municipal monitoring stations are used to calculate the Canadian Environmental Sustainability Indicators (CESI) air quality indicators. The indicators track ambient concentrations of fine particulate matter ($PM_{2.5}$), ground-level ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and volatile organic compounds (VOCs) at the national, regional, and urban levels, and at local monitoring stations.

Additional atmospheric monitoring carried out by ECCC includes the following networks:

- AEROCAN, the Canadian sub-network of NASA's global AERONET satellite network, takes optical readings of solar radiation to measure atmospheric aerosols
- The Canadian Brewer Spectrophotometer Network measures the total thickness of the ozone layer (known as total column ozone) and ultraviolet radiation (UV) at selected locations across Canada
- The Canadian Ozonesonde Network measures vertical column ozone from ground level up to 36 km altitude by launching weekly ozonesondes affixed to balloons, providing long-term ozone data

Figure 2. Canadian atmospheric monitoring sites



NAPS site location data is from 2021; all others from 2023.

ECCC makes its atmospheric monitoring data available to the public through national and international databases, including the Government of Canada Open Data Portal, the World Meteorological Organization (WMO), World Data Centres for GHGs, the WMO World Data Centre for Precipitation Chemistry, and, the WMO World Ozone and Ultraviolet Data Centre which is operated by the Meteorological Service of Canada.

The Air Quality Health Index (AQHI)

Data collected through the National Air Pollution Surveillance program are used to calculate the AQHI. The AQHI is a health protection tool designed to help people understand what the air quality around them means to their health. The AQHI is calculated based on the relative risks of a combination of the following common air pollutants known to harm human health:

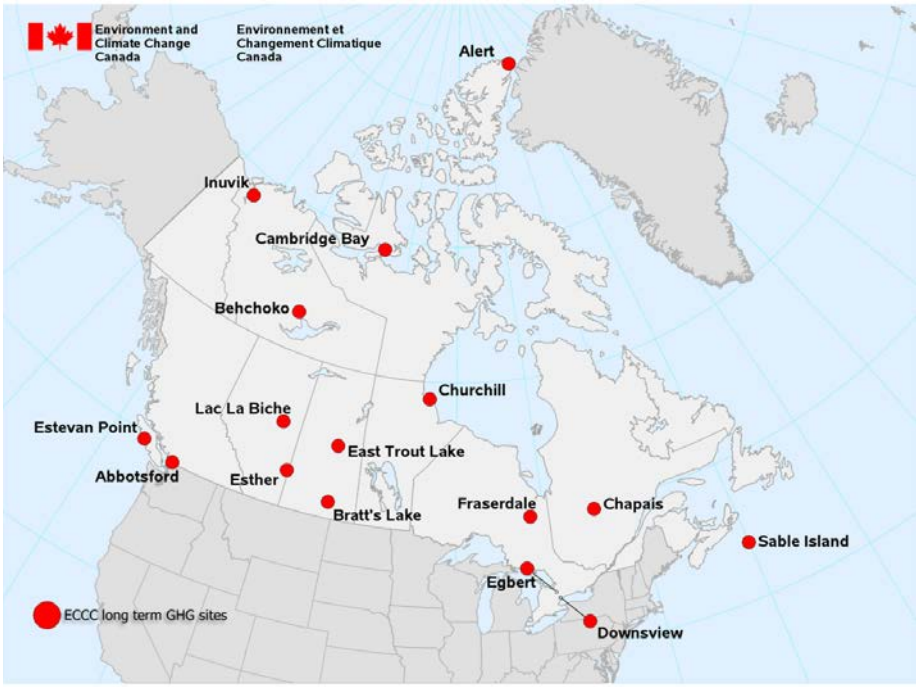
- Ozone (O_3) at ground level
- Particulate matter ($PM_{2.5}$/PM_{10})
- Nitrogen dioxide (NO_2)

The AQHI is measured on a scale ranging from 1-10+. The AQHI index values are grouped into health risk categories as shown below. These categories help to identify the level of risk easily and quickly.

2.3.2 Greenhouse gases

The Canadian Greenhouse Gas Measurement Program includes observations of carbon dioxide and other GHGs from 16 long-term measurement sites across Canada (Figure 3). Among the sites is the Alert Global Atmosphere Watch Observatory. Alert serves as one of three global GHG inter-comparison sites to ensure consistent measurement of carbon dioxide (CO_2) and other greenhouse gas concentrations across the world.

Figure 3. Canadian Greenhouse Gas Measurement Program monitoring sites



ECCC makes its atmospheric monitoring data available to the public through national and international databases, including the Government of Canada Open Data Portal, the World Meteorological Organization (WMO), World Data Centres for GHGs, the WMO World Data Centre for Precipitation Chemistry, and: the WMO World Ozone and Ultraviolet Data Centre which is operated by the Meteorological Service of Canada.

Measurements of atmospheric CO_2 and CH_4 at Alert, Nunavut

Measurements of atmospheric CO_2 began in July 1975 at Alert, Nunavut (**Figure 4**). The annual average CO_2 value at Alert in 2022 was 419.8 parts per million (ppm), which is slightly higher than the annual average CO_2 values at Alert in 2021 and 2020 which were 417.4 ppm and 414.9 ppm, respectively.

ECCC began measuring atmospheric methane (CH_4) in June 1985 at Alert, Nunavut (**Figure 5**). The annual average CH_4 value at Alert in 2022 was 1 997.2 parts per billion (ppb). Annual CH_4 concentrations are now increasing following the relatively stable period from about 1999 to 2007. The annual average values of CH_4 at Alert in 2021 and 2020 were 1 981.0 ppb and 1 967.7 ppb, respectively.

Figure 4. Atmospheric carbon dioxide measured at Alert, Nunavut

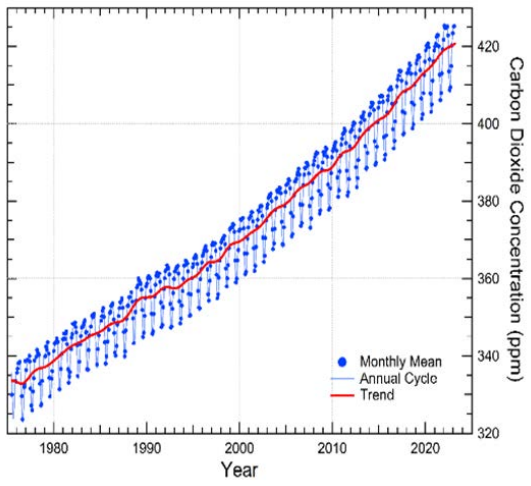
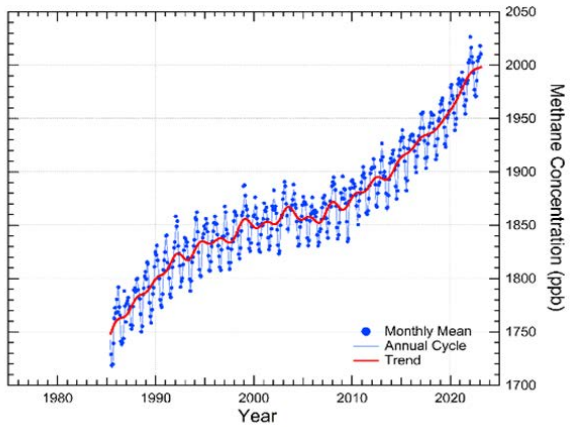


Figure 5. Atmospheric methane measured at Alert, Nunavut



2.4 Disposal at sea site monitoring program

By monitoring disposal sites, ECCC is able to verify that the permitting of disposals at sea is sustainable and that permit holders have continued access to suitable sites. Where monitoring indicates a problem or where the site has reached its capacity over time, management actions in the form of closing the site, moving the site, or altering the site use can occur. ECCC works with Indigenous groups, the public, and other stakeholders to ensure early and meaningful opportunities for engagement on proposed disposal activities and integration of recommendations and concerns as appropriate into monitoring and site management measures.

In 2022-2023, monitoring projects were completed at 14 ocean disposal sites nationally, which amounts to monitoring 20% of the 70 actively used sites. Due to the nature of field work cycles, analysis and interpretation of monitoring results is not always finalized in the same year that the monitoring was conducted. Therefore, any previous studies for which results have now become available are reported alongside the 2022-2023 results.

Pacific region

In 2022-2023, four sites were monitored in the Pacific region. In addition to the results for the 2022-2023 monitoring studies, final results are now also available for the 2021-2022 ocean bottom current monitoring at the Sand Heads disposal site.

ECCC collaborated with the Canadian Hydrographic Survey to complete multibeam bathymetric surveys at the Sand Heads disposal site. Multibeam bathymetric surveys measure the water depths and map the seafloor topography to delineate the disposal footprint and offer valuable temporal assessment of bathymetric and volumetric changes between surveys.

Monitoring at Point Grey and Kitimat Arm 2016 disposal sites consisted of sediment grab sampling for physiochemical parameters to better understand the potential effects related to disposal activities. Monitoring at the Kitimat Arm 2016 disposal site also consisted of sediment grab sampling for toxicity testing. Monitoring of the Point Grey disposal site also consisted of biological monitoring, incorporating two methods of benthic community assessment. The first method was to repeat a morphology-based benthic study to assess whether the benthic invertebrate communities within and near the Point Grey disposal site have changed since the last study in 2010. The second method was a pilot project to explore the use of environmental genomics in sediment as a monitoring tool for the disposal at sea site monitoring program. Environmental genomics is a novel approach to biodiversity characterization that does not require collection of whole biological specimens but instead relies on recoveries and analysis of DNA from the physical environment in which they live. Results will be reported when data analysis is completed.

Data collection began on the seasonal current velocity and directional information 1 metre above the seafloor at the Cape Mudge disposal site, part of an ongoing effort to increase understanding of the movement of sediments at disposal sites. Natural Resources Canada is leading this work and results will be reported when data analysis is complete.

Work continued on sediment contaminant monitoring in and around the Point Grey and Sand Heads disposal sites, in support of the Government of Canada's Whales Initiative. The Disposal at Sea program's participation in this five-year initiative (2018 to 2022), including data analysis, is ongoing and results will be reported when data analysis is completed.

Table 2. Results of monitoring disposal at sea sites in Pacific region in 2022-2023

Disposal Site	Results	Comments
Sand Heads	2021-2022: The results from the ocean bottom current monitoring confirmed that the site is strongly dispersive. 2022-2023: The results from the multibeam bathymetric survey confirmed that the site is located in a naturally dynamic area that is constantly changing. When comparing the 2020 and 2022 surveys, a significant amount of material has collapsed within the disposal site and moved down slope but it was not possible to conclusively determine source of material as natural river deposition or disposal at sea without extensive ground truthing.	ECCC is considering possible updates to the monitoring of the site, including sediment transport modelling to further understand the dynamics at the disposal site and the surrounding area.
Cape Mudge	Ocean bottom current data collection in progress.	Full results will be reported in the 2024-2025 CEPA annual report
Point Grey	The results from the sediment grab sampling confirmed that sediment contaminant concentrations were within ranges observed in results of previous past monitoring. The results from the morphology-based benthic invertebrate community study confirmed that the total biomass of macrofauna and meiofuana were similar between 2010 and 2022. There was no indication that sediment contaminants affected benthic infaunal structure and functioning in 2022 since sediment concentrations were typically higher surrounding the disposal site than within the disposal site. Analysis of the environmental genomics is in progress.	Results of the environmental genomics study will be reported in the 2024-2025 CEPA annual report.
Kitimat Arm 2016	Overall, the results from the sediment grab sampling confirmed that sediment contaminant concentrations within the disposal site were lower compared to outside of the disposal site. Exceptions to this were PAH, PCB, and PBDE concentrations, which were slightly higher inside the disposal site than outside but within ranges observed in results of previous monitoring and all samples passed toxicity tests. There are no concerns at this time.	There are currently no concerns. ECCC will continue monitoring the site at regular intervals.

Quebec region

In 2022-2023, a total of six disposal sites were monitored: three in the Gaspé region and three near the Magdalen Islands, one of them (Dépôt E) being the biggest site in the area. Post-disposal hydrographic surveys were conducted at these sites and compared to the results of previous surveys, providing a "before and after" survey of the sea floor. In addition to the results for the 2022-2023 monitoring studies, final results are now also available for hydrographic surveys conducted at 6 disposal sites in 2021-22. These included four in the Gaspé region and two near the Magdalen Islands (see Table 3).

The sites in the Gaspé and Magdalen Islands regions were monitored with the objectives of verifying compliance with permit conditions, establishing the height of the material deposited (i.e., mounds) for navigation safety purposes and to verify the dispersion of sediments. Hydrographic surveys in recent years at the disposal sites in the Gaspé region have given some perplexing results, where not all the material reported as deposited could be located at the site. The hydrographic surveys in 2021-2022 and 2022-2023 also aimed to evaluate whether this situation was persisting or if compliance promotion efforts had led to improvements. Results from 2021-2022 indicated that only one site, Saint-Godefroi, remains problematic, although results were inconclusive at L'Anse-à-Brillant due to the low volume of material disposed, while 2022-2023 results showed three problematic sites (see Table 3).

In order to determine whether conditions at the sites have changed and if permit assumptions about currents remain valid, a video study is being planned to enable visualization of the seafloor at and around the problematic disposal sites. ECCC is also in contact with the proponents as we continue work to determine the fate of material disposed at these locations.

Table 3. Results of monitoring disposal at sea sites off the coast of Quebec in 2022-2023 (and previously unreported results from 2021-22)

Disposal Site	Results	Comments
Gaspé		
Port-Daniel-Est (PD-6)	2021-2022: 2 720 m^3 of material was disposed of at the site and approximately the same volume at the correct coordinates was detected with the post-disposal hydrographic survey.	This result represents an improvement, given the fact the surveys in 2016, 2018 and 2020 did not detect the disposed volumes. This site is considered to be non-dispersive, but a more in-depth study may be pursued in the future help to assess the situation.
Saint-Godefroi (SG-2)	2021-2022: 2 366 m^3 of material was disposed of at the site but it was not detected with the post-disposal hydrographic survey. 2022-2023: 2 178 m^3 was disposed of at the site but it was not detected with the post-disposal hydrographic survey.	Despite reported disposal volumes of 2 366 m^3 in 2021-22 and 2 178 m^3 in 2022-2023 the material was not detected at the disposal site in post-disposal hydrographic surveys in either year. This site remains problematic, with the same pattern of results for the last 7 years. Annual monitoring is still required for the site, in addition to compliance promotion with the contractor. This site remains a priority for environmental enforcement officers to visit whenever possible.

L'Anse-à-Brilliant (ABR-1)	2021-2022: 1 500 m^3 of material was disposed of at the site but not detected in the post-disposal hydrographic survey.	Despite a reported disposal volume of 1 500 m^3 and 800 m^3 in 2022-2023, the material was not detected at the disposal site. The small volumes could explain this result as they may have dispersed before reaching the seabed. Annual monitoring is required for this site.
	2022-2023: 800 m^3 of material was disposed of at the site but not detected in the post-disposal hydrographic survey.	
L'Anse-à-Beaufils (AB-5)	2021-2022: 5 994 m^3 of material was disposed of at the site in 2021-22 and approximately the same volume at the correct coordinates was detected with the hydrographic survey.	The 2021-2022 result represents an improvement, given the fact the results for 2016, 2018 and 2020 did not detect the disposed volumes.
	2022-2023: 3 376 m^3 of material was disposed in 2022-2023 but no material was detected at the disposal site.	The 2022-2023 result went back to the situation of the hydrographic survey not detecting the disposed volume. Annual monitoring is required for this site and a priority for future field inspections.
Îles-de-la-Madeleine		
Millerand (M-5)	2021-2022: 9 845 m^3 of material was disposed of at the site and 40% of the volume was detected at the correct coordinates with hydrographic survey.	The result suggests a more dispersive site than expected; this trend has been observed for some years now. Hydrographic surveys showed over the time a creation of underwater sand dunes east of the disposal site, probably fed by the dredged material disposed of at the site.
Pointe-Basse (PBCM-1)	2021-2022: 37 019 m^3 of material was disposed of at the site and approximately the same volume at the correct coordinates was detected with the hydrographic survey.	The west side of the site has almost reached its capacity and the minimum depth (draft) for safe navigation, so could no longer be used. The east side of the side was used for disposal in 2022-2023.
	2022-2023: 43 171 m^3 of material was disposed of at the site and approximately the same volume at the correct coordinates was detected with the hydrographic survey.	No concerns have been identified.
L'Île-d'Entrée (IE-6)	2022-2023: 9 295 m^3 of material was disposed of at the site and 58% of the volume was detected at the correct coordinates with hydrographic survey.	Fiona storm seems to have contributed to movement of sediments outside of authorized coordinates, as shown in the surveys, which could explain the 2022 results.
Chenal de la Grande-Entrée (Dépôt E)	2022-2023: Hydrographic surveys showed a mound at the correct coordinates, but complete volume calculations were not possible.	Much of the sediment disposed of to the south of the disposal site could not be calculated because there was no recent survey previously done at that exact location. The 2022-2023 data can now form a baseline for future studies.

Arctic region

Final results are now available for the 2021-2022 monitoring study that ECCC, in partnership with the Canadian Hydrographic Service, undertook at the Frobisher Bay disposal site in the Arctic region, in the eastern Arctic in Nunavut (see Table 4). The objectives of this hydrographic survey were to verify compliance with permit conditions, establish the height of the material deposited, (i.e., mound), for navigation safety purposes and to verify the dispersion of sediments. Results were conclusive, even though the volume calculations were only an estimate, based on a synthetic reference image, and didn't allow for a reliable, high-precision calculation.

Table 4. Results of monitoring disposal at sea sites off the Arctic coast (previously unreported in 2021-2022)

Disposal Site	Results	Comments
Frobisher Bay (FB-01)	2021-2022: Hydrographic surveys showed a mound at the correct coordinates and approximately 92% of the sediment still in place.	Since volume calculations are only estimates, the stability of the disposal site cannot be validated with certainty.

Atlantic region

In 2022-2023, four sites were monitored in the Atlantic region. Hydrographic monitoring surveys were conducted at the Black Point and Shippagan Gully disposal sites off the coast of New Brunswick and optical monitoring surveys were conducted at the St. Lawrence, Newfoundland fish waste disposal site and the on a beach adjacent to the Point Sapin Small Craft Harbour disposal site.

In addition to the results for the 2022-2023 monitoring studies, final results are now also available for the three 2021–2022 monitoring studies and one 2019-2020 monitoring study and all are provided in this report. The 2021-2022 studies included hydrographic monitoring surveys conducted at the Black Point, NB and Shippagan Gully, NB disposal sites and an optical monitoring study conducted at the Charlottetown, Labrador fish waste disposal site. The 2019-2020 study was a physicochemical and biological sediment monitoring study conducted at the Black Point, NB disposal site. Results are explained by disposal site.

Black Point disposal site, New Brunswick

The Black Point disposal site is located in the Bay of Fundy and was initially believed to be dispersive. However, repetitive hydrographic surveys have shown significant sediment build-up, and an analysis of these surveys determined an average net retention rate of disposed material of 29.1%. Given this accumulation, ECCC is now assessing the elevation of the accumulated material annually, as per the site management plan, to confirm that the disposed material accumulation is less than 7 metres above the 1959 baseline elevation. The 7 metre threshold was selected by the DAS program as a conservative navigational criterion. In January 2021, ECCC moved the active release zone to a more northerly area of the disposal site as the elevation was approaching the 7 metre height difference criteria. The July 2021 and June 2022 hydrographic surveys were compared to each other and the 1959 baseline survey. Results showed that the release zone is well below the 7 metre height threshold.

In November 2019, sediment samples were collected from within the Black Point, NB disposal site and three associated reference areas located in the outer Saint John Harbour to undertake physical and chemical analyses and assessments of the biological communities. These types of monitoring are conducted every five years to understand short-term and longer-term environmental changes, if any, at and around the disposal site. Based on the collective analyses of the physical, chemical, and biological data, it is likely that the low abundance, richness and diversity at the disposal site are primarily a result of the physical impacts of the regular disposal of dredged sediments at the site, rather than because of contaminant concentrations in the discharged sediments. The results of the 2019 study are consistent with previous findings based on samples collected from 1959 to 2002, indicating that there has been little biological change at the disposal site, particularly since 2001 when the surrounding area was thoroughly sampled.

Shippigan Gully disposal site, New Brunswick

Monitoring at the Shippagan Gully disposal site is driven by the need to monitor the fate of disposed materials and to verifiy the rate of dispersion against that predicted by the model. Three hydrographic surveys were conducted in 2021 (spring, summer and fall) following the completion of disposal activities. The surveys were compared to each other and to the 2019 baseline survey. The results of the hydrographic surveys were be shared with Saint Mary's University, to be used in their proposed research program on the beneficial re-use of the dredged material and effectiveness of mitigation measures related to the Piping Plover Recovery Strategy.

Over the five and a half month timeframe of the 2021 hydrographic surveys, the disposal site did not appreciably diminish in size or configuration. When compared to the 2019 baseline, the seabed did not appear to be accreting material as the bathymetry remained essentially constant. It was concluded that five and a half months was not sufficient time to observe appreciable dispersion of the disposed material subsequent to the conclusion of disposal activities. Therefore, in 2022-2023, spring, summer and fall bathymetric surveys were conducted again in the area surveyed in 2021-2022. These 2022-2023 surveys will be compared to each other, to the 2021-2022 surveys and to the 2019 baseline survey and the results of these analyses will be reported in the 2024-2025 CEPA report.

Fish waste disposal sites: Charlottetown, Labrador and St. Lawrence, Newfoundland

Fish waste disposal sites are selected to be dispersive so that fish waste does not accumulate on the seafloor. Representative monitoring of fish waste disposal sites was conducted in 2021-2022 and in 2022-2023 to ensure that there was no build-up of fish waste or other visual indicators of impacts. The optical surveys were completed using a remotely operated vehicle (ROV) equipped with a 4K GoPro attachment (i.e., video footage).

In 2021-2022, a pre-disposal optical monitoring study was conducted at the Charlottetown, Labrador fish waste disposal site. There were no visual signs of fish waste build-up or environmental impacts resulting from disposal activities. In 2022-2023, two optical monitoring studies were conducted at the St. Lawrence, Newfoundland fish waste disposal site; one survey following the conclusion of disposal activities and the second after the winter storm season in order to assess the dispersiveness of the disposal site. Results confirmed that the site is dispersive and no evidence of fish waste or other impacts were observed.

Point Sapin Small Craft Harbour disposal site, New Brunswick

At the Point Sapin, NB DFO SCH, annual maintenance dredging is required to maintain safe navigational depths. Dredging is done by an excavator from the beach and the dredged material is then transported, by truck, to a near shore disposal site. Access to the dredge area is via an existing road/path which crosses a small section of Piping Plover Critical Habitat. In order to ensure protection of this critical habitat during dredging and disposal operations, several mitigation measures are in place, including restricting the timing of activities to a time of year when Piping Plover are not present, restricting equipment on the beach to just the required transit path and the use of truck mats on the transit path should the beach not be frozen. It is predicted that any residual effects would be limited to equipment tracks/wheel ruts and that these effects will disappear naturally through tide and wave activity between one and four weeks post project. In order to verify the accuracy of these impact predictions, a post-disposal optical monitoring study was conducted following the winter 2022-2023 dredging activities. A return to pre-use conditions occurred approximately seven weeks after the completion of dredging and disposal activities, confirming the impact predictions.

Table 5. Results of monitoring disposal at sea sites in Atlantic region in 2022-2023 (and previously unreported results from 2019-20 and 2021-22)

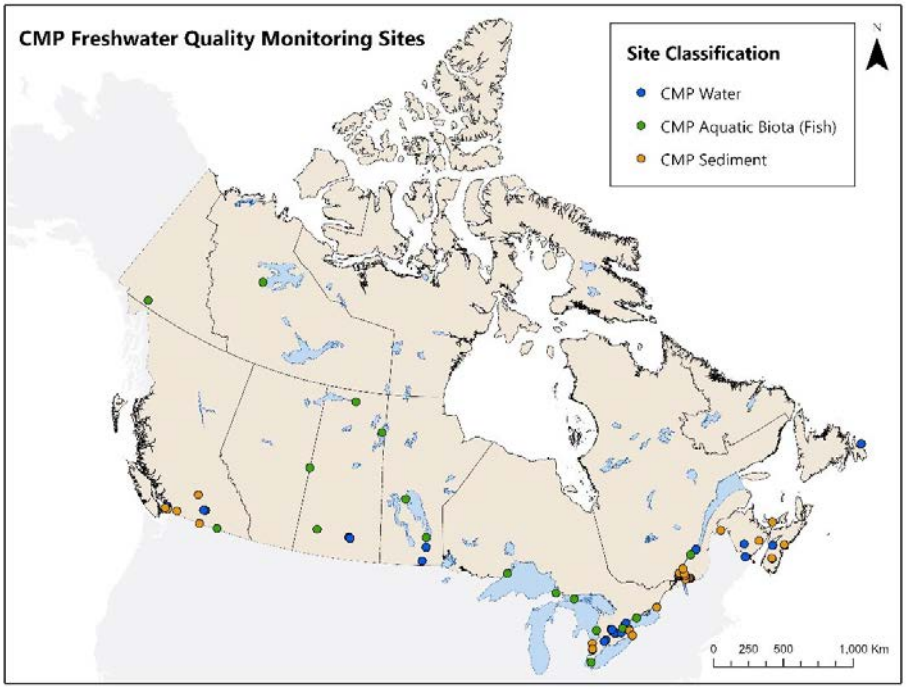
Disposal Site	Results	Comments
Black Point, NB 2019 Physical, Chemical and Biological Sediment Monitoring Study	The results of the 2019 study are consistent with previous findings based on samples collected from 1959 to 2002, indicating that there has been little biological change at the disposal site, particularly since 2001 when the surrounding area was thoroughly sampled.	Physical, chemical and biological monitoring will be repeated at 5year intervals.
Black Point, NB 2021-2022 and 2022-2023 Hydrographic Surveys	Hydrographic data analysis indicates the site was stable between 2020-2021, 2022 and 2023.	The 2021+ Release Zone may continue to be used for disposal activities.
Shippagan Gully, NB 2021-2022 and 2022-2023 Hydrographic Surveys	The analysis of the 2021-2022 hydrographic surveys indicated that the study period was not sufficient to observe appreciable dispersion of the disposed material.	Analysis of the 2022-2023 results and comparison to previous surveys will be reported in the 2023-2024 CEPA report. This will allow for a longer study period.
Charlottetown, Labrador 2021-2022 Optical Monitoring Study	Based on the analysis of the ROV footage, there are no visual signs of fish waste accumulation on the seafloor within or outside of the permitted disposal site.	Disposal activities are being conducted according to the DAS regulations and permit conditions. The disposal site is dispersive.
St. Lawrence, Newfoundland 2022-2023 Optical Monitoring Study	Based on the analysis of ROV footage, there are no visual signs of fish waste accumulation within or outside of the permitted disposal site.	Disposal activities are being conducted according to the DAS regulations and permit conditions. The disposal site is dispersive.
Point Sapin, NB 2022-2023 Optical Monitoring Study	A return to pre-use conditions occurred approximately seven weeks after the completion of dredging and disposal activities.	Given that Piping Plovers arrive on the breeding grounds from the end of March to early May and stay until early to mid July, it is believed that the winter dredging and disposal activities are unlikely to have a significant impact on Piping Plovers at this site.

2.5 Water quality monitoring in support to CMP surveillance sites

Freshwater quality monitoring has been a core ECCC program since the Department's inception in the early 1970s. The Department's monitoring and surveillance activities are critical for assessing and reporting on water quality status and trends in addition to fulfilling federal domestic and international commitments and legislative obligations. Much of the Program's monitoring is carried out through federal-provincial/territorial agreements, ensuring cost-effective and non-duplicative program delivery.

ECCC's Freshwater Quality Monitoring program continues to implement a risk-based adaptive management framework in conjunction with statistical analyses to better target monitoring activities to the risks of contaminants and human activities in Canadian watersheds. The approach has been used to optimize monitoring locations and adjust monitoring frequencies relative to the environmental risks and to report on changes in environmental condition. The program continues to monitor chemicals of concern in water, sediments and aquatic biota at national sites across Canada in support of the Chemicals Management Plan (CMP) and the Great Lakes Water Quality Agreement (Figure 6).

Figure 6. Freshwater quality monitoring programs sites in support of the CMP Environmental monitoring and surveillance in 2022-2023 (aquatic biota (fish), water, and sediment).



ECCC's Freshwater Quality Monitoring program continues to support performance measurement and evaluation of regulated chemicals by providing data and/or syntheses to determine the status and trends of polycyclic aromatic hydrocarbons (PAHs) and perfluorooctane sulfonate (PFOS) in the Canadian environment. The program also made contributions to the Toxic Chemicals assessment of the 2022 State of the Great Lakes Report for the water, sediment, and whole fish sub-indicators which evaluate the status and trends of several chemicals of concern.

Please see the *Canada Water Act* Annual Reports for updates on freshwater quality monitoring in Canada.

2.6 Wildlife contaminant monitoring

ECCC has been monitoring contaminants in wildlife, primarily bird eggs, since the early 1970s. The data has been used to assess the health of wildlife, including in polluted regions such as the Great Lakes Areas of Concern, and to determine the success of mitigation measures and changes to regulation and management of chemicals in reducing levels of chemicals in wildlife. The prime monitoring species are colonial waterbirds, such as gulls, which are monitoring in all three coasts, in the prairies, the Arctic, Great Lakes and the St. Lawrence River basin. Colonial waterbirds feed from the aquatic environment, and hence indicate trophic transfer of contaminants in both freshwater and marine ecosystems. Colonial waterbirds are monitored from both the Great Lakes Herring Monitoring Program (annual collections from 1974 onward), and the Chemicals Management Plan (CMP) Environmental Monitoring and Surveillance Program from 2008 onward.

European starlings are also monitored throughout Canada on both the east and west coasts, in the prairies, the Arctic, Great Lakes and the St. Lawrence River basin. Starlings represent the terrestrial element of the wildlife monitoring component and collection sites target rural, urban sites and landfills as possible sources of emissions to the environment. Starlings have been monitored annually as part of CMP Environmental Monitoring and Surveillance since 2009.

Data collected from the eggs of these birds are used to assess legacy compounds, such as PCBs, pesticides and mercury, but also current or recently used substances of mutual concern, such as PFAS, brominated flame retardants, and rare earth elements.

3. Addressing key risks: risk assessment and risk management

Risk assessments help to identify the sources of pollution that pose the greatest risk to the environment and human health. While risk assessment is the prelude to, and informs, the **risk management** stage for all programs under CEPA, the Act provides explicit direction on the assessment of toxic substances and the assessment of wastes and other matters that are destined for disposal at sea.

3.1 Chemicals

CEPA includes specific requirements for the assessment and management of substances in Canada. The Minister of Environment and Climate Change and the Minister of Health jointly administer this part of the Act.

There are two streams of risk assessment for substances in Canada:

- existing substances: a substance that is being or has been used in Canada as a commercial substance or product, or released into the Canadian environment as a single substance, effluent, mixture, or contaminant
- new substances: a substance (chemicals, polymers or living organisms) being introduced into the Canadian marketplace that are not on the Domestic Substances List

Progress under the Chemicals Management Plan

The Chemicals Management Plan (CMP) is a program, jointly delivered by ECCC and HC, to assess and manage environmental and health risks posed by chemical substances that can be found in food and food products, consumer products, cosmetics, drugs, drinking water and industrial releases. Included is a commitment to address approximately 4 300 existing substances of potential concern. The Government also conducts pre-market assessments of health and environmental effects of approximately 350 new substances to Canada each year.

Chemicals Management Plan Update

Since the launch of the CMP in 2006, the Government of Canada has been managing potential risks to Canadians and the environment. As of March 31, 2023, the Government of Canada has:

- addressed **95% (4 144)** of the 4 363 **existing substances** identified as priorities in 2006
- found **353** existing substances to be harmful to the environment and/or human health, for a total of **602** when including toxic substances identified prior to 2006
- implemented over **210 risk management** actions for existing substances
- assessed approximately **6 996 notifications for new substances** prior to their introduction into the Canadian market
- implemented **320 risk management actions** for new substances

3.1.1 Information gathering

Mandatory notices issued under CEPA are used to gather information needed to inform priority-setting, risk assessment and risk management activities, as well as decision making for chemical substances. In 2022-2023:

- ECCC and HC continued to respond to inquiries and receive data from information gathering notices published in the *Canada Gazette* in late 2021-2022, specifically with respect to bisphenol A (BPA) and BPA structural analogues and certain substances on the Revised In Commerce List.
- ECCC and HC also continued to hold discussions with stakeholders on the future direction of the information-gathering program, in particular balancing stakeholder concerns while ensuring program core data needs.
- In July 2022, ECCC published an updated information-gathering plan.
- In March 2023, ECCC published a non-confidential summary of bisphenol A (BPA) and BPA structural analogues information gathering initiative on their open data platform.

Identifying risk assessment priorities

Since 2014, ECCC and HC have developed and implemented an approach to the identification of risk assessment priorities (IRAP) for chemicals under CEPA. As part of this approach, both departments compile new information on substances, evaluate this information, and then subsequently determine if further action on the substance(s) may be warranted.

Results from past IRAP review cycles (2015, 2016, 2017-2018 and 2019) and from ECCC's 2022 Science Approach Document for the *Ecological Risk Classification of Organic Substances version 2.0* (ERC2) are available online and will continue to inform future risk assessment activities, including data gathering.

- The program initiated a new IRAP review cycle in 2022, including collection of internal nominations from CMP program partners, and further scoping of substances identified in previous IRAP cycles. Results of these prioritization activities will feed into the development of a new risk assessment workplan that will be consulted on prior to implementation.

3.1.2 Existing substances

3.1.2.1 Risk assessment of existing substances

ECCC and HC conduct risk assessments or screening assessments to determine whether existing substances on the DSL meet or are capable of meeting any of the criteria for toxicity as set out in section 64 of the Act. Draft screening assessments are published for a 60-day public comment period, followed by the publication of the final screening assessments.

During 2022-2023, the Ministers (see Table 6):

- published 1 draft screening assessment and reports covering 5 substances
- published 17 final screening assessment reports covering 69 substances
- published an additional risk characterization document in support of the draft screening assessment for the Furans Compounds Group
- concluded that 9 substances meet one or more of the toxicity criteria set out in section 64 of CEPA

3.1.2.2 Risk management of existing substances

Risk management instruments are put in place to reduce or eliminate risks to the environment and/or human health after a substance has been concluded toxic. Risk management instruments may take the form of regulations, pollution prevention plans, release guidelines or codes of practice, environmental performance agreements, and environmental quality guidelines. The risk management scope is published to outline the Government of Canada's early thinking on risk management. If the final screening assessment maintains the toxic conclusion, the risk management approach is published and outlines in more detail the Government of Canada's plan for risk management.

Risk management scope and approach documents

When a draft risk assessment proposes a conclusion that the substance is "toxic" under CEPA, meaning that the substance has met one or more of the criteria in section 64, a **risk management scope document** is developed and published at the same time as the draft assessment report.

- There were no risk management scope documents published in 2022-2023 (see Table 6). However, on March 18, 2023, an Addendum to the Risk Management Scope for Furan Compounds - Furfuryl alcohol and tetrahydrofuran in outdoor air was published for a 60-day public comment period ending May 17, 2023.

When the final screening assessment report concludes that a substance is "toxic" under CEPA, a **risk management approach document** is developed and published at the same time as the final risk assessment report.

In 2022-2023, 2 risk management approach documents were published for substances, or groups of substances, that met one or more of the toxicity criteria set out in section 64 of CEPA (see Table 6).

Final decision by the Ministers

The Ministers may recommend the addition of a substance to Schedule 1 of CEPA if a screening assessment concludes that a substance meets one or more of the toxicity criteria set out in section 64 of CEPA.

- No final Orders were published in 2022-2023, therefore, no substances were added to Schedule 1.

Proposed regulations

Proposed regulations are published in the *Canada Gazette*, *Part I* and are linked to the CEPA Registry.

- On May 14, 2022, the proposed *Prohibition of Certain Toxic Substances Regulations, 2022* were published. The proposed *Prohibition of Certain Toxic Substances Regulations, 2022* would repeal and replace the *Prohibition of Certain Toxic Substances Regulations, 2012* and introduce restrictions on the manufacture, use, sale and import of DP and DBDPE, and products containing these substances. The proposed Regulations would also further restrict the manufacture, use, sale and import of PFOS, PFOA, LC-PFCAs, HBCD and PBDEs, and products containing these substances, which are already prohibited, with some exemptions, under the current Regulations.
- On May 14, 2022, the proposed *Order amending Schedule 3 to the Canadian Environmental Protection Act, 1999* (the Export Control List) was published in *Part I* of the *Canada Gazette*, for a 75-day public comment period. Notably, the proposed Order would add certain substances, including DBDPE, DP, HBCD, PFOA, LC-PFCAs, PBDEs and ferbam to the Export Control List making their exports subject to the *Export of Substances on the Export Control List Regulations*.
- On December 24, 2022, the proposed *Regulations Amending the Products Containing Mercury Regulations* were published. The main objective of the proposed Amendments to the *Products Containing Mercury Regulations* (the proposed Amendments) is to protect people in Canada by lowering the risk of mercury releases into the environment from lamps in Canada. In addition, the proposed Amendments would ensure the Regulations meet the requirements under the Minamata Convention and in some cases, go beyond what is required in the Convention to further decrease mercury releases.

Final regulations

Final regulations are published in the *Canada Gazette*, *Part II* and are linked to the CEPA Registry.

- On February 3, 2023, the *Prohibition of the Manufacture and Importation of Wheel Weights Containing Lead Regulations* were published. The Regulations aim to reduce human and environmental exposure to lead by prohibiting the manufacture and import of lead wheel weights destined for the Canadian market, which will help reduce the adverse health impacts resulting from lead exposure, and help improve air, water and soil quality.

Regulatory administration

The *Ozone-depleting Substances and Halocarbon Alternatives Regulations* control the export, import, manufacture, sale and certain uses of ozone-depleting substances and hydrofluorocarbons, as well as certain products containing or designed to contain these substances.

- In 2022-2023, approximately 135 permits were issued under these Regulations. Additionally, consumption allowances for hydrofluorocarbons (HFC) and hydrochlorofluorocarbons (HCFCs) were issued to eligible companies and 30 requests for transfer of allowances were granted. The Department publishes the list of HFC and HCFC allowance holders as well as holders of essential purpose permits.

The *Export of Substances on the Export Control List Regulations* apply to the export of substances listed on Schedule 3 of CEPA (known as the Export Control List) and to the export of products containing these substances.

- In 2022-2023, 63 notices of proposed export were submitted to the Minister of the Environment and Climate Change. No export permits were requested.

Codes of practice

Codes of practice are voluntary instruments that recommend procedures and practices or environmental controls relating to works, undertakings, and activities. They aim to encourage the sustainable use of the environment and to reduce pollution. Codes of practice are not enforceable. They set out official national standards that companies and organizations should follow.

- On February 4, 2023, the proposed *Code of Practice for the Environmentally Sound Management of Chemical Substances in the Chemicals, Plastics and Rubber Sectors* was published for chlorhexidine and its salts. The objective of this Code of Practice is to identify and promote best practices in the management and handling of chemical substances in the manufacturing and distribution of chemicals, plastics, and rubber products in order to prevent releases of these substances into the environment.
- On February 4, 2023, a Notice regarding the proposed *Code of Practice for the Environmentally Sound Management of Chemicals* was published in *Canada Gazette, Part I* for a 60-day comment period. The purpose of the proposed Code is to provide guidance on best practices to manufacturers, formulators and distributors in the chemicals, plastics and rubber sectors in order to prevent releases of chemical substances to the environment.

The complete list with status updates for all active codes of practice is available online.

Environmental performance agreements

An environmental performance agreement is a voluntary and non-statutory instrument that allows parties with common goals to address a particular environmental or human health issue, such as reducing the use or release of chemicals, promoting product stewardship or conserving sensitive habitats. These agreements may be used to complement a regulation, a code of practice or a pollution prevention planning notice under CEPA.

- On November 21, 2022, the final *Environmental Performance Agreement for the Formulation of Chlorhexidine Products* was published. This 5-year environmental performance agreement aims to protect the aquatic environment by minimizing participating companies' releases of chlorhexidine and its salts, from their facilities that formulate chlorhexidine-based products.
- On January 18, 2023, the second progress report for the *2020 to 2025 Environmental Performance Agreement Respecting the Use of Tin Stabilizers in the Vinyl Industry* was published. This progress report indicates that all participating facilities continue to meet the objective of the agreement.

Pollution prevention planning notices

The Minister may require the preparation and implementation of pollution prevention plans (P2 plans) for CEPA toxic substances (substances that have been added to Schedule 1 of CEPA). To invoke these requirements, the Minister publishes notices in the *Canada Gazette*, *Part I*, requiring persons to prepare and implement P2 plans for a substance or group of substances.

There were no P2 plans published in 2022-2023. The complete list with status updates for all active P2 notices is available online.

Environmental quality guidelines

Environmental quality guidelines provide benchmarks for the quality of the ambient environment. They may be developed nationally through the Canadian Council of Ministers of the Environment (CCME) as Canadian Environmental Quality Guidelines (CEQGs, found in Table 7) or federally under section 54 of CEPA as Federal Environmental Quality Guidelines (FEQGs, found on Table 8). In addition, an FEQG summary table is available online as of February 2021.

- On August 20, 2022, a notice was published in in the *Canada Gazette, Part I* indicating the following FEQGs are now available:
  - aluminum to improve water quality
  - selenium to reduce exposure to fish tissue, and bird egg
  - siloxane D4 to improve quality of water, sediment, and reduce exposure to in wildlife from the consumption of aquatic biota

Other risk management actions on CEPA toxic substances

- **Proposed additions to the cosmetic ingredient hotlist**
  - On November 17, 2022, a Notice to Stakeholders was published proposing to amend the Cosmetics Ingredients Hotlist to include new proposed addition of Benzophenone, Chlorocresol, and Triarylmethanes – Malachite Green under Prohibitions and an anthraquinone (Solvent Violet 13) under Restrictions, due to health concerns. Additionally, revisions to the Talc entry are proposed to help reduce exposures from certain cosmetics which may be inhaled, or which may result in perineal exposure to the population with intact ovary/ovaries.

- **Final additions to the cosmetic ingredient hotlist**
  - On August 26, 2022, the Changes to the Cosmetic Ingredient Hotlist were published. Ethylhexyl Ethylhexanoate was added to the list of restricted substances due to health concern, as assessed by CMP.

Subsequent regulations or instruments

Bill S-5, *Strengthening Environmental Protection for a Healthier Canada Act* received Royal Assent on June 13, 2023. As part of the public accountability framework, the Ministers must report annually to Parliament, as part of the CEPA annual report, on their progress in implementing the Plan of Chemicals Management Priorities. Where the Ministers propose to develop more than one risk management instrument in respect of a substance, the Ministers must report on progress made in developing subsequent regulations or instruments in the Annual Report, along with an update on estimated timelines and reasons for any delay.

Because S-5 passed after the fiscal reporting year of 2022-2023, policy development is underway between HC and ECCC to track and report subsequent actions, as outlined in the modernized CEPA in the next CEPA Annual Report for 2023-2024.

Significant new activity requirements

A Significant New Activity (SNAc) requirement may be applied when an existing substance has been assessed and no risks were identified with current activities but there is a suspicion that new activities may pose a risk to human health and/or the environment. When it is applied, new uses or activities must be reported to the government. This ensures that departmental experts can evaluate whether the new use of a substance poses a risk to human health or the environment and determine if risk management should be considered.

- In 2022-2023, 5 SNAc Notices of Intent were issued covering 9 existing substances (see Table 9).
- In 2022-2023, 2 SNAc Orders were issued for 4 existing substances (Table 10).

Risk management performance measurement evaluation

Performance measurement evaluations provide individuals in Canada with information on the effectiveness of risk management actions for substances found to be toxic under CEPA. The risk management, human health and environmental objectives are systematically evaluated using robust data and expert analysis.

- In 2022-2023, performance measurement evaluation reports were published for the substances nonylphenol and its ethoxylates (NP and NPEs), dioxins and furans (health component) and dichloromethane (DCM).

3.1.3 New substances

3.1.3.1 Risk assessment

Substances that are new to Canada require notification to the government prior to being imported into or manufactured in Canada. In 2022-2023:

- 308 New Substances Notifications were assessed pursuant to section 81 of CEPA and the *New Substances Notification Regulations (Chemicals and Polymers)*
- 18 new substances risk assessment summaries were published online
- 57 waivers of information requirements were published in the *Canada Gazette* for new chemical and polymer substances
- 23 pre-notification consultations were held to help companies better understand the notification requirements for their specific chemical or polymer before submitting a New Substances Notification

Substances in products regulated under the *Food & Drugs Act* (FDA) are subject to the new substances provisions in CEPA for examination of potential risks to the environment and indirect exposure to humans.

- Of the 308 New Substances Notifications that were assessed in 2022-2023, 61 were for new substances in products regulated under the FDA.

When the assessment of a new substance identifies a risk to human health or the environment, CEPA allows the Minister of Environment and Climate Change to intervene prior to or during the earliest stages of its introduction into Canada. In this case, 3 actions may be taken. The Minister may:

1. permit the manufacture or import of the substance subject to specified conditions
2. prohibit the manufacture or import of the substance
3. request additional information considered necessary for the purpose of assessment

In 2022-2023, the Minister of Environment and Climate Change issued 10 Notices of Ministerial Conditions for 10 new substances and varied 1 Notice of Ministerial Conditions that was previously published (see Table 11).

A Significant New Activity (SNAc) requirement can be applied when a substance has been assessed and no risks were identified with current activities but there is a suspicion that significant new activities may pose a risk to human health and/or the environment.

- In 2022-2023, 4 SNAc Notices were published (see Table 12)

3.1.4 Communication activities

Communications and outreach activities provide individuals in Canada with timely and credible information about the CMP and its achievements, and how to protect themselves from the risks of chemical substances and pollutants.

In 2022-2023, ECCC and HC continued to raise awareness of the safe use and potential risks of chemical substances and pollutants. A variety of communications materials were developed and published on Canada.ca and on ECCC and HC social media channels to accompany the technical and scientific documents on chemical substances and pollutants. These outreach products include information sheets, fact sheets, plain-language summary pages, social media campaigns, and brochures/postcards made available for publication in community papers, blogs, and websites. These products provide supplemental and/or non-technical information about aspects of the program and about substances, for stakeholders and the public.

The following communications activities and products relating to the health and environmental risks of chemicals were published:

- 2 new fact sheets as part of the Fact sheet series: Topics in risk assessment of substances under CEPA. The following communications activities and products relating to the health and environmental risks of chemicals were published on Canada.ca:
  - use of assessment factors in ecological risk assessment for deriving predicted no-effect concentrations
  - consideration of vulnerable populations in risk assessment
- 1 information sheet webpage summary of a draft screening assessment
- 17 information sheet webpage summaries of final screening assessments and/or risk management approach documents (where applicable)
- 1 information sheet webpage update for an additional risk characterization document in support of a draft assessment and an addendum to a risk management scope document
- 13 information sheet webpage updates for risk management activities and proposed or final orders listing substances to Schedule 1
- 18 new substances notification assessment summaries

Implementation of the Healthy Home social marketing campaign continued. The campaign aims to empower people in Canada to take action to protect themselves from the risks of chemical substances and pollutants in and around the home. A mix of both traditional and digital marketing and communication tactics have been utilized.

- 110 social media posts were published on Health Canada's Facebook, X (formerly known as Twitter) and LinkedIn accounts (635 455 impressions), which promoted the campaign and drove traffic to Healthy Home related web pages
- 297 706 page views of Healthy Home related web pages
- an advertising campaign saw 23.5 million impressions through search engine marketing (Google AdWords and Bing), Yahoo ads and more. Several environmental health topics were promoted, such as: asbestos, boric acid, flame retardants, and formaldehyde
- published and printed four new publications:
  - Healthy Home Guide
  - Tips for renters
  - Tips for pregnancy and preparing for baby
  - Tips for do-it-yourself projects and renovations
- completed the second phase of the Healthy Home Challenge, an interactive online game designed to help inform the public about the potential health risks associated with certain chemicals and pollutants found in the home. The game will be completed and promoted next fiscal year.

Health Canada Regional offices continued to deliver Healthy Home sessions as virtual and in-person public outreach events. The objective of this educational tool is to raise awareness of potential health risks posed by chemicals and pollutants in and around the home and provide tangible actions to protect health. This enables direct delivery of CMP and environmental health information to people in Canada, with a focus on reaching intermediaries such as nurses, community health officers, early childhood educators, health care providers, and parents. These intermediaries further disseminate messaging through their professional networks and reach populations that may be disproportionately impacted, such as Indigenous communities, newcomers, seniors, pregnant women and people, children, and youth.

Health Canada's Risk Communications and Public Involvement officers continued working with staff across Environmental Health Programs to generate cross promotion of related and relevant environmental health messaging, including reading product labels, safe home renovations, radon testing, mould removal, reducing chemical exposures, and maintaining indoor air quality. In 2022-2023:

- 102 in person and virtual outreach activities were delivered across the country, including Healthy Home sessions, and exhibits at trade shows, science fairs, and conferences. This included 10 Train-the-Trainer collaborations.
- surveys show that 98% of Health Canada outreach session participants had increased knowledge and that 96% plan to apply what they learned
    - Healthy Home Sessions and other public outreach activities helped to reach people living in Canada, such as: Bringing an Awareness of Senior Safety Issues to the Community (BASSIC) working group developed and distributed 41K calendars to seniors in Ontario
    - a postcard on poison prevention was distributed to 117K homes in the Atlantic region, Manitoba and Saskatchewan
    - Healthy Home booth displays upgraded to better integrate Health Canada environmental health programs to meet accessibility, health and safety, engagement and sustainability goals
    - contract with EcoSchools Canada to distribute action cards "Environmental Health" and "Let's Talk Air" on their environmental certification platform, reaching 77 637 K-12 students across Canada. In addition, Action cards were distributed to over 12K students

3.2 Animate products of biotechnology

Living organisms, defined in CEPA as animate products of biotechnology (CEPA section 104), are regulated for health and safety purposes by a variety of federal departments and agencies across the government. CEPA sets the federal standard for assessment and risk management of new and existing living organisms that are animate products of biotechnology. Other Canadian acts meeting the federal standard set by CEPA are listed in Schedule 4 of the Act. Living organisms manufactured or imported for a use not covered by an act listed on Schedule 4 are regulated under CEPA. These include naturally occurring and genetically modified organisms (such as bacteria, fungi, viruses, and higher organisms, such as fish or pigs) used for various environmental, industrial, and commercial purposes.

3.2.1 Risk assessment of living organisms

The Act requires that all 68 living organisms grandfathered to the DSL (i.e., those in commerce between 1984 and 1986) undergo a screening assessment to determine whether the living organism is toxic or capable of becoming toxic. ECCC and HC have completed joint assessments for 45 of those living organisms to date. The remaining 23 living organisms have since been or will be removed from the DSL. In addition, ECCC and HC jointly perform the assessment of living organisms that are new to the Canadian marketplace and require notification to the government prior to being imported into or manufactured in Canada.

Risk assessment of existing living organisms

On November 23, 2022, a Ministerial Order deleting one masked living organism from the DSL was published in the *Canada Gazette, Part II*, as this living organism does not meet the criteria set out in subsection 105(1) of the Act (see Table 13).

Risk assessment of new living organisms

During 2022-2023, 43 notifications for new animate products of biotechnology were assessed under the *New Substances Notification Regulations (Organisms)*. Of these, 18 were for new substances in products regulated under the *Food and Drugs Act.*

Also, during 2022-2023:

- 13 pre-notification consultations were completed to help companies better understand the notification requirements for their specific living organism before submitting a New Substances Notification
- 74 waivers of information requirements for new living organisms were granted and published in the *Canada Gazette*, *Part I*

Risk assessment of new higher organisms

Environment and Climate Change Canada and Health Canada are promoting more public engagement in the risk assessment of higher organisms (such as genetically modified plants and animals) conducted by the New Substances (NS) program.

The voluntary engagement initiative was launched in 2018. The NS program publishes summaries of New Substances Notifications submitted for higher organism and invites stakeholders to share scientific information and test data related to potential risks to the environment or human health from the new living organisms. Information that could be shared to inform the risk assessment process includes:

- environmental fate information
- ecological effects information
- human health effects information or
- exposure information (including sources and routes of exposure)

A public comment period was completed on four new genetically modified aquarium fish and another on a new genetically modified fruit fly to inform risk assessments. Further information on past engagement initiatives may be found online.

3.2.2 Risk management

Risk management instruments are put in place to reduce or eliminate risks to the environment and/or human health after a living organism has been concluded toxic.

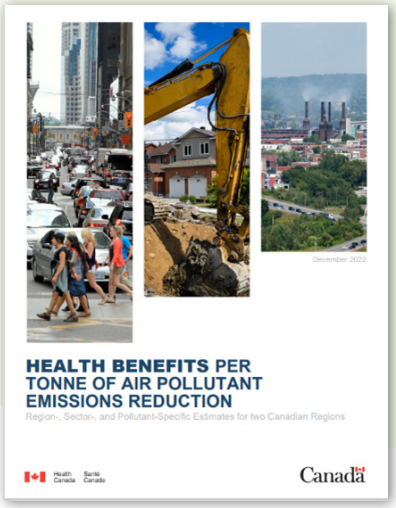
- In 2022-2023, the Minister of Environment and Climate Change did not issue any Ministerial Conditions or SNAc Notices for new living organisms.
- In 2022-2023, 1 SNAc Order was issued for two existing living organisms (see Table 14).

3.3 Air pollutants and greenhouse gases

Air pollutants and greenhouse gases (GHGs) originate from numerous domestic and international sources, such as industry and transportation. CEPA provides authorities to develop and administer regulatory and non-regulatory risk management instruments to reduce the releases of air pollutants and GHGs.

3.3.1 Risk assessment

Health and environmental risk assessments of air pollutants underpin air quality risk management decisions made by federal, provincial, territorial, and municipal governments. Comprehensive risk assessments are completed in support of decisions to establish or update Canadian Ambient Air Quality Standards (CAAQS) and sector-based assessments are conducted to inform management and regulation of air pollution sources. In addition to CAAQS for fine particulate matter ($PM_{2.5}$), ground level ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2), HC is developing health-based air quality objectives (HBAQOs) as there are other pollutants in outdoor air that that may not be as ubiquitous in the environment, but nonetheless can be harmful to human health. HC is initiating development of an HBAQO for arsenic, others to follow will include benzene; formaldehyde; carbon monoxide; and PM_{10}, that is, particles with a diameter of 10 microns and smaller.



In December 2022, HC published the assessment document *Health Benefits per Tonne of Air Pollutant Emissions Reduction: Region-, Sector- and Pollutant-specific Estimates for Two Canadian Regions.* The report provides a way to calculate the dollar value of health benefits associated with a one tonne reduction in air pollutant emissions in the regions of southwestern British Columbia and the Windsor- Quebec City corridor. These calculations can support local/ regional decision makers in the evaluation of air pollution or GHG mitigation strategies.

In February 2023, HC published *Health Impacts of Air Pollution from Transportation, Industry and Residential Sources in Canada: Estimates of Premature Mortality and Morbidity Outcomes at National, Provincial, Territorial and Air Zone Levels*, This assessment provides a comparative analysis of the health impacts associated with $PM_{2.5}$, NO_2 and ground level ozone air pollution attributable to 20 individual anthropogenic sectors/subsectors for the year 2015. The top three sectors contributing to air pollution health impacts in 2015 were home firewood burning, on-road transportation, and ore and mineral industry.

In March 2023, HC published the report *Benzene releases from gasoline stations – Implications for human health*. This assessment evaluates the potential magnitude of benzene vapour emissions from gasoline stations and the associated health risks.

3.3.2 Risk management

Different regulatory and non-regulatory instruments are available under the authorities provided by CEPA to limit and reduce emissions of air pollutants and/or greenhouse gases from vehicles, engines and fuels, consumer and commercial products, landfills, and industrial sectors, as well as for establishing national ambient air quality objectives to drive air quality improvements.

Cooperation among governments is key in managing air pollution. The Air Quality Management System (AQMS), agreed to by federal, provincial and territorial environment ministers in 2012, provides a collaborative approach to reducing air pollution and improving the health of Canadians and the environment. The AQMS includes:

- Canadian Ambient Air Quality Standards
- local air zones and regional airsheds that cross jurisdictional borders
- industrial emission requirements for several industrial sectors and equipment types
- work to address emissions from mobile sources
- reporting on the state of the air to people in Canada

The AQMS system is supported by significant monitoring of outdoor air pollutants, through the National Air Pollution Surveillance program undertaken in cooperation with provinces and territories. Canadian Ambient Air Quality Standards (CAAQS) are health and environment-based air quality objectives that apply to the concentration of specific air pollutants in the outdoor air. They provide the drivers for local air quality management actions that are meant to promote continuous improvement in air quality across the country. ECCC in collaboration with HC lead the process under the Canadian Council of Ministers of the Environment (CCME) to develop, review and update CAAQS. Once approved by the federal, provincial and territorial ministers of the environment, CAAQS are published by the Ministers of the Environment and the Minister of Health as objectives under CEPA. CAAQS for 2020 and 2025 are in place for ground level ozone (O_3), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). CAAQS for $PM_{2.5}$, are in place for 2020. The process to finalize the review and potential update of the 2020 CAAQS for $PM_{2.5}$ to more stringent standards is ongoing.

Industrial sector emissions

The *Multi-Sector Air Pollutants Regulations* (MSAPR) which came into force in 2016, put in place industrial emissions requirements agreed under the AQMS for equipment types used in several industrial sectors and for the cement sector. The regulations established nationally consistent industrial emissions performance standards that limit nitrogen oxide (NO_x) emissions from large industrial boilers and heaters and stationary sparkignition engines, used in several industrial sectors, that burn gaseous fuels (such as natural gas).

For stationary spark-ignition engines covered by the MSAPR, emission requirements for modern engines are in force, with annual compliance reports due each July 1. Emission requirements for certain engines began to apply in 2021, and the first annual compliance reports were submitted on July 1, 2022.

The MSAPR also limit NO_x and SO_2 emissions from kilns at 14 cement manufacturing facilities in Canada. As of the end of 2022, 13 of the 14 facilities are meeting the SO_2 limit and 12 of the 14 facilities are meeting the NO_X emission limits as defined in the MSAPR. The facility not meeting the SO_x emissions limit has re-commissioned their SO_2 scrubber and is on track to meet the SO_x limit for 2023 as set out in the regulation. The two facilities not meeting the NO_X emissions limits have implemented, or are in the process of implementing, a selective non-catalytic reduction system to reduce their NO_X emissions and meet the NO_X limit as set out in the regulation.

Several non-regulatory instruments to reduce air pollutants from other industrial sectors have been put in place under CEPA and continued to be administered by the Department in 2022-2023:

- Aluminium sector
  - code of practice for $PM_{2.5}$
  - performance agreements for SO_2, polycyclic aromatic hydrocarbons, $PM_{2.5}$, and total particulate matter (TPM)
- Base metals smelting sector
  - five company-specific performance agreements for SO_2, TPM
- Iron ore pellet sector
  - performance agreements for NO_x, SO_2, $PM_{2.5}$
- Iron, steel and ilmenite sectors
  - code of practice for TPM and VOCs
  - pollution prevention notice for SO_2, NO_x, VOCs
- New natural gas-fueled stationary combustion turbines
  - guidelines for NO_x
- Potash sector
  - code of practice for $PM_{2.5}$
- Pulp and paper sector
  - code of practice for SO_2, TPM

Oil and gas sector emissions

The first requirements under the *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)*, came into force on January 1, 2020, in order to help fulfill Canada's commitment to reduce emissions of methane from the oil and gas sector by 40 to 45% below 2012 levels, by 2025. The remaining requirements related to venting from well completions involving hydraulic fracturing and venting from compressors came into force on January 1, 2023.

In 2021, Canada committed to achieving at least a 75% reduction in methane emissions from its oil and gas sector from 2012 levels by 2030. Also in 2021, Canada joined over 100 countries in signing the Global Methane Pledge, committing to reduce global anthropogenic methane emissions by at least 30% from 2020 levels by 2030. Canada was subsequently pleased to accept an invitation to be a Global Methane Pledge Champion. In March 2022, ECCC launched public consultations with Indigenous organizations, industry, research organizations and civil society through a discussion paper to inform the development of more stringent regulations to achieve further methane emission reductions in the oil and gas sector. Following the public comment period from March 25, 2022 to May 25, 2022, ECCC reviewed comments received leading to the development and publication of a proposed regulatory framework in *Faster and Further: Canada's Methane Strategy*, published in September 2022. ECCC plans to publish proposed regulations by the end of 2023. In November 2022, at the 27th session of the Conference of the Parties (COP 27), Canada announced increased cooperation with the United States on reducing oil and gas sector emissions—with a special focus on methane. Canada also joined the International Methane Emissions Observatory contributing $250 000 to the initiative and agreeing to serve on its Implementation Committee. The observatory works to reconcile methane data in near real-time from measurement studies, satellites and reported data, in order to help countries and companies take fast mitigation action on methane.

In July 2022, following more than six months of preliminary meetings with key interested parties, ECCC, in collaboration with NRCan, released a discussion paper that launched formal consultations on a key commitment in the Government's 2030 Emissions Reduction Plan—capping and cutting emissions from the oil and gas sector. During the formal comment period, the Government of Canada received over 25 000 written submissions in response to the discussion paper and held a number of information webinars and bilateral meetings with interested parties. Engagement with provinces, territories, Indigenous Peoples, industry, non-governmental organizations, and other Canadians on the oil and gas sector emissions cap is ongoing.

Electricity generation

ECCC currently administers 2 regulations pertaining to electricity generation under CEPA:

- The *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations*, were amended in 2018 for the purpose of meeting the Government's commitment to phase out the unabated generation of electricity using coal, coal derivatives and petroleum coke by January 1, 2030.
- The *Regulations Limiting Carbon Dioxide Emissions from Natural Gas-fired Generation of Electricity*, which came into force starting January 1, 2019, set performance-based standards for new natural gas units as well as conditions for the operation of coal units converted to run on natural gas. Under these regulations, new natural gas-fired electricity generation is required to use efficient technology and higher emitting coal-to-gas converted units will be phased out more rapidly than better performers.

In 2020, Canada committed to achieving a net-zero electricity system by 2035 as a key part of its plan to achieve a net-zero economy by 2050 through the clean electrification of other sectors, such as transportation, buildings, and industry. In support of this goal, ECCC has been developing the *Clean Electricity Regulations* (CER), which will set a technology-neutral emissions performance standard for the generation of electricity provided to the grid. The CER will be part of a suite of measures that supports a net-zero electricity system by 2035.

To support early engagement and inform the development of the CER, ECCC published the discussion paper, *A clean electricity standard in support of a net-zero electricity sector*, in March 2022, and the *Proposed Frame for the Clean Electricity Regulations* in July 2022. These publications launched a collaborative process with provinces, territories, Indigenous partners, and other interested parties so that the design of the CER provides a clear and workable basis for provinces and territories to be able to plan and operate their grids in a way that will continue to deliver clean, reliable and affordable electricity to people in Canada.

As part of early engagement on the CER, ECCC has taken a distinctions-based engagement approach with Indigenous Peoples, inviting representatives of National Indigenous Organizations (NIOs) to informational webinars, meeting bilaterally with NIOs and extending an open offer to continue meeting on a bilateral basis and hosting a specific webinar for First Nations to hold a conversation about the proposed Regulations. Engagement will continue through development of the final regulations.

Vehicle and engine emissions and fuels

ECCC administers six vehicle and engine emission regulations and nine fuel regulations under CEPA.

ECCC collaborates with the California Air Resources Board, as per their Memorandum of Understanding, to promote and carry out cooperative activities on policy and regulatory measures that reduce emissions of air pollutants and greenhouse gases including from vehicles, engines, and fuels. In addition, ECCC and the U.S. Environmental Protection Agency (U.S. EPA) continue to collaborate closely through the Canada-United States Air Quality Agreement towards the development of aligned vehicle and engine emission standards, related fuel quality regulations, and their coordinated implementation, including collaborative research and testing projects.

On October 21, 2022, the *Regulations Amending Certain Regulations Made Under the Canadian Environmental Protection Act, 1999* were published. These regulatory amendments were proposed to maintain alignment with the amendments published by the U.S. EPA in June 2021. The U.S. EPA amendments were made to improve accuracy

and reduce testing burden related to vehicles and engines, and to make a number of housekeeping changes. Maintaining alignment with the U.S. EPA emission standards for vehicles and engines minimizes the overall regulatory burden for companies operating in the integrated Canada–U.S. market and maintains fair regulatory conditions for importers and manufacturers. Most changes made by the U.S. EPA apply automatically in Canada due to the use of incorporation by reference in the various vehicle and engine emission regulations. However, minor changes were needed for three of the Canadian regulations, including modifying definitions and regulatory text and updating some references to the U.S. regulations. The proposed changes are not anticipated to have adverse economic or environmental impacts in Canada and do not affect the stringency of emission standards.

In the *2030 Emissions Reduction Plan* (ERP), ECCC committed to develop zero-emission vehicle requirements to implement new targets of at least 20% zero-emissions vehicle (ZEV) sales by 2026, 60% ZEV sales by 2030 and 100% ZEV sales by 2035. On December 31, 2022, the Department published the proposed *Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations* in *Canada Gazette, Part I*. The amendments introduced new requirements for manufacturers and importers to ensure that their fleet of new light-duty vehicles offered for sale in Canada meets specified annual targets of ZEVs in line with the ERP. These ZEV sales targets would begin with model year 2026 and reach full stringency in 2035. In addition, the amendments also modified flexibilities and fix provisions related to the pre-2026 model year fleet average GHG emission standards.

In addition, the Emissions Reduction Plan committed ECCC to develop regulations to require 100% of medium and heavy-duty vehicle sales to be ZEVs by 2040 for a subset of vehicle types based on feasibility, with interim 2030 regulated sales requirements that would vary for different vehicle categories based on feasibility and explore interim targets for the mid-2020s.

ECCC is currently engaged in research and technical feasibility studies to establish the ZEV requirements for medium and heavy-duty vehicles, as per the commitments made under the ERP. These studies aim to evaluate the industry sector profile and the practicality of implementing ZEVs in the Canadian context, particularly considering aspects like cold climate conditions and the use of heavier vehicles, to determine realistic and attainable ZEV targets. The Department is also continuing to engage a broad range of stakeholders, including industry, manufacturers and trucking fleets, provincial and territorial governments, and its U.S. counterparts, as well as continuing to work with other federal departments on the integrated strategy.

Regulatory administration of vehicle, engine, and fuel quality regulations

ECCC administers a compliance program under the vehicle and engine regulations, as well as the fuels regulations. This includes processing regulatory reports and importation declarations; managing defects and recall notices; testing selected vehicles and engines; analyzing fuel samples; reviewing fuel supplier's production and import records; and verifying compliance with the regulatory prohibitions and reporting requirements.

- During 2022-2023, under the vehicle and engine regulatory administration program, ECCC:
  - received approximately 200 regulatory reports for vehicles and engines
  - responded to over 1200 inquiries regarding the vehicles and engines regulations
  - conducted testing on nearly 200 vehicles and engines
  - processed over 900 Canada-unique[4] submissions, over 100 temporary importation submissions, and over 60 000 importation declaration entries representing over 1.8 million vehicles and engines
  - processed over 90 defect and recall notifications covering over 470 000 vehicles and engines. ECCC continues to provide basic information summarizing notices of defect and other company notifications received
  - provided compliance promotion material to over 2300 known or potential regulatees for the Transportation Division's six regulatory instruments

4 A Canada-unique vehicle or engine is a vehicle or engine that is specifically listed on a United States Environment Protection Agency (EPA) certificate and sold in Canada, but not sold in the United States; or a vehicle or engine that is not specifically listed on an EPA certificate.

Volatile organic compound (petroleum sector) regulations

The *Reduction in the Release of Volatile Organic Compounds Regulations (Petroleum Sector)* require the implementation of comprehensive leak detection and repair programs at Canadian petroleum refineries, upgraders and certain petrochemical facilities to reduce fugitive emissions of volatile organic compounds (VOCs) from process equipment. In addition, these facilities are required to monitor and report on the concentrations of certain VOCs in the air at the fence line.

During 2022-2023, ECCC updated bilingual compliance material and created bilingual reporting templates. Additionally, ECCC continued to develop regulations to reduce VOC emissions from the storage and loading of petroleum liquids.

Clean Fuel Regulations

ECCC finalized the *Clean Fuel Regulations* which were registered on June 21, 2022 and published in the *Canada Gazette, Part II,* on July 6, 2022. The Regulations require gasoline and diesel primary suppliers (i.e., producers and importers) to reduce the lifecycle carbon intensity (CI) of the gasoline and diesel they produce in, and import into, Canada from 2016 CI levels by 3.5 grams of carbon dioxide equivalent per megajoule (gCO2e/MJ) in 2023, increasing to 14 gCO2e/MJ in 2030. In addition, the Regulations repeal the *Renewable Fuels Regulations* (RFR) but retain the minimum volumetric requirements (at least 5% low CI fuel content in gasoline and 2% low CI fuel content in diesel fuel) currently set out in the RFR.

The Regulations also establish a credit market whereby the annual lifecycle CI reduction requirement could be met via three main categories of credit-creating actions:

1. actions that reduce the CI of the fossil fuel throughout its lifecycle,
2. supplying low-CI fuels, and
3. supplying fuel and energy in advanced vehicle technologies.

Parties that are not fossil fuel primary suppliers would be able to participate in the credit market as voluntary credit creators (e.g., low-CI fuel producers and importers) by completing certain actions. Credit creation became eligible as of the date of registration of the Regulations (based on credit-creation activity). The annual reduction requirements for primary suppliers will come into force on July 1, 2023.

Consumer and commercial products emissions

On December 24, 2022, the proposed *Regulations amending the Products Containing Mercury Regulations* were published. These amendments will allow Canada to fully align with all the requirements of the Minamata Convention on Mercury for mercury-containing products. Furthermore, to accelerate the transition to LEDs, which are mercury-free and more energy efficient, the manufacture and import of most lamps containing mercury will be phased-out. The proposed amendments are expected to reduce the quantity of mercury released to the environment, as well as generate savings in avoided GHG emissions and energy savings from switching to more energy efficient lamps.

Guidance materials were published for the permit programs and compliance unit trading system under the *Volatile Organic Compound Concentration Limits for Certain Products Regulations* in advance of these regulations coming into force on January 1, 2023. The regulations apply to manufacturers and importers and establish concentration limits for volatile organic compounds (VOCs) in approximately 130 product categories and subcategories. The objective of the regulations is to protect the environment and health of people in Canada from the effects of air pollution by reducing VOC emissions.

A Code of practice for reduction of VOC emissions from cutback and emulsified asphalt, a non-regulatory instrument, has been in place under CEPA and continued to be administered by the Department in 2022-2023.

In July 2022, the Government of Canada published a renewed version of the *Federal Agenda for the Reduction of Volatile Organic Compound (VOC) Emissions from Consumer and Commercial Products* in the *Canada Gazette*, *Part I*. This agenda signals the government's intention to take further action between 2022 and 2030 to protect the health of people in Canada and their environment from the impacts of air pollution.

Planned actions contained in the renewed agenda include:

- reducing the amount of VOCs released by portable fuel containers
- amending current regulations targeting VOCs in architectural coatings and automotive refinishing products
- developing regulations covering VOCs in industrial and commercial adhesives and sealants
- developing a non-regulatory risk management instrument targeting VOC emissions from printing on plastic packaging

The renewed agenda was finalised considering input from stakeholder consultations held in 2021. A summary of the Government of Canada's responses to comments received during the consultation was published on the departmental website.

On January 7, 2023, the final *Formaldehyde Emissions from Composite Wood Products Regulations* came into force. The regulations help reduce people in Canada's exposure to formaldehyde emissions in indoor air from composite wood products sold, offered for sale or imported into Canada. The regulations place limits on the amount of formaldehyde that composite wood products can emit. Further to the requirements to meet emission limits, the regulations impose requirements on industry for record keeping, labelling and reporting. The Canadian requirements for composite wood products are similar to those in the United States thereby helping to minimize burden for businesses operating in both Canada and the United States. On June 17, 2023, the proposed *Regulations Amending the Formaldehyde Emissions from Composite Wood Products Regulations* were published to address a drafting oversight in the regulations, to clarify record-keeping requirements and to enhance enforceability of the regulations. The final amendments are anticipated to be published in late 2024.

Indoor air quality

In addition to the penetration indoors of outdoor pollutants, indoor air can be contaminated by emissions from building materials, products, and activities inside the home, and by the infiltration of naturally occurring radon from the soil under the building.

Mould indoors is the greatest indoor air issue of concern among members of the public contacting HC. With the changing climate and an increased frequency of extreme weather events, mould indoors is expected to continue to be a health concern. In January 2023, HC published The Guide to Addressing Moisture and Mould Indoors. It provides practical recommendations to address the health hazards of indoor mould.

In addition to residential environments, indoor air quality in public spaces is an important health issue, and a priority for many of HC's partners and stakeholders. Draft guidance on improving indoor air quality in office buildings was published for comment in February 2023. It summarizes ways to remediate, maintain and improve indoor air quality in office buildings and is an update of a 1995 document of similar scope.

The Residential Indoor Air Quality Guidelines summarize the health risks posed by specific indoor pollutants, based on a review of the best scientific information available at the time of the assessment and propose evidence-based strategies to reduce exposure. The final Residential Indoor Air Quality Guidelines for Xylenes were published in October 2022. Xylenes are contaminants of concern in particular for newly constructed or renovated homes, and those with an attached garage.

Communication activities

Communication and outreach activities provide people in Canada with timely and credible information about the air quality program and its achievements, and how to protect themselves from the risks of air pollution.

HC and ECCC continued to work collaboratively to raise awareness of the Air Quality Health Index (AQHI) and potential risks of air pollutants. A variety of communications materials were developed and published on Canada.ca and on ECCC and HC social media channels to accompany the technical and scientific documents on air pollutants. These outreach products, targeted to stakeholders and the general public, include factsheets, infographics, guides, videos and short, illustrated, empowering articles made available for publication in community papers, blogs, websites and newspapers.

The following outreach activities and products relating to air quality and health were completed:

- updating of the Wildfire Smoke, Air Quality and Health web content
- development and distribution of wildfire smoke resource toolkit for stakeholders and the media
- development of wildfire smoke health messaging for ECCC's Special Air Quality Statements
- development and distribution of campaign website, social media images, videos and stakeholder resource toolkit for residential wood smoke to the general public, health professionals and local government decision makers
- development and distribution of written news articles and radio spots to Canadian media outlets on wildfire smoke, mould, protecting indoor air quality
- updating of web content for transportation-related air pollution
- development of educational videos on air quality for students in grades 3 to 8
- development and distribution of web messaging and social media posts and images in collaboration with Canadian Environmental Network to raise the profile of Clean Air Day across Canada by increasing stakeholder and public engagement on topics related to air pollution and climate change, particularly where they intersect with impacts on health

HC Regional Air Quality and Health Specialists also completed outreach and engagement activities in their regions on various air quality topics targeted to audiences such as the general public, provincial/territorial and municipal partners, health professionals, academics and industry. In 2022-2023, Regional Air Quality and Health Specialists:

- completed 39 outreach activities such as tradeshows, presentations, media interviews, mailouts
- delivered 15 projects such as organizing stakeholder workshops, developing air quality educational materials for schools, air quality monitoring and community engagement, applying Health Canada's Guidance for Cleaner Air Spaces During Wildfire Smoke Events with municipalities, developing AQHI training modules for sports organizations and developing a digital behaviour change platform featuring air quality topics
- participated in 11 external working groups and other collaborations in their regions as part of:
  - the New Brunswick Environmental Network
  - Government of Japan delegation visit in BC
  - Clean Air Hamilton, BASSIC (Bringing Awareness of Senior Safety Issues to the Community)
  - Bulletin intégré de vigilance saisonnière du Québec (BIVSQ)
  - St-Sauveur Winter Smog Project Working Group
  - the Réseau sur la ventilation et la qualité de l'air intérieur des habitation

Air quality outreach activities for Indigenous Peoples

HC collaborated with the Centre for Indigenous Environmental Resources (CIER) to adapt messaging, to develop and distribute resources as well as to promote Clean Air Day to Indigenous audiences. CIER developed a website featuring adapted HC messaging and created a toolkit with air quality, climate change and mental and spiritual health resources for their partners and Indigenous communities. They also promoted these topics on social media in the months leading up to Clean Air Day 2023.

In February 2023, HC collaborated with Innovation 7 to engage with Indigenous organizations and communities to provide feedback on certain air quality outreach products (mould, wildfire smoke, AQHI and ventilation). Participants in the feedback sessions provided comments and suggestions on adapting messaging as well as the formatting and images on the products to better resonate with Indigenous audiences.

In March 2023, HC also engaged the First Nations Education Council and presented information to help schools improve their indoor air quality. Approximately 100 school principals and building officials representing 20 community school boards were in attendance.

3.4 Drinking water quality

Work on water quality under CEPA includes leadership on the development of guidelines for water quality. HC collaborates with the provinces and territories to establish a list of priority contaminants for developing or updating the Guidelines for Canadian Drinking Water Quality (GCDWQ) and their technical documents.

Health-based guidelines are developed for drinking water contaminants that are found, or expected to be found, in drinking water supplies across Canada at levels that could lead to adverse health effects. All provinces and territories use the GCDWQ to establish regulations and policy for the quality of drinking water in their jurisdictions. HC uses a similar collaborative process for developing the Guidelines for Canadian Recreational Water Quality, which provinces and territories use as appropriate to their jurisdictions.

Priorities for guideline development are established every four to five years by examining exposure information from federal, provincial and territorial sources, current science, international actions, and jurisdictional needs. The process for prioritizing the development and updating of GCDWQ was updated in November 2020. HC continues to address the priority contaminants identified in 2019 in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water. The committee's role in reviewing the guidelines and ensuring they meet the needs of all jurisdictions is crucial to fostering a consistent approach across the country to drinking water safety.

New or updated GCDWQ are published in the *Canada Gazette*, *Part I*, while supporting technical documents are published on HC's website. The draft GCDWQ undergo a 60-day public consultation period and the final GCDWQ are accompanied by a plain language summary to increase the public's access.

Table 15 lists the guidelines finalized in 2022-2023 and those under development.

In 2022-2023, HC published seven final and four draft guidelines and guidance documents on the quality of Canadian drinking and recreational water.

- Drinking water guidelines: dimethoate and omethoate (final), malathion (final), boron (final), corrosion control (draft), objective on per- and polyfluoroalkyl substances (PFAS, draft), and antimony (draft)
- Drinking water guidance: waterborne pathogens (final)
- Recreational water guidelines: physical, aesthetic and chemical characteristics (final), indicators of fecal contamination (final), understanding and managing risks (final), and microbiological pathogens (draft)

Communication activities

Communication and outreach activities provide people in Canada with timely and credible information about the water quality program and its achievements, and how to protect themselves from the risks of poor water quality.

A variety of communications materials were developed and published on Canada.ca and on HC social media channels to accompany the technical and scientific documents on water quality. These outreach products targeted to stakeholders and the general public include factsheets, infographics, videos and short, illustrated, empowering articles made available for publication in community papers, blogs, websites and newspapers.

The following outreach activities and products relating to water quality and health were completed:

- development of recreational water web content
- development and distribution of lead filtration and aerator cleaning infographics
- development and distribution of written news articles to Canadian media outlets on recreational water and lead in drinking water
- development of educational videos on water quality for students in grades 3-8

From January 17-19, 2023, HC hosted a three-day Private Well Water Testing Workshop. The workshop was sponsored by the Federal-Provincial-Territorial Committee on Drinking Water and the goal was bring stakeholders together to explore how jurisdictions could work together towards an objective of developing common communication and outreach tools and strategies to promote and encourage higher rates of private well water testing. The workshop was a live and interactive online event and featured 13 Canadian and international presenters. Over 100 participants attended representing drinking water and public health programs from ten provinces, one territory and several federal departments.

3.5 Waste

Waste generally refers to any material, non-hazardous or hazardous, that has no further use, and is managed at recycling, processing or disposal sites or facilities. In Canada, the responsibility for managing and reducing waste is shared between the federal, provincial, territorial and municipal governments.

ECCC exercises responsibilities with respect to disposal at sea of specified materials, as well as the international and interprovincial movements of hazardous waste and hazardous recyclable material.

In addition to the activities listed below, risk management actions described in section 3.1.2.2 on toxic substances also contribute to the overall improvement of waste management.

3.5.1 Plastic pollution

Plastic that is discarded, disposed of, or abandoned in the environment outside of a managed waste stream is considered plastic pollution. Plastic pollution has been detected on shorelines, and in surface waters, sediment, soil, groundwater, indoor and outdoor air, drinking water and food.

In June 2022, the Government finalized the *Single-use Plastics Prohibition Regulations*. These regulations progressively ban six categories of single-use plastic which were found to be prevalent in the environment, harmful to wildlife, difficult to recycle, and where viable alternatives were available. The Regulations are projected to prevent 22 000 tonnes of plastic pollution and 1.3 million tonnes of plastic waste over 10 years.

On July 25, 2022, the Government launched two pre-consultations on developing rules for recyclability and compostability labelling and establishing a federal plastics registry for producers of plastic products. The Government published the *Consultation Paper: Towards Canada-wide rules to strengthen the recycling and composting of plastics through accurate labelling* and *Consultation paper: a proposed federal plastics registry for producers of plastic products*

to solicit feedback and information on the proposed approaches outlined in the documents from partners, stakeholders and interested parties. A *What We Heard Report* summarizing feedback and information solicited was published by the Government on February 17, 2023.

These efforts are part of Canada's comprehensive plan that includes a range of complementary actions across the lifecycle, to transition to a circular economy for plastics.

3.5.2 Disposal at sea

Part 7, Division 3 of CEPA imposes a general prohibition on the disposal at sea or onto sea ice of substances. Disposal at sea activities conducted under a permit from ECCC are exempt from this prohibition and permits are only available for a short list of low-risk wastes. A permit is only granted after an assessment, and only if disposal at sea is the environmentally preferable and practical option.

International activities

The disposal at sea provisions of CEPA help Canada to meet its obligations as a party to the 1996 London Protocol, which is a more modern version of the *London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972*. Canada reports the number of permits, quantities and types of wastes disposed, and results of disposal site monitoring to the London Protocol Secretariat each year.

At the London Protocol meetings in 2022, Canada led a group working to determine what types of marine geoengineering could be regulated by the London Protocol and supported technical assistance to bring implementation within reach of more countries. Canada continues to serve as a member of the London Protocol Compliance Group, which encourages and supports compliance and ratification of the treaty. Canada is also a member of technical working groups seeking to address marine plastic pollution, evaluate the potential environmental effects of marine geoengineering, update guidance to assess carbon capture and storage in sub-sea geological formations, and to promote the re-use of materials disposed of at sea.

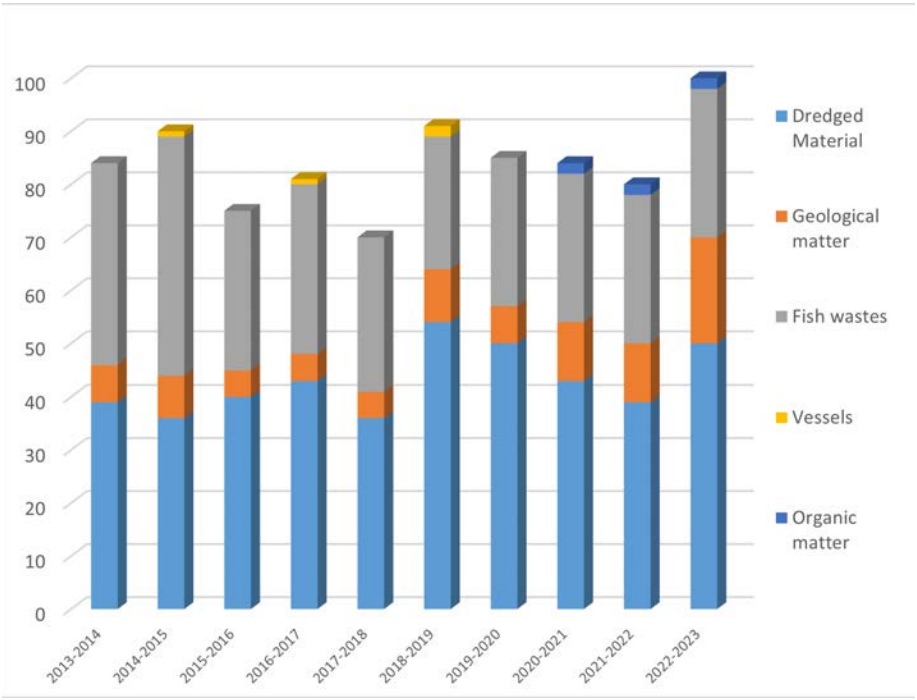
Disposal at sea permits

From April 1, 2022 to March 31, 2023, 100 permits were issued in Canada for the disposal of 8.59 million tonnes of waste and other matter at sea (see Table 16), compared to 80 permits for the disposal of 5.61 million tonnes in 2021-2022.

Both the total number of permits and quantity of waste permitted has increased from the previous year. The quantity of permitted material increased by more than 2.98 million tonnes and the total number of permits by 20.

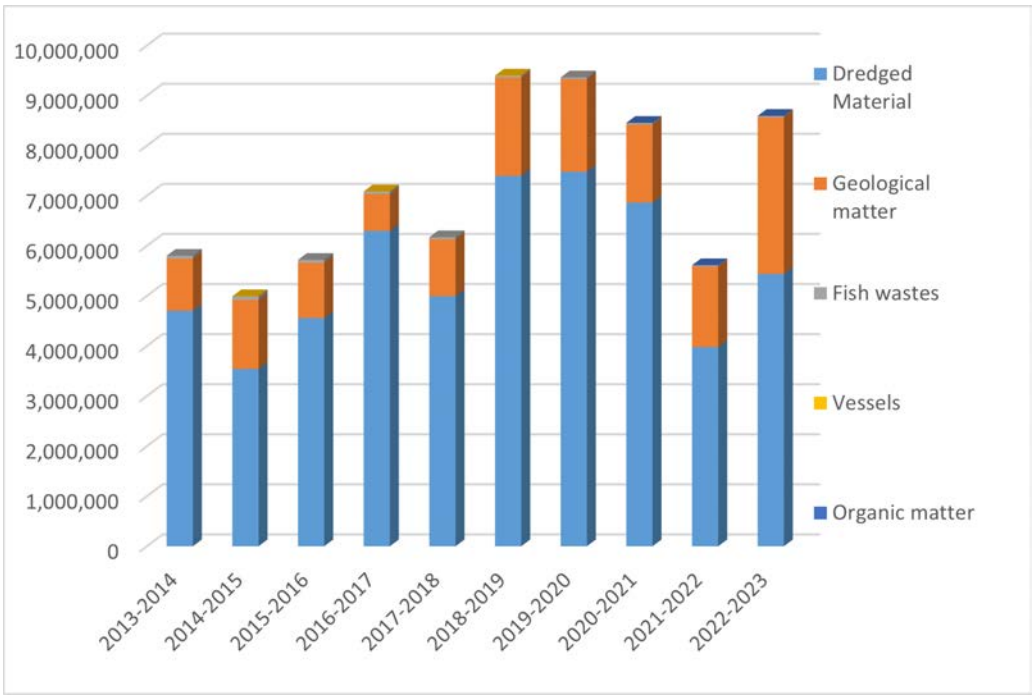
The trends in the number of permits issued over the last decade is illustrated in Figure 7, with the number of permits issued increasing in 2022-2023 compared with the previous year.

Figure 7. Number of disposal at sea permits issued in each fiscal year by type of material.



The trends in the quantity of material permitted each year is illustrated in Figure 8. The quantities permitted continue to fluctuate from year to year. 2022-2023 saw an increase in quantities permitted for dredged material and inert, inorganic geological matter. Fish wastes and organic matter saw a small decrease in quantities permitted.

Figure 8. Annual disposal at sea quantities permitted (in millions of tonnes).



Further information on disposal at sea is available online.

Indigenous engagement for disposal at sea program

In 2022-2023, the Disposal at Sea Program in Pacific Region continued to work with Indigenous Nations to strengthen Nation-to-Nation relationships, advance reconciliation, achieve joint environmental priorities, support the mandate of the department, and fulfill our legal obligations. Over the course of the year, we have engaged on a variety of environmental programs, policies, and activities. We have consulted with, and where necessary accommodated, Indigenous Nations when a decision or activity may have adversely impacted potential or established rights. As a result of these engagements the disposal at sea program in Pacific Region is continually evolving, expanding, and strengthening to address Indigenous concerns and feedback. Some specifics from 2022-2023 include:

- consulting with Nations on proposed disposal site monitoring plans and studies
- inviting Nations to join us during monitoring
- prioritising monitoring plans and studies based on Indigenous feedback
- expanding and tailoring mitigation measures and permit conditions to address Indigenous concerns
- developing new processes and partnerships to address archaeological concerns
- reviewing Tier 1 (physical monitoring) parameters and Tier 2 (chemical and biological assessments) testing
- working on capacity funding mechanisms for Indigenous engagement
- incorporating Indigenous values regarding reuse of material net environmental benefit in permit reviews

Pacific Region engaged with 18 different First Nations on 118 disposal at sea permit referrals, collectively, conducted quarterly meetings with the Musqueam Indian Band regarding disposal at Sea and shared technical reports and proposals with Indigenous Nations for review and comment. In addition, Pacific Region continued to operationalize the Multi-Jurisdictional Review Body as established under the Agreement on Collaborative Decision-Making

Regarding Disposal at Sea between the Tsleil-Waututh Nation and the Minister of Environment and Climate Change. This included finalizing a Data Sharing agreement and working towards the development of a joint permit review process and a site management plan for the Point Grey disposal site.

During consultation on the Black Point, New Brunswick, disposal at sea site, there was a commitment to undertake an Indigenous Land Resource Use Study in order to better understand how the area was used by community members from the Wolastoqey Nation of New Brunswick (WNNB) and to further learn about any impacts to rights. This study was undertaken by the WNNB in 2022-2023.

In 2022-2023, the Atlantic Region issued 14 dredge disposal permits for sites in New Brunswick, Nova Scotia and PEI; consultation was successfully undertaken conducted for each project.

3.5.3 Hazardous waste and hazardous recyclable material

With respect to managing the movement of hazardous waste and hazardous recyclable material, CEPA provides authority to:

- make regulations governing the export, import and transit of waste (including both hazardous and prescribed non-hazardous waste) and hazardous recyclable materials
- establish criteria for refusing an export, import or transit permit, should the hazardous waste or hazardous recyclable material not be managed in a manner that will protect the environment and human health
- make regulations governing movements of hazardous waste and hazardous recyclable materials between provinces and territories

The *Cross-border Movement of Hazardous Waste and Hazardous Recyclable Material Regulations (XBR)* repealed and replaced three current regulations *(Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations,* the *Interprovincial Movement of Hazardous Waste Regulations* and the *PCB Waste Export Regulations, 1996*). These new Regulations ensure greater clarity and consistency of the regulatory requirements, while maintaining the core permitting and movement tracking requirements of the former regulations. Most permits issued in 2021 were delivered under the *Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations*.

The implementation of the XBR enables Canada to meet its obligations under the following instruments:

- The United Nations Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention)
- The Decision OECD/LEGAL/0266 of the Council of the Organisation for Economic Co-operation (OECD) Concerning the Control of Transboundary Movements of Wastes Destined for Recovery Operations (OECD Decision)
- The Canada-USA Agreement on the Transboundary Movement of Hazardous Wastes (Canada-US Agreement)

In 2022, ECCC processed 1990 notices for proposed imports, exports and transits of hazardous wastes and hazardous recyclables. The notices received covered 46 763 waste lines, which exhibited a range of hazardous properties such as being flammable, acutely toxic, oxidizing, corrosive, dangerously reactive and environmentally hazardous. Of the notices received, 1 710 permits were issued.

Sufficient data for the transboundary shipments that took place in 2020 and 2021 were not available at the time of publication of the 2021-2022 CEPA annual report as restrictions in place during the COVID-19 pandemic impacted the compilation of data on the transboundary shipments of hazardous waste and hazardous recyclable material. During 2021, at least 43 791 individual transboundary shipments of hazardous waste and hazardous recyclable material were reported in movement documents received by ECCC. By comparison, in 2020, 38 837 individual transboundary shipments were done, an increase of about 12.8% in 2021.

In 2021, almost all imports (99.8%) and exports (91.0%) of hazardous wastes and hazardous recyclable materials occurred between Canada and the United States. The remaining import exchanges occurred with Germany, United Kingdom and India while the remaining exports occurred with the Republic of Korea, Mexico, Germany, Malaysia, Belgium and France.

The quantity of hazardous wastes and hazardous recyclable materials imported into Canada was 411 064 metric tonnes (t) in 2021. This represents an increase of 60 123 t or 14.6% compared to 2020.

Imports of all hazardous wastes and hazardous recyclable materials in 2021 were shipped to authorized facilities in four provinces: Quebec, Ontario, British Columbia and Alberta. Hazardous recyclable material imported into Canada were mostly composed of:

- lead acid batteries
- environmentally hazardous substance, liquid
- corrosive liquids
- environmentally hazardous substances, solid

The remaining 144 178 t imported were hazardous wastes (about 35%) and were mostly composed of:

- environmentally hazardous substances, solid
- aluminum dross
- flammable liquids, toxic and/or corrosive
- environmentally hazardous substance, liquid

Table 17. Trends in the quantities of hazardous wastes and hazardous recyclable materials imported from 2012-2021.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Waste	101 796	190 841	159 008	118 403	118 130	129 311	146 832	149 136	116 378	144 178
Recyclables	243 434	245 110	221 354	249 323	258 984	240 661	241 457	249 874	234 563	266 886
Total imports	345 230	435 951	380 362	367 726	377 114	369 972	388 289	399 010	350 941	411 064

The quantity of hazardous waste and hazardous recyclable materials exported was 431 607 t in 2021. This represents an increase of 16 215 t or 3.9% from 2020. Exports in 2021 originated from eight provinces: Ontario, New Brunswick, Quebec, British Columbia, Alberta, Manitoba, Saskatchewan and Nova Scotia.

Shipments exported for recycling totaled 360 814 t and represented about 83.6 % of all exports in 2021. The majority of hazardous recyclable material exported for recycling composed of:

- sulphuric acid
- environmentally hazardous substances, solid
- lead acid batteries
- caustic alkali liquids
- environmentally hazardous substance, liquid

The remaining 70 793 t exported were hazardous wastes (16.4%) and were mostly composed of:

- environmentally hazardous substances, solid
- aluminum dross
- sulphuric acid
- clinical waste, biomedical waste, or regulated medical waste

Table 18. Trends in the quantities of hazardous wastes and hazardous recyclable materials exported from 2012-2021.

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Waste	91 847	93 786	94 601	86 623	63 513	70 929	63 094	60823	64 086	70 793
Recyclables	413 614	422 388	436 608	429 391	349 412	316 384	315 221	306 642	351 305	360 814
Total exports	505 461	516 174	531 209	516 014	412 925	387 313	378 315	367 465	415 391	431 607

Note: Data are revised periodically as new information becomes available. Therefore, information presented here may differ from information published in other reports.

In April 2022, ECCC initiated consultations with stakeholders and other interested parties on the review of the definitions of hazardous waste and hazardous recyclable material under the XBR. To facilitate this review, a discussion document was published to outline the elements of the definitions being reviewed and provide an opportunity for stakeholders and interested parties, including Indigenous groups, to give feedback on potential changes. Consultations were complete by May 23, 2022. ECCC received 23 written responses during this consultation period.

Additionally, on March 22, 2023, ECCC published a discussion document on proposed amendments to the XBR that were being considered as part of an expedited process to place Canada in a position to accept amendments to the Basel Convention and its Annexes, namely the Ban Amendment and the amendments on electrical and electronic waste. Emails were sent to over 1 800 stakeholders and other interested parties, including Indigenous groups, to invite comments on proposed amendments that would allow Canada to meet its obligations under the Basel Convention, strengthen implementation and improve clarity of the XBR.

3.5.4 Reducing landfill methane emissions

ECCC is developing new regulations aimed at reducing Canada's landfill methane emissions by about 50% by 2030 from the 2019 level. ECCC published a discussion paper in January 2022 to initiate the pre-consultation and a "What We Heard Report" in September 2022. Throughout Fall 2022 and into Winter 2023, ECCC engaged a technical working group of experts from across Canada to support in-depth discussions on potential elements of the regulations.

Canada has joined more than 100 countries in supporting the Global Methane Pledge and working collectively to reduce anthropogenic methane emissions by 30% below 2020 levels by 2030. The planned regulations to reduce landfill methane emissions are a key pillar in Canada's Methane Strategy.

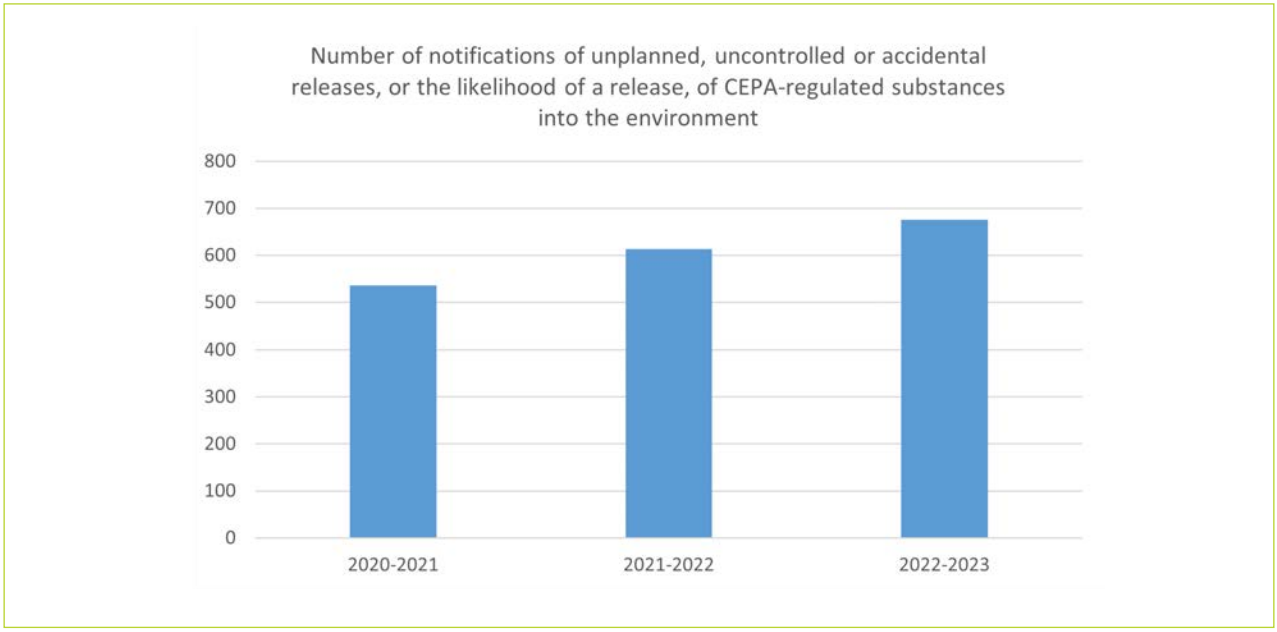
3.6 Environmental emergencies

Part 8 of CEPA (Environmental Matters Related to Emergencies) addresses the prevention of, preparedness for, response to and recovery from uncontrolled, unplanned or accidental releases into the environment of substances that pose potential or immediate harm to the environment or danger to human life or health.

In the event of a significant pollution incident, the National Environmental Emergencies Centre (NEEC) oversees that response actions are taken by the responsible party to repair, reduce or mitigate any negative effects on the environment or human life or health that result from the environmental emergency

- NEEC provides science-based expert advice 24 hours a day, 7 days a week, in collaboration with other federal, provincial and territorial governments, municipalities, and stakeholders to inform actions that reduce the consequence of environmental emergencies.
- In 2022-2023, NEEC recorded 676 notifications involving an uncontrolled, unplanned or accidental release of CEPA-regulated substances into the environment. Of these notifications:
  - 49 were escalated to one of the Centre's duty officers for additional assessment and to ensure that all reasonable measures were being taken to protect the environment and human health
  - 5 incidents resulted in specific communication with senior management (Heads-up and advisories)
  - 2 incidents resulted in services being provided to the agency leading the response to inform decisions about appropriate response measures and operations. Such services include:
    - special weather forecasts
    - air dispersion modelling
  - 1 incident resulted in the involvement of an environmental emergency officer as an Operation Branch Coordinator to support the agency leading the response to the incident

Figure 9. Number of notifications involving uncontrolled, unplanned or accidental release of CEPA-regulated substances.



The *Environmental Emergency Regulations, 2019* require any person who owns, manages, or has the control of a regulated substance at a place in Canada, at or above the the established quantity and/or maximum container capacity, to notify ECCC. A total amount of 4 126 facilities from different sectors, subjected to the regulation, have submitted notifications. Of this amount, 2 622 higher risk facilities have informed ECCC that their Environmental Emergency Plan has been brought into effect.

3.7 Government operations on federal and aboriginal land

3.7.1 *Federal Halocarbon Regulations, 2022*

The *Federal Halocarbon Regulations, 2022* were published in the *Canada Gazette, Part II*, on May 20, 2022. The regulations reduce and prevent emissions of halocarbons to the environment from refrigeration, air conditioning, fire extinguishing and solvent systems that are located on aboriginal or federal lands or are owned by federal departments, boards and agencies, Crown corporations, or federal works and undertakings.

- In 2022-2023, 16 permits to charge fire-extinguishing systems with a halocarbon were issued under the *Federal Halocarbon Regulations, 2003*.

The *Federal Halocarbon Regulations, 2022* repeal and replace the *Federal Halocarbon Regulations, 2003*. The scope of the *Federal Halocarbon Regulations, 2022* remains the same as the *Federal Halocarbon Regulations, 2003*. The Regulations clarify definitions and requirements, reduce administrative costs for the regulated community, remove or update obsolete provisions and enhance regulatory alignment with other jurisdictions.

3.7.2 *Storage Tank Systems for Petroleum Products and Allied Petroleum Product Regulations*

The objective of the *Storage Tank Systems for Petroleum Products and Allied Petroleum Product Regulations* is to reduce the risk of contaminating soil and groundwater due to releases of petroleum products and allied petroleum products from storage tank systems (STS). They establish technical standards for the design and installation of storage tank systems, and include requirements for operation, maintenance, removal, reporting, and record keeping. They apply to storage tank systems that:

- are comprised of tanks that have a capacity of more than 230 liters and are designed to be installed in a fixed location; and
- contain petroleum products or allied petroleum products; and
- are either:
  - located on **aboriginal land**, including systems owned or operated by band councils or private businesses such as gas stations; or
  - located on **federal land**, including systems in federal parks owned or operated by private companies; or
  - operated by a **federal department, board, or agency**, or owned by the Crown regardless of where the systems are located; or
  - operated to provide a service to, or belongs to, a **federal work or undertaking**, including a railway, a port authority, or an airport.

In winter 2023, ECCC completed a review of the *Storage Tank Systems for Petroleum Products and Allied Petroleum Product Regulations* as part of the departmental Regulatory stock review plan. The objective of the review was to clarify some aspects of the current Regulations and to get feedback on technology, knowledge, and strategies as they have evolved since the Regulations came into force.

In March 2022, ECCC initiated pre-engagement to increase awareness of the process. Subsequently, in July 2022, ECCC published a discussion document to solicit feedback from Indigenous peoples, regulatees, and other interested stakeholders. Over 12 000 contacts received notification of the publication of the discussion document. A variety of engagement activities were held such as written comments, webinars, and hoc meetings.

Based on the 700 comments received, there was general support for improving the *Storage Tank Systems for Petroleum Products and Allied Petroleum Product Regulations*. Several key issues and challenges were raised which will be taken into consideration during ECCC's continued analysis.

The conclusion of the stock review process is a recommendation to amend the Regulations.

4. Compliance promotion and enforcement

4.1 Compliance promotion

Compliance promotion relates to planned activities undertaken to increase awareness, understanding and compliance with the law and its regulations. Through these activities, compliance promotion officers provide information to regulated communities on what is required to comply with the law, the benefits of compliance and the consequences of non-compliance. The goal is to achieve desired environmental results more efficiently through education and awareness-building, which helps mitigate consequential enforcement actions.

Tools used to promote compliance include:

- information sessions
- conferences and workshops
- facts sheets
- manuals
- guidelines
- reports
- *Canada Gazette* notices

Indigenous communities face unique challenges associated with compliance promotion and require a different combination of supports. Compliance promotion activities therefore need to be tailored to the context and needs of the community. It is important that compliance promotion activities include efforts to establish and maintain strong relationships with supporting organizations such as Circuit Riders, Indigenous Services Canada, Technical Associations, and Tribal Councils, to ensure consistency in communications and better tailor material to audience needs.

4.1.1 Compliance promotion priorities

Each year, ECCC establishes priorities for compliance promotion activities among the wide variety of CEPA's regulatory and non-regulatory instruments. To determine the priorities, ECCC considers a number of factors to assess the need for promoting compliance of the instrument. These include whether the instrument is new or amended, has new requirements coming into force, has a low level of compliance, or there is a need to maintain awareness, understanding, or compliance. ECCC's Compliance Promotion Program then aligns resources to priority instruments and carries out compliance promotion activities in collaboration with the managers responsible for the instruments and enforcement personnel.

In 2022-2023, compliance promotion activities were carried out on the following prioritized CEPA instruments, namely:

- *Chromium Electroplating, Chromium Anodizing and Reverse Etching Regulations*
- *Clean Fuel Regulations*
- Code of Practice for the Environmental Management of Road Salts
- Code of Practice for the Reduction of Volatile Organic Compound (VOC) Emissions from the Use of Cutback and Emulsified Asphalt
- *Concentration of Phosphorus in Certain Cleaning Products Regulations*
- *Cross-border Movement of Hazardous Waste and Hazardous Recyclable Material Regulations*
- *Export of Substances on the Export Control List Regulations*
- *Federal Halocarbon Regulations, 2022*
- *Formaldehyde Emissions from Composite Wood Products Regulations*
- *Microbeads in Toiletries Regulations*

- *Multi-Sector Air Pollutants Regulations (MSAPR)*
- *New Substances Notification Regulations (Organisms)*
- *Ozone-depleting Substances and Halocarbon Alternatives Regulations*
- *PCB Regulations*
- *Products Containing Mercury Regulations*
- *Prohibition of Asbestos and Asbestos Products Regulations*
- *Prohibition of Certain Toxic Substances Regulations, 2012*
- *Single-use Plastics Prohibition Regulations*
- *Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations*
- *Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements Regulations)*
- *Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations*
- *Volatile Organic Compound (VOC) Concentration Limits for Automotive Refinishing Products Regulations*
- *Volatile Organic Compound (VOC) Concentration Limits for Certain Products Regulations*

4.1.2 Compliance promotion activities

Compliance promotion activities aim to increase voluntary compliance with regulatory and non-regulatory instruments, in an effort to limit consequential enforcement actions. Multiple approaches were used to reach the regulated communities, including information sessions, presentations, information package emails, mail-outs, articles, phone calls, and social media platforms. Many of these activities were carried out in collaboration with other government departments, or non-governmental organizations and associations.

In 2022-2023, 19 147 known or potential regulatees received compliance promotion material and 3 815 stakeholders contacted ECCC by email, fax, letter and telephone to get clarification of regulatory requirements and/or additional information.

During 2022-2023, ECCC launched the following compliance promotion initiatives:

- developed and shared guidance material and supporting documents for the *Clean Fuel Regulations*, including Quantification Methods, training material, as well as other guidance material and user guides
- for Part 2 of the Multi-Sector Air Pollutants Regulations, stakeholders were reminded of reporting requirements and deadlines through ongoing compliance and promotion engagement activities
- sent tailored letters and emails to importers of certain toxic substances to increase awareness of the *Prohibition of Certain Toxic Substances Regulations, 2012*, and collaborated with non-Canadian exporters to further identify potential Canadian importers in order to share regulatory information
- developed new targeted promotional materials on the *Single-use Plastics Prohibition Regulations*, including a new factsheet, cover letters, and updated webpages
- sent emails to manufacturers and importers on the coming into force dates for the prohibition of certain product categories under the *Single-use Plastics Prohibition Regulations*, and engaged with associations working with the retail and restaurant sectors to promote and discuss upcoming bans on products including single-use plastic straws
- conducted market research on commercial and industrial laundry detergent products, to assess the state of compliance with the *Concentration of Phosphorus in Certain Cleaning Products Regulations*
- collaborated with HC and announced the coming into force of the *Formaldehyde Emissions from Composite Wood Products Regulations*, and distributed a factsheet to stakeholders

- submitted an article to two newsletters published by industry associations in order to increase awareness of the *Tetrachloroethylene (use in Dry Cleaning and Reporting Requirements) Regulations*
- participated in multiple associations' annual meetings, conferences, and tradeshows to engage with stakeholders and promote awareness of the *PCB Regulations* and *Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations*
- conducted a voluntary online survey to laboratories, nuclear facilities, and companies in the construction and transportation sectors, in order to measure the performance of past compliance promotion activities associated with the *Prohibition of Asbestos and Products Containing Asbestos Regulations*
- tailored and delivered a presentation regarding the *Federal Halocarbon Regulations, 2022* for trade school students studying refrigeration and HVAC systems in Quebec

4.2 Enforcement

CEPA provides enforcement officers with a wide range of powers to enforce the Act, including the powers of a peace officer. Enforcement officers can carry out inspections to verify compliance with the Act; enter premises, open containers, examine contents and take samples; conduct tests and measurements; obtain access to information (including data stored on computers); stop and detain conveyances; search, seize and detain items related to the enforcement of the act; secure inspection warrants to enter and inspect premises that are locked and/or abandoned or where entry has been refused; seek search warrants; and arrest offenders.

Enforcement activities are conducted in accordance with the Compliance and Enforcement Policy for CEPA (1999).

4.2.1 Enforcement priorities

Each year, ECCC develops an Integrated Enforcement Plan that sets out the enforcement activities to be carried out in that fiscal year, including activities to address non-compliance with CEPA. This risk-based approach allows the department to target entities where evidence indicates an offence is likely to occur and where significant environmental or conservation damage would result from an offence.

In 2022-2023, the Integrated Enforcement Plan prioritized the following CEPA instruments:

- *2-Butoxyethanol Regulations*
- *Chromium Electroplating, Chromium Anodizing, and Reverse Etching Regulations*
- *Cross-border Movement of Hazardous Waste and Hazardous Recyclable Material Regulations*
- *Disposal at sea regulations*
- *Environmental Emergency Regulations*
- *Fuels Information Regulations, No. 1*
- *Microbeads in Toiletries Regulations*
- *Off-Road Compression-Ignition Engine Emission Regulations*
- *Ozone-depleting Substances and Halocarbon Alternatives Regulations*
- *PCB Regulations*
- *Prohibition of Asbestos and Products Containing Asbestos Regulations*
- *Prohibition of Certain Toxic Substances Regulations, 2012*
- *Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations*
- *Volatile Organic Compound Concentration Limits for Automotive Refinishing Products Regulations*

In the context of the Integrated Enforcement Plan, ECCC initiated a series of risk assessments in 2018-2019 to assess and determine the risk of noncompliance with its laws and regulations – including those under CEPA. The results from the 2019-2020 threat risk assessment on toxic substances were used to inform planning. In 2020-2021, a series of risk-based projects were launched based on the results of the threat risk assessments. The projects in 2021-2022 focused on increased inspections for ammonia, siloxane D4, metallurgical projects, and textile mill effluent. Ammonia, siloxane D4 and metallurgical projects continued to be a priority in 2022-2023 with the addition of other projects on power generation and fuels imports. Additional risk assessments are currently ongoing and will inform decision-making processes and help to better align enforcement actions and resources to protect the environment and human health. In addition to the planned inspections carried out under the Integrated Enforcement Plan, enforcement activities under CEPA also include a large number of unplanned inspections resulting from responses to complaints, notifications from partners, intelligence or departmental referrals, reported spills and incidents, or other information.

4.2.2 Enforcement activities

Enforcement activities undertaken between April 2022 and March 2023 are summarized in Tables 19 and 20 .

- Table 19 provides the number of on-site and off-site inspections for each regulation, the breakdown of investigations for each regulation for which at least 1 investigation occurred or closed, and the total number of enforcement measures resulting from inspections and investigations that were imposed for each regulation
- Table 20 provides the number of prosecutions for each regulation

4.2.2.1 Inspections

Inspections are defined as the active process of gathering information to verify compliance with legislation. This may include site visits, examining substances, products or containers, taking samples and reviewing records. An on-site inspection involves visiting a site, such as a factory, border crossing, an airport, or a port of entry, to conduct any activity, operation, or analysis required to verify the regulatee's compliance with a regulation. An off-site inspection is normally undertaken at the officer's place of work or in another location that is not at the regulated site and is usually limited to documentation verification.

Table 19 details the 1 106 inspections conducted under CEPA for fiscal year 2022-2023. The number of inspections relates to the number of times the regulation or other instrument was inspected for compliance, using the start date of the inspection for the reference period.

4.2.2.2 Investigations

An investigation involves gathering, from a variety of sources, evidence and information relevant to a suspected violation. An enforcement officer will conduct an investigation when he or she has reasonable grounds to believe that an offence has been committed under the Act.

Table 19 details the 40 investigations conducted under CEPA during 2022-2023.

4.2.2.3 Enforcement measures

Enforcement measures available to address alleged violations of CEPA and its regulations include warnings to bring an alleged violation to the attention of an alleged offender, and if applicable, return to compliance. In addition, environmental protection compliance orders (EPCOs) require action to be taken to stop an ongoing violation from continuing, or to prevent a violation from occurring, and administrative monetary penalties (AMPs) provide a financial disincentive to noncompliance.

Enforcement measures also include tickets, prosecutions and environmental protection alternative measures (EPAMs).

For reporting purposes, prosecutions are all instances in which charges were laid against a person (individual, corporation, or government department). The decision to prosecute ultimately rests with the Director of Public

Prosecution of Canada or their delegated agent. While reviewing the data, it should be noted that prosecutions often continue through multiple fiscal years, so there may be more prosecutions tabulated during a particular year than actual charges laid.

Tickets for offences under CEPA can be issued under the *Contraventions Act*, usually where there is minimal or no threat to the environment or human health. Where an offence has taken place and this offence is designated as ticketable, enforcement officers will issue a ticket, unless they have determined that, in accordance with the criteria of the Compliance and Enforcement Policy for CEPA, another enforcement measure is the appropriate response. Tickets are available in all provinces except Saskatchewan, Alberta, and the three territories.

An EPAM is an agreement that is negotiated with the accused in order to return an alleged violator to compliance with CEPA. It can be used only after a charge has been laid and before the matter goes to trial, as an alternative measure to prosecution for an alleged violation of the Act.

Table 20 outlines the number of prosecutions and tickets under CEPA for fiscal year 2022-2023. Only those regulations or other instruments under which prosecutions or tickets resulted during the time period are listed in this table. There was one EPAM agreement made in 2022-2023.

4.2.2.4 Environmental Damages Fund

In 2022-2023, $199,600 was directed to the Environmental Damages Fund (EDF) through the issuance of Administrative Monetary Penalties (AMPs). A total of $665,115 was directed to the Environmental Damages Fund in 2022-2023, which included $465,000 in other fines from convictions. Table 20 includes a breakdown of the regulations under which these AMPs and other fines were issued.

The EDF is a specified purpose account, administered by ECCC, to provide a mechanism for directing funds received as a result of fines, court orders, and voluntary payments to priority projects that will benefit our natural environment.

4.2.2.5 Environmental Offenders Registry and Enforcement Notifications

The Environmental Offenders Registry contains information on convictions of corporations obtained under certain federal environmental laws, including CEPA, from June 18, 2009 to the present. This tool allows the media and the public to search for corporate convictions using keywords such as the name of the corporation or the legislation under which the conviction was obtained.

The Enforcement Notifications provide information regarding successful prosecutions across Canada under the acts and regulations administered by ECCC or involving ECCC enforcement officers (including CEPA).

4.3 International enforcement cooperation

Enforcement-related activities are carried out under various international and domestic agreements and organizations. ECCC actively participates in INTERPOL's Pollution Crime Working Group, which brings together member countries to work collectively on pollution crime issues.

In 2023, ECCC participated in the World Customs Organization (WCO) Demeter IX operation, the largest in the series with 90 participating customs administrations. It focused on addressing illegal waste and illegal trade in ozone-depleting substances. Intelligence and Enforcement Officers, working with the Canada Border Services Agency, refused export for 32 containers representing approximately 694 000 kilograms of waste as they did not comply with cross-border requirements.

5. Reporting programs and emission inventories

There are 2 mandatory programs under CEPA, which require facilities to report on their releases or emissions of specified substances into the environment:

- Greenhouse Gas Reporting Program
- National Pollutant Release Inventory

Data for both programs is submitted through ECCC's Single Window Information Management (SWIM) system.

The most recent reports on Canada's National Pollutant Release Inventory and from its Facility-level Greenhouse Gas Reporting Program are available online.

ECCC compiles and maintains 5 inventories of substances released into the environment using information reported through these programs as well as other key data sources. These are the:

- Greenhouse Gas Inventory
- National Pollutant Release Inventory
- Air Pollutant Emissions Inventory
- Black Carbon Emissions Inventory
- Facility-level Greenhouse Gas Emissions Inventory

5.1 Greenhouse Gas Reporting Program and Inventory

Under CEPA section 46, facilities (mostly large industrial operations) are required to report the quantities of greenhouse gases released to the air through its Greenhouse Gas Reporting Program (GHGRP). Any facility emitting a combined total quantity of greenhouse gases above the equivalent of 10 000 tonnes of carbon dioxide must report their information each June. The GHGRP is part of ECCC's ongoing effort to maintain and continuously enhance, in collaboration with various provinces, a nationally consistent, mandatory GHG reporting system, in order to meet the GHG reporting needs of all jurisdictions and to minimize the reporting burden for industry and government.

Key objectives of the GHGRP are to provide people in Canada with consistent information on facilitylevel GHG emissions, to inform the development of the National Greenhouse Gas Inventory, and to support regulatory initiatives. The data collected are also shared with provinces and territories.

- Facilities submitted their information on greenhouse gas emissions for 2021 by June 1, 2022. ECCC undertook its yearly review of the submitted data to assess and resolve compliance or data quality issues. The reviewed data was prepared for public release on April 14, 2023 (see below for details on the data).
- The 2022 reporting cycle continued the additional requirements (introduced in 2017) as part of an expansion to the GHG Reporting Program to include enhanced reporting and methodological requirements for 14 industry sectors. ECCC will continue to assess the need for further expansion in future years.
- On January 28, 2023, ECCC published a notice in the *Canada Gazette*, *Part I* requiring the reporting of greenhouse gas emissions for the 2022 and 2023 calendar years. Requirements largely reflected those issued for 2021 data (in December 2021), with a few key changes being implemented following consultations held in the summer 2022. These changes include updates to global warming potential values used under the program, and an intent to publish more detailed data (see the GHGRP Response Document published on January 23, 2023 for more details).

5.2 Facility-level Greenhouse Gas Emissions Inventory

Accurate and consistent tracking of greenhouse gas emissions from individual facilities contributes to ECCC's efforts to monitor environmental performance and develop policies related to climate change by providing a more precise picture of emission levels from large emitters in Canada. The most recent data available, collected under the Greenhouse Gas Reporting Program, is for the 2021 reporting year.

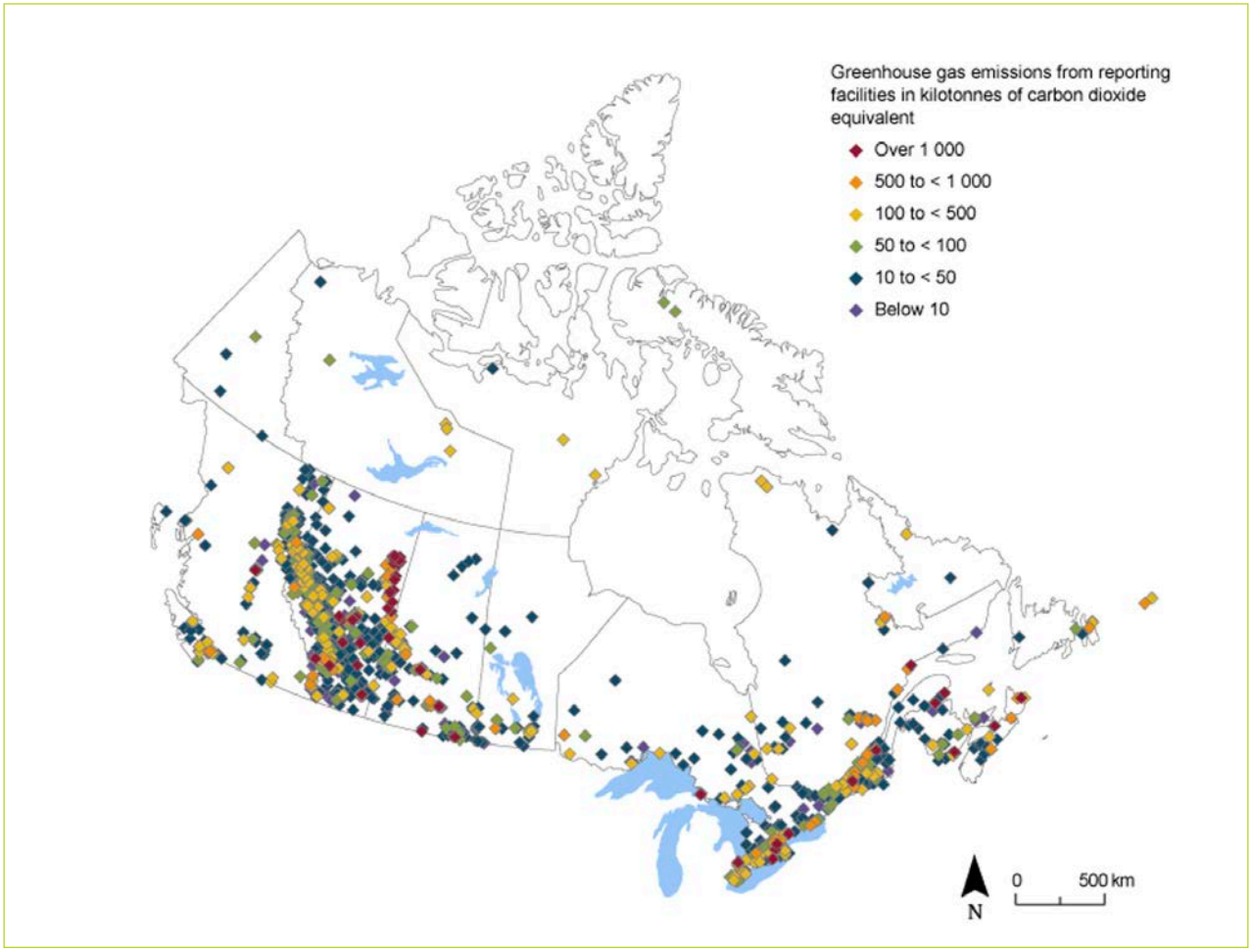
In 2021, 1 733 facilities reported their greenhouse gas emissions (see Figure 10), totaling 285 million tonnes (Mt) of carbon dioxide equivalent (CO_2 eq). The reported emissions are largely distributed across 3 sectors: Mining, Quarrying, and Oil and Gas Extraction (41%); Manufacturing (30%); and Utilities (21%).

- Total facility-reported emissions were 4% greater than the reported total in 2020 (275 Mt) due mainly to increased emissions in the Mining, Quarrying, and Oil and Gas Extraction and Manufacturing sectors. Increased emissions in 2021 are largely a result of increased production levels for facilities after a 2020 year marked with production slow-downs and disruptions associated with the COVID-19 pandemic.

The complete data set of greenhouse gas emissions from facilities and the corresponding indicator provides consistent information on emissions from the largest emitting facilities in Canada and is published annually.

The latest data reported to the GHGRP shows that emissions from the reporting facilities account for 43% of Canada's total GHG emissions in 2021.

Figure 10. Map of facilities reporting greenhouse gas emissions in 2021.



5.3 National Greenhouse Gas Inventory

As a signatory to the *United Nations Framework Convention on Climate Change* (UNFCCC) Canada is obligated to prepare and submit an annual national greenhouse gas (GHG) inventory covering anthropogenic emissions by sources and removals by sinks. ECCC is responsible for preparing Canada's official national inventory with input from numerous experts and scientists across Canada. The National Inventory Report (NIR) contains Canada's annual GHG emission estimates dating back to 1990. In addition to providing GHG emission data by mandatory reporting categories, the NIR also presents emission data by Canadian economic sectors, which support policy analysis and development.

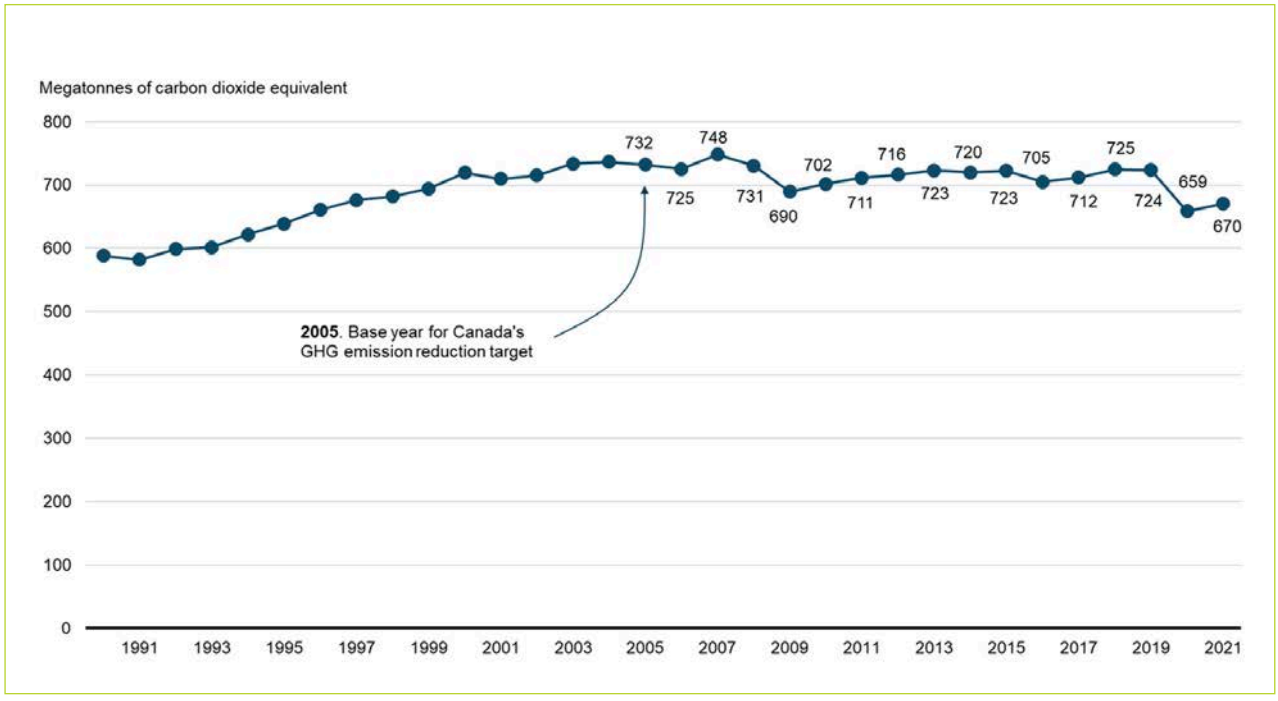
The NIR, along with the Common Reporting Format (CRF) tables, comprise Canada's inventory submission to the UNFCCC and are prepared in accordance with the UNFCCC Reporting Guidelines on annual inventories. The 2023 NIR provides data up to 2021.

The 2023 NIR shows the following trends:

- In 2021, Canada's greenhouse gas (GHG) emissions were 670 megatonnes of carbon dioxide equivalent (Mt CO_2 eq), decreasing by 62 Mt (8.4%) from 2005 and increasing by 12 Mt (1.8%) from 2020, but remaining 53 Mt (7.4%) below pre-pandemic (2019) emission levels.
- Transport and oil and gas extraction combustion emissions increased by 9.0 Mt (5.0%) and 4.0 Mt (4.0%), respectively, between 2020 and 2021, while emissions from residential stationary combustion sources and agricultural soils decreased by 1.5 Mt (4.0%) and 1.4 Mt (7.0%), respectively.
- During the period covered by this inventory (1990-2021), Canada's economy has grown more rapidly than its GHG emissions; the emissions intensity for the entire economy (GHG per Gross Domestic Product [GDP]) has declined by 42% since 1990 and 29% since 2005.

While the COVID-19 pandemic undoubtedly impacted recent year emissions, the sustained decline in emission intensities over time can be attributed to fuel switching, increases in efficiency, the modernization of industrial processes and structural changes in the economy.

Figure 11. Canada's greenhouse gas emissions, 1990 to 2021.



5.4 National Pollutant Release Inventory

The National Pollutant Release Inventory (NPRI), Canada's legislated, publicly accessible national inventory, collects information from Canadian industrial, commercial and institutional facilities on their releases (to air, water and land), disposals, and transfers of pollutants and other substances of concern.. Since 1993, owners or operators of facilities that have met the NPRI requirements have reported on an annual basis.

- NPRI data for the 2021 reporting year was submitted to ECCC by June 1, 2022 (details on the data follows below). Reviewed data for 2021 was published on November 19, 2022, and updated on March 20, 2023.

The NPRI Multi-Stakeholder Work Group is the primary consultation mechanism for the NPRI program with representatives from industry associations, environmental groups and Indigenous organizations providing input on changes to the requirements and other aspects of the program, such as tools to access the data.

- Consultations during 2022-2023 included a number of virtual and in-person meetings to begin consultations on proposals for specific changes that would take effect for reporting of 2025 data. After taking into account input received during these consultations, ECCC will publish the updated NPRI requirements for 2025 to 2027 in the *Canada Gazette, Part I* in early 2025. Key changes under consideration include the addition of substances that have been found to meet the criteria of s. 64 of CEPA so that releases and transfers of these substances can be tracked through the NPRI.

In addition to the above-mentioned consultations, the NPRI program shares information and gathers ideas from stakeholders and the public. Activities include engaging users of NPRI data to get input on how to meet their needs, working collaboratively with other government programs and international organizations, and, updating stakeholders regularly on the NPRI.

NPRI information is also a major starting point for identifying and monitoring sources of pollution in Canada and in developing indicators for the quality of our air, land and water. The NPRI helps determine if regulatory or other action is necessary to ensure reductions, and if so, the form that action should take. Public access to the NPRI data through annual data highlights, an online data search tool, location-based data for use in mapping and downloadable datasets encourages industry to prevent and reduce pollutant releases and improves public understanding about pollution and environmental performance in Canada.

The most recent reviewed NPRI data available at the time of publication is for the 2021 reporting year. In 2021, 7 191 facilities (Figure 12) reported to the NPRI approximately 4.99 million tonnes of pollutants covering over 320 substances (Figure 13):

- 2.92 million tonnes of pollutants were released directly to the environment
- 1.73 million tonnes were disposed to landfills, applied to land or injected underground, either on the facility site or off-site
- 340 461 tonnes were transferred off the facility site for treatment prior to final disposal or for recycling and energy recovery

Figure 12. Location of facilities that reported to the NPRI for the 2021 reporting year.

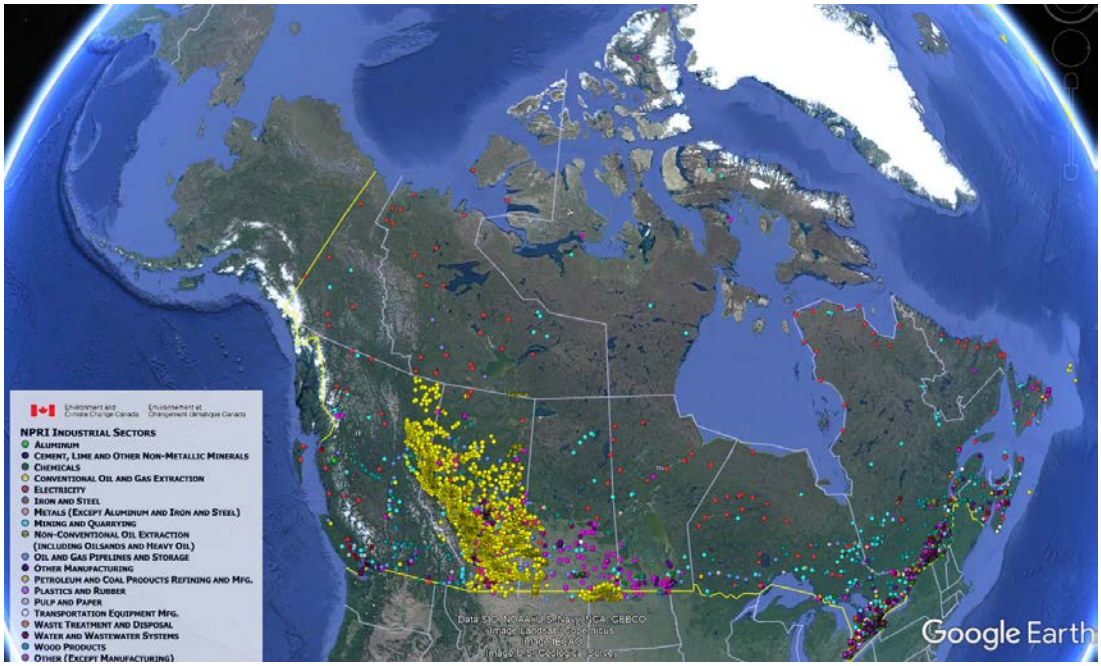
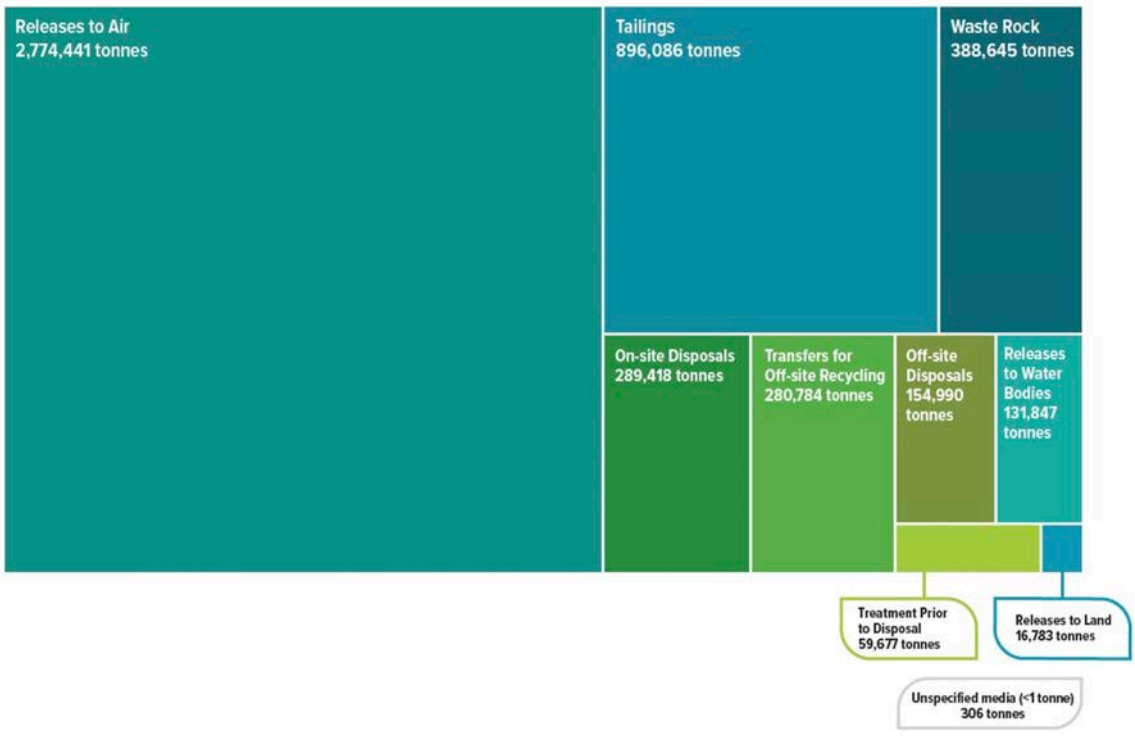


Figure 13. Breakdown of total quantities reported to NPRI for 2021, by reporting category.



Between 2012 and 2021, releases to the environment to all media reported to the NPRI **decreased** by 503 403 tonnes. In particular:

- releases to air decreased by 506 971 tonnes
- releases to water decreased by 5 964 tonnes
- releases to land increased by 9 532 tonnes
- releases of substances (i.e., unspecified media) where the total release quantity was less than 1 tonne decreased by 116.4 tonnes

Between 2012 and 2021, total disposals and transfers **increased** by 457 674 tonnes. In particular:

- off-site disposals decreased by 155 674 tonnes
- on-site disposals (excluding tailings and waste rock) increased by 51 522 tonnes
- off-site transfers for recycling decreased by 18 628 tonnes
- disposals of waste rock (rock removed to reach ore) increased by 356 951 tonnes
- disposals of tailings (materials left when minerals are removed from ore) increased by 223 502 tonnes

5.5 Air Pollutant Emissions Inventory

Canada's Air Pollutant Emissions Inventory (APEI) is a comprehensive inventory of air pollutant emissions at the national, provincial and territorial levels primarily developed using 2 types of information:

- facility-reported data primarily from the NPRI
- in-house estimates, including diffuse sources and other sources that are too numerous to be accounted for individually

Since 1990, the APEI has compiled emissions of 17 air pollutants contributing to smog, acid rain and reduced air quality.

This inventory serves many purposes including fulfilling Canada's international reporting obligations under the *1979 Convention on Long-range Transboundary Air Pollution* (CLRTAP) and the associated protocols ratified by Canada for the reduction of various types of air pollutant emissions. These emissions include sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOCs), fine particulate matter ($PM_{2.5}$), cadmium (Cd), lead (Pb), mercury (Hg), dioxins and furans, and other persistent organic pollutants (POPs). The APEI also reports emissions of additional air pollutants including ammonia (NH_3), carbon monoxide (CO), coarse particulate matter (PM_{10}) and total particulate matter (TPM).

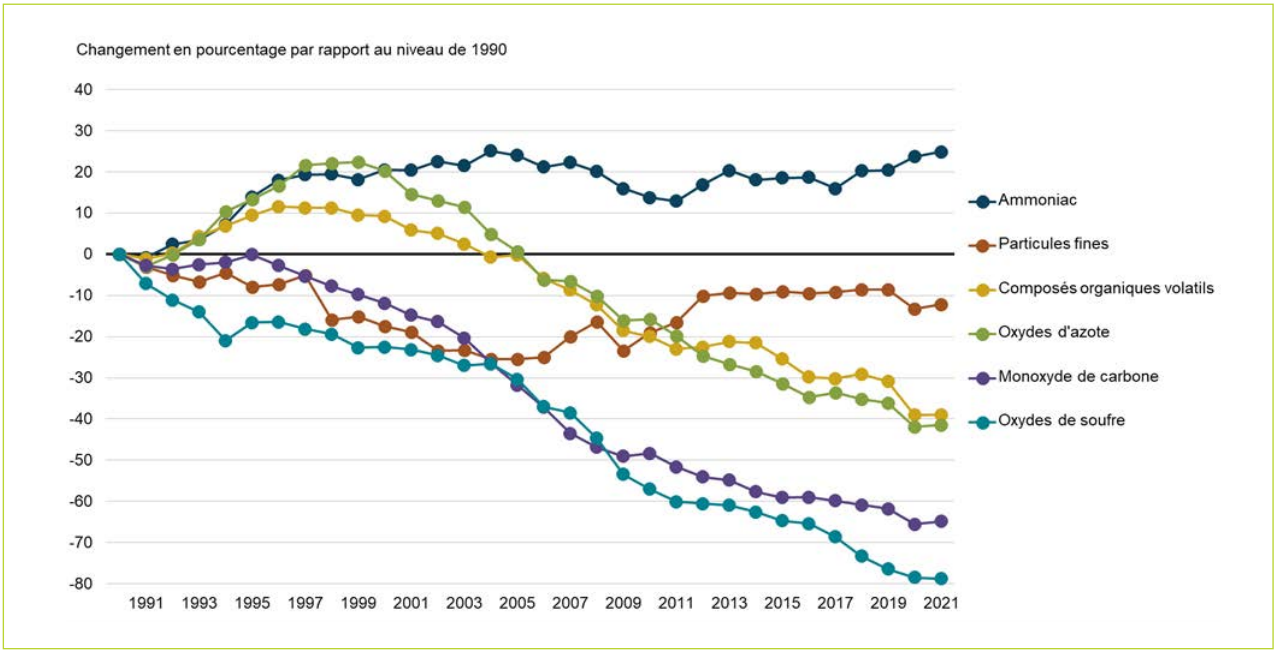
Moreover, the APEI supports monitoring and reporting obligations under the Canada-U.S. Air Quality Agreement, the development of air quality management strategies, policies and regulations, provides data for air quality forecasting models, and informs people in Canada about pollutants that affect their health and the environment.

The 2023 APEI Report summarizes the most recent estimates of air pollutant emissions for 1990 to 2021, as of February 2023. The inventory indicates that emissions of 14 of the 17 reported air pollutants are decreasing compared to historical level (see Figure 14). A few key sources of pollutants account for a significant portion of the downward trends in emissions (see Table 21).

The most recent years for which data are available for this report, 2020 and 2021, were marked by the COVID-19 pandemic. This coincides with observed emission decreases between the years 2019 and 2020 for almost all pollutants with the exception of NH_3. Between 2020 and 2021, most of the pollutant emissions increased, but remained below their 2019 pre-pandemic levels, except for NH_3 and hexachlorobenzene (HCB) both of which exceeded their 2019 emission levels in 2021. In contrast to these increases, SO_x, Pb, and polycyclic aromatic hydrocarbons (PAHs) emissions continued to decrease between 2020-2021, while VOC emissions did not show a discernable trend.

Despite significant decreases in emissions of most pollutants, since 2005, emissions of particulate matter have risen by 38% (TPM), 33% (PM_{10}) and 18% ($PM_{2.5}$). These increases are largely from dust emissions associated with transportation on unpaved roads as well as construction operations. Another exception to the general downward trends is the steady increase in emissions of NH_3, which in 2021 were 25% above 1990 levels, and 1% above 2005 levels. The upward trend in NH_3 emissions is primarily driven by inorganic nitrogen fertilizer application.

Figure 14. Emissions trends for selected air pollutants in Canada, 1990 to 2021.



5.6 Black Carbon Emissions Inventory

Black carbon is a component of particulate matter (PM) and a short-lived small aerosol (or airborne particle) linked to both climate warming and adverse health effects. Canada produces an annual black carbon inventory report, as well as an associated biennial national report, as part of its commitments under the Arctic Council Framework for Action on Enhanced Black Carbon and Methane Emissions Reductions. The biennial Black Carbon Inventory Report serves to inform people in Canada about black carbon emissions, to provide valuable information on domestic actions to reduce emissions, and to help track action and progress towards the Arctic Council collective goal to reduce emissions of black carbon by 25-33% below 2013 levels by 2025.

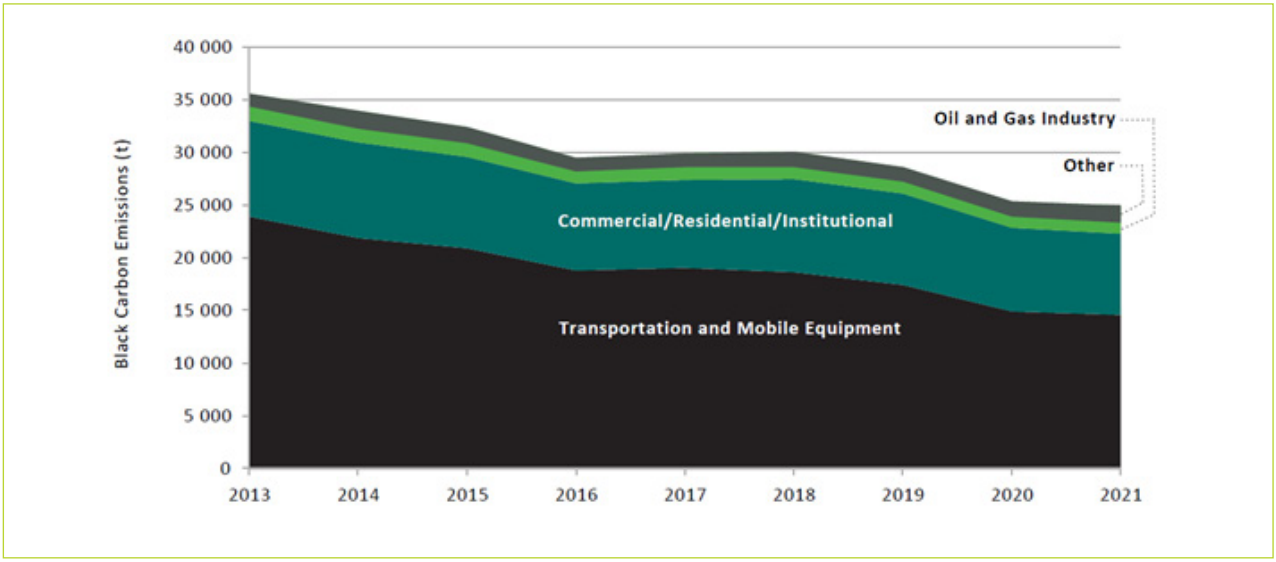
The data used to quantify black carbon emissions are taken from the APEI and based on $PM_{2.5}$ emissions from combustion-related sources, such as transportation and mobile equipment and home firewood burning.

According to Canada's 2022 Black Carbon Inventory Report, the following trends are notable (see Figure 15).

- In 2021, approximately 26 kilotonnes (kt) of black carbon were emitted in Canada from anthropogenic sources, not including natural sources, such as wildfires.
- The largest sources of black carbon emissions are transportation and mobile equipment (notably diesel engines from on-road and off-road transport) and fuel combustion in the Commercial/Residential/Institutional sector, most notably from home firewood burning, accounting for 15 kt (56%) and 7.7 kt (30%) respectively, of total emissions in 2021.

- The most recent years for which data are available for this report, the years 2020 and 2021, were marked by the COVID-19 pandemic, coinciding with observed decreases in emissions of 3.4 kt or 11% between 2019 and 2020, and 0.43 kt or 1.7% between the years 2020 and 2021. This is most notable in transportation and mobile equipment where emissions decreased by 2.6 kt or 15% between 2019 and 2020 and by 0.31 kt or 2.1% between 2020 and 2021, mostly from off-road diesel equipment. There were less off-road diesel engines in use in 2020 relative to 2019, and they consumed less diesel fuel. Between 2020 and 2021, because of fleet turn-over, more off-road diesel engines were in compliance with the latest exhaust emission standards.
- Since 2013, black carbon emissions in Canada have decreased overall by 11 kt (30%).
- Trends in black carbon emissions are largely driven by transportation and mobile equipment and are consistent with observed downward trends in emissions of fine particulate matter from combustion-related activities (upon which black carbon estimates are based).

Figure 15. Canada's black carbon emissions trends, 2013 to 2021.



Data and various material are also made available through the departmental data catalogue (Open Data Portal), and may be accessed through the following links:

- APEI: Canada's Air Pollutant Emissions Inventory – Open Government Portal
- Black Carbon: Canada's Black Carbon Inventory – Open Government Portal
- GHG: Canada's Official Greenhouse Gas Inventory – Open Government Portal
- GHGRP: Canada's Greenhouse Gas Reporting Program (GHGRP) – Facility Greenhouse Gas (GHG) Data

6. Administration, engagement with Indigenous People and public participation

Administration, engagement with Indigenous People and public participation covers stakeholder engagement and inter-jurisdictional relationships.

6.1 Federal, provincial, territorial cooperation

National Advisory Committee

The National Advisory Committee (NAC) provides a forum for provincial, territorial and Aboriginal governments to advise the Ministers on certain actions being proposed under the Act, enables national cooperative action, and seeks to avoid duplication in regulatory activity among governments. The committee was provided opportunities to advise and comment on initiatives under the Act. More information on the committee is available online.

To carry out its duties in 2022–2023, the CEPA NAC held two teleconference meetings; one on June 14, 2022 and the other on February 7, 2023.The NAC Secretariat corresponded regularly with committee members regarding various initiatives implemented under CEPA, including to inform members of actions taken under the Act and to provide them with opportunities to comment and advise on proposed regulatory and policy measures.

Members were provided an opportunity **to comment** on:

- 1 draft screening assessment
- 2 risk management approach documents and 4 Notices of Intent to apply the Significant New Activity Provisions (SNAc) included with final screening assessments
- 7 proposed orders adding various substances to Schedule 1 of the Act, including the substances: Basic Violet 3, Malachite Green, Basic Violet 4, and Basic Blue 7; benzophenone; dinoseb; Solvent Violet 13 (anthraquinones); TMTD; crude tall oil (resins and rosins) and cyanides
- 2 proposed regulations (*Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations* and the *Regulations amending the Products Containing Mercury Regulations*
- draft updated Protocols and Performance Specifications for Continuous Monitoring of Gaseous Emissions from Thermal Power Generation and other sources
- the key items for discussion at the Conferences of the Parties to the Basel, Rotterdam and Stockholm Conventions

Members were provided with an **offer to consult** on:

- a Notice with Respect to the Proposed Code of Practice for the Environmentally Sound Management of Chemical Substances in the Chemicals, Plastics and Rubber Sectors
- a draft Decision-Recommendation of the Organization for Economic Cooperation and Development (OECD) concerning chemical accident prevention, preparedness, and response

Members were provided with an **opportunity to advise** on:

- the proposed *Prohibition of Certain Toxic Substances Regulations, 2022* and a proposed Order Amending Schedule 3 to CEPA
- Amendments to the *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)*

Members were also **informed** of:

- 17 final screening assessments
- the publication of 3 regulations (*Prohibition of the Manufacture and Importation of Wheel Weights Containing Lead Regulations; Single-use Plastics Prohibition Regulations*; and the *Federal Halocarbon Regulations, 2022*)
- 3 orders amending the Domestic Substances List to apply the SNAc provisions to calcium 2-ethylhexanoate; monoglyme, diglyme and triglyme; and two living organisms
- publication of an Environmental Performance Agreement (EPA) for the Formulation of Chlorhexidine Products
- the publication of Federal Environmental Quality Guidelines (FEQG) for aluminium, selenium and siloxane-D4

6.2 Federal-provincial/territorial agreements

Part 1 of the Act allows the Minister of Environment and Climate Change to negotiate an agreement with a provincial or territorial government, or an Aboriginal people, with respect to the administration of the Act. It also allows for equivalency agreements, which allow the Governor in Council to suspend the application of federal regulations in a jurisdiction that has equivalent regulatory provisions. The intent of an equivalency agreement is to eliminate the duplication of environmental regulations. Table 22 indicates the administrative and equivalency agreements in place under sections 9 and 10 of CEPA and the activities under them during 2022-2023.

Memoranda of understanding between Canada and Quebec

In order to maximize the effectiveness of regulatory efforts and reduce the administrative burden on the pulp and paper industry, the Province of Quebec and the Government of Canada have been collaborating since 1994. The parties currently co-operate through a memorandum of understanding for data collection, whereby Quebec provides a single data-entry portal for regulatees for the following federal regulations:

- *Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations* made pursuant to CEPA
- *Pulp and Paper Mill Defoamer and Wood Chip Regulations* made pursuant to CEPA
- *Pulp and Paper Effluent Regulations* made pursuant to the *Fisheries Act*

The Memorandum of Understanding continued to provide ECCC with real time access to historical and current data during 2022-2023.

Table 22. Current administrative and equivalency agreements under CEPA by jurisdiction

Jurisdiction (s)	Agreement	Description	Activities for 2022-2023
British Columbia	Canada-British Columbia Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	No new information
	Agreement on the Equivalency of Federal and British Columbia Regulations Respecting the Release of Methane from the Oil and Gas Sector in British Columbia, 2020	Equivalency agreement (s.10) Signed on February 26, 2020, and came into force on March 25, 2020 when the Order Declaring that the Provisions of the Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector) Do Not Apply in British Columbia was registered. While in force, the following CEPA regulations no longer apply in British Columbia: • *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)*	The Government of British Columbia delivered an annual report describing regulatory activity and compliance data as described in the Equivalency Agreement. Similar information will be submitted each year throughout the duration of the equivalency agreement, allowing ECCC to monitor the implementation of the provincial regulation and ensure an equivalent outcome is achieved.
Alberta	Canada-Alberta Equivalency Agreement 1994	Equivalency agreement in place since 1994 that applies to pulp and paper mills and secondary lead smelters. The following CEPA regulations no longer apply in Alberta: • *Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations* (all sections) • *Pulp and Paper Mill Defoamer and Wood Chips Regulations* (sections 4(1), 6(2), 6(3)(b), 7 and 9) • *Secondary Lead Smelter Release Regulations* (all sections)	No new information
	Canada-Alberta Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	No new information

Jurisdiction (s)	Agreement	Description	Activities for 2022-2023
	Agreement on the Equivalency of Federal and Alberta Regulations Respecting the Release of Methane from the Oil and Gas Sector in Alberta, 2020	Equivalency agreement (s.10) Signed on October 7, 2020, and came into force on October 26, 2020 when the Order Declaring that the Provisions of the Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector) Do Not Apply in Alberta was registered. While in force, the following CEPA regulations no longer apply in Alberta: • *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)*	The Government of Alberta delivered an annual report describing regulatory activity and compliance data as described in the Equivalency Agreement. Similar information will be submitted each year throughout the duration of the equivalency agreement, allowing ECCC to monitor the implementation of the provincial regulation.
Saskatchewan	Canada-Saskatchewan Administrative Agreement for the Canadian Environmental Protection Act	Administrative agreement in place since 1994 that deals with compliance promotion and enforcement of regulations pertaining to pulp and paper mills and ozone-depleting substances, as well as general information sharing. Partially amended by 2016 Environmental Occurrences Notification Agreement.	No new information
	Canada-Saskatchewan Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016 Amended the 1994 Administrative agreement with respect to the notification of environmental occurrences.	No new information
	An agreement on the equivalency of federal and Saskatchewan regulations for the control of greenhouse gas emissions from electricity producers in Saskatchewan, 2020	Equivalency agreement (s.10) Signed on May 3, 2019, and came into force on January 1, 2020. While in force, the following CEPA regulations no longer apply in Saskatchewan: • *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations*	Annual compliance data was received for the first and second years of implementation (2020 and 2021) and reviewed. Similar information will be submitted each year throughout the duration of the equivalency agreement, allowing ECCC to monitor the implementation of the provincial regulation and ensure an equivalent outcome is achieved.

Jurisdiction (s)	Agreement	Description	Activities for 2022-2023
	Agreement on the Equivalency of Federal and Saskatchewan Regulations Respecting the Release of Methane from the Oil and Gas Sector in Saskatchewan, 2020	Equivalency agreement (s.10) Signed on September 29, 2020, and came into force on October 26, 2020 when the Order Declaring that the Provisions of the Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector) Do Not Apply in Saskatchewan was registered. While in force, the following CEPA regulations no longer apply in Saskatchewan: • *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)*	The Government of Saskatchewan delivered an annual report describing regulatory activity and compliance data as described in the Equivalency Agreement Similar information will be submitted each year throughout the duration of the equivalency agreement, allowing ECCC to monitor the implementation of the provincial regulation.
Manitoba	Canada-Manitoba Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	No new information
Ontario	Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health	Administrative agreement (s.9) New agreement came into force June 1, 2021. Agreement outlines how the governments of Canada and Ontario will cooperate and coordinate their efforts to restore, protect and conserve the Great Lakes basin ecosystem from 2021 to 2026.	See the *Canada Water Act* Annual Report 2021-2022 for an update on progress under this Agreement.
	Canada-Ontario Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	No new information
Nova Scotia	An agreement on the equivalency of federal and Nova Scotia regulations for the control of greenhouse gas (GHG) emissions from electricity producers in Nova Scotia, 2020	Equivalency agreement (s.10) Signed on November 14, 2019 and came into force on January 1, 2020. On that date, the following CEPA regulations continue to no longer apply in Nova Scotia: • *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations*	Annual compliance data was received for the first and second years of implementation (2020 and 2021) and reviewed. Similar information will be submitted each year throughout the duration of the equivalency agreement, allowing ECCC to monitor the implementation of the provincial regulation and ensure an equivalent outcome is achieved.

Jurisdiction (s)	Agreement	Description	Activities for 2022-2023
Yukon	Canada-Yukon Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	No new information
British Columbia, Manitoba, New Brunswick, Nova Scotia, Ontario, Quebec, Prince Edward Island, Newfoundland and Labrador, Saskatchewan, Northwest Territories, Nunavut, Yukon	National Air Pollution Program Memorandum of Understanding	Administrative agreement (s.9) renewed in 2018	All parties submitted to ECCC their data from NAPS Sites collected in 2019. After validation and data packaging, data are now publicly available on the federal government Open Data Portal. The NAPS data collected in the first 6 months of 2020 were used to assess the impact of the COVID-19 lockdown on air quality. Observed decreases in some pollutant levels were mostly due to reduction in traffic volumes.

*Purpose is to establish a streamlined notification system and reduce duplication of effort for persons required to notify federal and provincial/territorial governments of an environmental emergency or environmental occurrence, such as an oil or chemical release.

6.3 Engagement with Indigenous Peoples

6.3.1 Implementation of the *United Nations Declaration on the Rights of Indigenous Peoples*

Amendments to the preamble of CEPA introduced by Bill S-5 confirm the Government's commitment to implement the *United Nations Declaration on the Rights of Indigenous Peoples*, including free, prior and informed consent, and recognizes the role of Indigenous knowledge in decision making related to the protection of the environment and human health. Bill S-5 also introduced requirements to include information on activities under CEPA that involve Indigenous peoples, such as: consultations and the key issues raised; measures taken to advance reconciliation; and, key findings or recommendations of any report made under an Act of Parliament in respect of the administration of CEPA and Aboriginal peoples and Aboriginal governments.[5] Upcoming annual reports will endeavor to highlight stories of successful engagement opportunities resulting in partnerships and progress toward reconciliation with Indigenous peoples.

5 Bill S-5 continues to apply the term "Aboriginal" as previously used in the *Canadian Environmental Protection Act, 1999* and as used in s.35 of the *Constitution Act, 1982*

Some of the actions taken by ECCC and HC during 2022-2023 to work toward reconciliation are highlighted throughout this report, and include measures such as:

- consultation on the development of more stringent regulations to achieve further methane emission reductions in the oil and gas sector
- engagement on the development of the *Clean Electricity Regulations* (CER)
- collaboration with the Centre for Indigenous Environmental Resources (CIER) to adapt messaging and to develop and distribute resources to promote Clean Air Day to Indigenous audiences
- engagement by the disposal at sea program to address some Indigenous concerns
- consultations undertaken by the NPRI Multi-Stakeholder Work Group
- provision of funding through the Indigenous Participation stream of the CMP Engagement and Outreach Contribution Program
- establishing and maintaining strong relationships with supporting organizations (i.e., Indigenous Services Canada, Tribal Councils) to help advance compliance promotion efforts

The Tsleil-Waututh Nation and Environment and Climate Change Canada begin next step to make decisions together for Disposal at Sea

On May 24, 2022, the Tsleil-Waututh Nation (TWN) and ECCC celebrated their landmark, first-of-its-kind agreement to co-manage Disposal at Sea within Burrard Inlet, with their *Agreement on Collaborative Decision Making Regarding Disposal at Sea* (signed in 2018). Representatives of ECCC and TWN met at Whey-ah-Wichen/Cates Park in North Vancouver for a celebration and a traditional Tsleil-Waututh ceremony to recognize the progress made to date.

This agreement recognizes the TWN's essential role as a partner with Canada in monitoring, protecting, and restoring the health of the Burrard Inlet and its long stewardship over the land. While Canada prevents pollution in oceans with initiatives such as the Disposal at Sea Program under its *Canadian Environmental Protection Act*, in Tsleil-Waututh law, the TWN has an obligation to protect the health of its lands and waters, which include the Burrard Inlet in the greater Vancouver region.

This important step on the path to reconciliation will ensure that disposal at sea in the Burrard Inlet is informed by Tsleil-Waututh science and deep knowledge of their traditional lands and waters. It will help to ensure the Burrard Inlet and its critical ecosystem are managed sustainably, safeguarding the health of local communities, and of the watershed, for generations to come.

> *"I want to acknowledge the commitment and vision of the members of the Tsleil-Waututh Nation and celebrate the implementation of this first-of-its-kind agreement to co-manage disposal at sea applications in the Burrard Inlet. This is a significant step in strengthening our partnership with the Tsleil-Waututh Nation and supports common efforts to protect ecosystems. We are partnering with Indigenous communities to better understand how we can sustainably and responsibly manage our lands and waters."*
>
> – The Honourable Steven Guilbeault, Minister of Environment and Climate Change

> *"Tsleil-Waututh Nation are People of the Inlet, and have a sacred obligation to care for the lands and waters that we have lived in and stewarded since time out of mind. Tsleil-Waututh Nation is proud to celebrate the Agreement on Collaborative Decision Making Regarding Disposal at Sea and the collaborative work we've accomplished to get to this point. Our Tsleil Waututh people work diligently to protect the lands and waters to restore the health of the Burrard Inlet, because when the lands and waters are healthy, our people are healthy."*
>
> – Chief Jen Thomas, Tsleil-Waututh Nation

6.3.2 Environmental protection on First Nation reserves

In the 2018 *Follow-up report to the House of Commons Standing Committee on Environment and Sustainable Development on the Canadian Environmental Protection Act, 1999*, the Government committed to engage with First Nations on a path forward to address environmental protection on First Nation reserves, including possible improvements to authorities in CEPA that could enhance environmental protection on First Nations reserve lands. A multi-year, multi-phase approach was validated with regional First Nations organizations in 2019.

Since 2020, Environment and Climate Change Canada and Indigenous Services Canada have worked with eight regional First Nations organizations to identify environmental protection challenges and priorities on reserve and validate those priorities through community-level engagements. This phase of engagement was extended due to the COVID-19 pandemic. Participating organizations come from Saskatchewan, Ontario, Quebec, and Nova Scotia and collectively represent 263 First Nations communities. During 2022, one participating regional organization submitted its final report describing its engagement activities and no CEPA related issues were raised.

6.4 Public participation

6.4.1 CEPA registry & public consultation

Part 2 of CEPA (Public Participation) provides for the establishment of an environmental registry.

The CEPA Registry was launched on ECCC's website when the Act came into force on March 31, 2000. Continuous efforts are made to increase the Registry's reliability and ease of use. The Registry encompasses thousands of CEPA-related documents and references. It has become a primary source of environmental information for the public and private sectors, both nationally and internationally, and has been used as a source of information in university and college curricula.

From April 2022 to March 2023, the CEPA Registry website had 55 799 visits and 13 354 page views.

CEPA also has many provisions requiring consultation and public comment periods for proposed orders, regulations and other statutory instruments, and requirements to publish information to the Registry.

In addition, engaging stakeholders and the public is central to several programs under CEPA. For example, at various stages of the CMP management cycle, stakeholders are engaged and the public has the opportunity to be involved and to comment (for example, on proposed assessments of substances or groups of substances).

There were 70 opportunities posted on the Registry between April 1, 2022 and March 31, 2023 for stakeholders and the members of the public to provide comments on proposed initiatives under CEPA. These include:

- 2 screening assessments
- 15 final decisions on assessments
- 3 results of investigations
- 8 waivers of information
- 4 significant new activity notices
- 1 objective
- 14 proposed guidelines
- 11 ministerial conditions
- 1 code of practice
- 7 notices of intent
- 2 notices with respect to reporting of certain substances
- 2 independent publications

Please see the CEPA Registry public consultations, available online.

6.4.2 CMP-related committees and activities

HC and ECCC continue to advance an enhanced engagement strategy with a view to better enabling equitable and meaningful engagement with CMP stakeholders and partners. The first multi-stakeholder webinar of the renewed CMP was held in May 2022 to present program updates and forward direction, as well as the updated CMP engagement strategy.

A key element of the enhanced approach was the creation of a new CMP Engagement and Outreach Contribution Program. This Contribution Program will better equip the CMP to address government priorities, (e.g., Reconciliation, protection of populations that may be disproportionately impacted). It also facilitates the engagement of a wider breadth of stakeholders and partners to help navigate an increasingly complex chemicals management landscape that requires a range of knowledge and perspectives for effective program decision-making. The Contribution Program is composed of three funding streams: Outreach (public awareness and education), Public Participation and Indigenous Participation.

The Contribution Program funded four recipients in 2022-2023:

1. Maliseet Nation Conservation Council

   The Maliseet Nation Conservation Council conducted a study among their six communities, surveying community members to better understand exposure to chemicals during domestic and traditional activities carried out by community members. The organization subsequently organized two engagement sessions with community members and the CMP and partners in February and March 2023. As a result, members of the Maliseet communities in New Brunswick had the opportunity to raise concerns and views on potential effects of chemicals in their environment. The results of this engagement activity will inform future program directions and underscored the importance of a holistic, “environmental health” approach to Indigenous engagement.

2. Inuvialuit Regional Corporation

   In support of an Inuivaluit-led research project on microplastics in drinking water, the Inuvialuit Regional Corporation engaged Inuvialuit youth and trained them to collect raw and treated water samples from their community water treatment plants and collected qualitative data from Elders and language holders to answer water quality-related questions. They also provided an opportunity for community members to voice their concerns and needs around water quality and access to clean water during Open House meetings.

3. New Brunswick Lung Association

   The New Brunswick Lung Association created a Toxic Caucus, a mechanism intended to bring the voices of a wider range of people in Canada to engage in the CMP. The goal of the Caucus is to support Canadian Civil Society Organizations (CSOs) and populations that may be disproportionately impacted to engage in the CMP and other environmental health initiatives. The organization also received funding for young parents and Indigenous breastfeeding mothers. They facilitated information sessions on domestic chemicals and created a bilingual website with tools on how to reduce chemical exposure at home (e.g. product comparison sheet, information on non-stick appliances, fragrances, plastic, as well as DIY cards for non-toxic cleaning supplies).

4. Newcomer Centre of Peel

   This organization developed knowledge products for newcomers and refugees in Ontario. Information was shared through weekly social media posts on various topics such as hand washing, lead in drinking water, hazard symbols, storage of chemicals and disposal of chemicals, parabens, radon gas, carbon monoxide and fire safety and home ventilation. In-person workshops on Healthy Home were also provided with simultaneous interpretation in six languages to help reduce environmental health risks.

In March 2023, the Government of Canada (GoC) hosted its inaugural CMP-CSO Bilateral Meeting between the Toxics Caucus and CMP Directors General, Directors and staff from HC and ECCC. The intention of this meeting was to provide a dedicated forum for civil society to engage with CMP representatives, and to identify areas where CSOs collective voices could be brought into the program. Discussions from the meeting covered priority areas for future engagement, including implementation of S-5 and the planned development of an implementation framework for the right to a healthy environment.

7. Report on research

Scientists from ECCC and HC conduct a wide range of research to inform the assessment and management of risks associated with various substances to human health or the environment. Frequently, scientists from other agencies and universities across Canada and the world collaborate with this research.

This section provides highlights of the research published in 2022-2023. The digital object identifier (DOI) or the International Book Standard Number (ISBN) has been provided for each research publication. To obtain online access to a particular publication, copy and paste the DOI (for example, DOI:17.1019/acs.est.1q03279) or ISBN into the search bar of your search engine. A comprehensive list of all research published in 2021-2022 has been included in the Annex.

7.1 Chemical substances and living organisms

Research on substances is designed to primarily:

- fill data gaps in risk assessment and risk management
- develop novel methods and approaches to improve priority setting, support risk assessment and work towards the goal of reducing animal testing
- evaluate the fate and the impact of toxic substances, and other substances of concern on the environment and human health
- develop non-target analysis (NTA) screening methods to assess complex chemical signatures and reveal possible unknown contaminants, in supporting risk assessment to better understand the complete exposure and potential effects on wildlife and human health
- determine the extent of ecological and human health exposure to contaminants and real-world chemical mixtures
- investigate the toxicity of chemicals, including effects on endocrine systems
- investigate complex environmental mixtures
- investigate the health effects of chemicals on human health

HC and ECCC also undertake research to support the development of regulations and guidelines, with the goal of improving human health by reducing population exposure to pollutants.

During 2022-2023, research on chemicals was carried out by both departments under a number of programs, including the Chemicals Management Plan (CMP), the Northern Contaminants Program (NCP), the Strategic Technology Applications of Genomics in the Environment (STAGE) Program, Genome Canada and the Great Lakes Protection Initiative.

7.1.1 Environment and Climate Change Canada research

ECCC conducted research activities under the CMP as part of 19 projects. These projects were either new projects or a continuation of existing projects delayed by the pandemic and related suspension of laboratory and fieldwork. Some of the latter work was able to progress for those research projects conducted in partnership with universities that experienced short shutdown periods. Investigations related to the identification of complex mixtures in the environment are underway (e.g., municipal effluent studies included the characterization of toxic discharges related to industrial applications). Field and laboratory assessments of priority chemical substances including perfluoroalkyl substances, alkylbenzene sulfonates and lead in crustaceans, fish, mussels, and frogs were also initiated. Significant progress was made for all research projects in terms of data analysis and publication of manuscripts.

A selection of the papers related to chemicals in the environment published by ECCC scientists in 2022-2023 are referenced below.

7.1.1.1 Chemicals in the environment

- **A review of polymeric per/polyfluoroalkyl substances (PFAS) in the environment**

  Focus of research: The focus of this review study was on the present state of the science and knowledge on polymeric per- and polyfluoroalkyl substances (PFAS) in the environment. PFAS are within the CEPA mandate and identified in the CEPA renewal Bill S-5, 2023, and falling under and contributing to the Controlling of Toxic Substances through A. the Chemicals Management Plan and B. Assessment of Substances.

  Results: PFAS is a diverse group of thousands of known chemicals falling under non-polymeric and polymeric categories. Polymeric PFAS are comprised of fluoropolymers, perfluoropolyethers, and side-chain fluorinated polymers (SCFPs). Fluorinated polymers have gained a significant market due to their chemical stability. To date, research and regulatory concern has primarily focused on the environmental occurrence and health effects of non-polymeric PFAS, particularly perfluoroalkyl acids and precursors. Industries consider many polymeric PFAS as being "polymers of low concern," although there is already a considerable environmental burden and widespread contamination resulting from their production and use. For example, SCFPs are widely used, and known to release their perfluorinated side chains. Concerted action is needed to address the dearth of environment-associated information and understanding on polymeric PFAS. This was an invited review by the journal *Current Opinions in Green and Sustainable Chemistry*, published February 27, 2023, and is a collaboration between Robert Letcher (ECCC) and Rainer Lohmann at the University of Rhode Island, U.S.A.

  Publication: Lohmann, R., Letcher, R.J. 2023. *The universe of fluorinated polymers and polymeric substances and potential environmental impacts and concerns*. Current Opinion in Green and Sustainable Chemistry, Vol. 41, Article #100795, DOI: /10.1016/j.cogsc.2023.100795

7.1.1.2 Chemical substances in the water

- **Distribution and fate of UV absorbents and industrial antioxidants in the St. Lawrence River, Quebec, Canada**

  Focus of Research: Benzotriazole ultraviolet absorbents and industrial antioxidants are contaminants of emerging concern and are additives in many commodities including cosmetics, food packaging, automotive lubricants, and rubber. The focus of this research was to investigate the distribution and partitioning of ultraviolet absorbents and industrial antioxidants in surface water, sediment, and various tissues of two fish species. The study site was in the St. Lawrence River near Montreal, Quebec, Canada.

  Results: Results indicated higher concentrations in water downstream of Montreal compared to the upstream site, suggesting that urban activities may be a driver of higher emissions. In fish, there were higher concentrations in Lake Sturgeon compared to Northern Pike, due to greater exposure via sediment-feeding behaviour. The bioaccumulation factors based on fish and water measurements were comparable or lower than modeled values, which indicates the physical properties of the chemicals are not a sole predictor of accumulation potential and other factors, such as biotransformation, are relevant. *This study was conducted in collaboration with Environment and Climate Change Canada and Université du Québec à Rimouski.*

  Publication: Castilloux, A.D., Houde, M., Gendron, A., De Silva, A., Soubaneh, Y.D., Lu, Z. 2022. *Distribution and Fate of Ultraviolet Absorbents and Industrial Antioxidants in the St. Lawrence River, Quebec, Canada*. Environmental Science & Technology Vol. 56, Issue 8, pp 5009-5019, DOI: 10.1021/acs.est.1c07932

- **Lanthanides release and partitioning in municipal wastewater effluents**

  Focus of Research: Lanthanides are rare earth elements and are used in a variety of industrial applications including electronics, aerospace, automotive and defense sectors. Releases to the environment are important due to the growing consumption of electronic equipment and e-waste. The focus of this research was to evaluate the concentrations of lanthanides in wastewater influent and effluent and wastewater removal efficiency.

Results: In this study, total rare earth elements ranged from 900 to 7 000 ng per L in influent and 160 to 330 ng per L in effluent. The most abundant rare earth element in effluent was gadolinium (Gd), representing 80% of the total rare earth elements concentration. Compared to ambient surface water, wastewater effluent was enriched in heavy rare earth elements (Europium to Lutetium). The removal of rare earth elements from wastewater treatments were evaluated by comparing effluent concentrations to influent. Removal rates were greater than 75% for the majority of the rare earth elements, but only up to 50% removal of Gd. These results suggest that Gd, primarily used in medical imaging, persists as a soluble complex in wastewater.

Publication: Turcotte, P., Smyth, S.A., Gagné, F., Gagnon, C. 2022. *Lanthanides Release and Partitioning in Municipal Wastewater Effluents.* Toxics Vol. 10, Issue 5, pp 254-267, DOI: 10.3390/toxics10050254

- **Organic chemicals and metals in recycled plastic materials**

Focus of Research: Plastic manufactured items that are disposed of outside of a waste management system constitute plastic pollution. Potential ecological risks of plastic manufactured items can be informed by their chemical content. The focus of this research was to evaluate the concentration of and identify chemical identity in recycled plastic raw materials. Pelleted and flaked recycled plastics were subsampled and subjected to a general solvent-based extraction. Plastic pellets and flakes were acquired from Canadian recycling companies and analyzed.

Results: Over 220 organic chemicals were identified in the sample of recycled plastic at low concentrations. Various chemical classes including halogenated flame retardants, organophosphate flame retardants, perfluoroalkyl acids, ultraviolet filter chemicals, paint and coating additives, antimicrobials, etc. were identified. Many of the substances are classified under Schedule 1 of CEPA, however, their ecological risk will be dependent on the leaching of the substances from finished recycled plastic goods.

Publication: Chibwe, L., De Silva, A.O., Spencer, C., Teixera, C.F., Williamson, M., Wang, X., Muir, D.C.G. 2023. *Target and nontarget screening of organic chemicals and metals in recycled plastic materials.* Environmental Science & Technology Vol. 57, Issue 8, pp 3380-3390, DOI: 10.1021/acs.est.2c07254

7.1.1.3 Chemicals and effects in wildlife, fish and associated food webs and ecosystems

- **Changes over time and the influence of climate on persistent organic pollutants in Arctic and Antarctic biota**

Focus of research: This study was part of an assessment of the Arctic Council's Arctic Monitoring and Assessment Program (AMAP) and reviewing links between climate and/or biological variables and the time trends of persistent organic pollutants (POPs) in Arctic and Antarctic biota. This review is published in a Special Issue of the journal *Environmental Science, Processes and Impacts.* This research falls under CEPA mandates as legacy and emerging POPs of Arctic concern are identified in the CEPA renewal Bill S-5, 2023, and priorities of the ECCC-CMP and the Northern Contaminants Program (NCP) and contributes to Pollution Prevention Plans and Controlling of Toxic Substances through B. Assessment of Substances.

Results: This review summarizes the potential links between changes in climate-related physical and biological variables and time trends of priority and mainly legacy POPs based on available information in the literature. Several correlative relationships were identified between POP temporal trends in freshwater and marine biota and physical climate parameters such as oscillation indices, sea-ice coverage, temperature and precipitation. Biological data indicate changes in the diet and trophic level of some species, especially seabirds and polar bears, with consequences for their POP exposure. Studies from the Antarctic highlight increased POP availability after iceberg calving. Physical and/or biological parameters in the POP time trend analysis led to small deviations in some declining trends. This review was published September 4, 2022, and is a collaboration of several ECCC research scientists (Magali Houde, Derek Muir, Robert Letcher) as well as other polar researchers from other countries and institutions (Denmark, Norway, Sweden, U.S.A and Italy).

Publication: Vorkamp, K., Carlsson, P., Corsolini, S., de Wit, C., Dietz, R., Gribble, M.O., Houde, M., Kalia, V., Letcher, R.J., Morris, A.D., Rigét, F.F., Routti, H., Muir, D.C.G. 2022. *Influences of climate change on long-term time series of persistent organic pollutants (POPs) in Arctic and Antarctic biota* Special Issue-Environmental Science, Processes and Impacts, Vol. 24, Article #1643. DOI: /10.1039/d2em00134a

- **Testosterone in relation to persistent organic pollutants in polar bears**

  Focus of research: Legacy persistent organic pollutants (POPs) are chemicals that undergo long-range transport to the Arctic. POPs possess endocrine disruptive properties raising concerns for development and reproduction. This study focuses on the relationship between POPs and testosterone in polar bears. This research falls under CEPA mandates as legacy POPs of Arctic concern are identified in the CEPA renewal Bill S-5, 2023, and priorities of the Northern Contaminants Program (NCP) and contributes to Pollution Prevention Plans.

  Results: In this research the relationships between concentrations of testosterone (T) and measured POPs were examined in forty East Greenland male polar bears sampled during January to September 1999–2001. The ΣPOP concentrations in adipose tissue showed that the Σpolychlorinated biphenyls (ΣPCBs) were found in highest concentrations. The variation in T concentrations explained by sampling date (season), biometrics and adipose tissue POP concentrations. The results showed that age, body length, and adipose lipid content in adult males contributed to the variation in POP concentrations. However, although some significant relationships between individual organochlorine contaminants and T concentrations in both juveniles/subadults and adult polar bears were identified, no significant relationships between T and POP concentrations were identified. Our results suggest that confounders such as biometrics and reproductive status may mask the endocrine disruptive effects that POPs have on blood T levels in male polar bears, demonstrating why it can be difficult to detect effects on wildlife populations. This review was published January 26, 2023 and is a collaboration between Robert Letcher (ECCC) and several Arctic researchers (e.g. Rune Dietz, Christian Sonne, Tomasz Ciesielski and Bjorn Jenssen) from Denmark, Norway and Greenland.

  Publication: Ciesielski, T.M., Sonne, C., Smette, E.I., Villanger, G.D., Styrishave, B., Letcher, R.J., Hitchcock, D.J., Dietz, R., Jenssen, B.M. 2023. *Testosterone and persistent organic pollutants in East Greenland male polar bears (Ursus maritimus).* Helyion, Vol. 9, Article #e13263. DOI: 10.1016/j.heliyon.2023.e13263

- **Priority perfluroalkyl acids (PFAAs) and the role of diet in an omnivorous bird from the Great Lakes, the herring gull**

  Focus of research: The focus of this research study was on bioaccumulative perfluoroalkyl acids (PFAAs) and the role of diet in individual herring gull eggs from one site on Lake Superior, Ontario, Canada. To understand these differences, stable carbon and nitrogen isotopes and fatty acid dietary tracers were measured in the same eggs. PFAS are within the CEPA mandate and identified in the CEPA renewal Bill S-5, 2023, and falling under and contributing to the Controlling of Toxic Substances through A. the Chemicals Management Plan and B. Assessment of Substances.

  Results: Herring gulls are generalist feeders; contaminant levels in their eggs reflect chemical exposure and uptake due to foraging in both aquatic and terrestrial environments. Hence, contaminant levels in their eggs provide insights into sources and relative importance of aquatic versus terrestrial pathways of chemical transfer. Here, bioaccumulative PFAAs were measured in individual herring gull eggs from sites in Lake Superior, Ontario. Thirteen perfluorinated carboxylates (PFCA, C4-C18) and four perfluorinated sulfonates (PFSA, C4-C10) were measured. Total PFCA and total PFSA concentrations varied 4- and 5-fold, respectively, among eggs. Stable isotopes were not useful in explaining inter-egg differences in PFAA concentrations. Omega 3 fatty acids were positively correlated with egg PFAA concentrations while only the Omega 6 fatty acids exhibited negative relationships. Results indicated that increased use of aquatic food led to heightened PFAA exposure in these generalist consumers sampled in a relatively remote area. They also highlight the utility of employing a variety of dietary markers for understanding contaminant exposure and accumulation. This research paper was published September 6, 2022 and is a collaboration of ECCC research scientists (Craig Hebert, Robert Letcher) and the Parks Canada Agency (Christine Drake).

Publication: Hebert, C.E., Letcher, R.J., Cyr, F., Drake, C. 2022. *Fatty acid ecological tracers highlight the role of diet in perfluoroalkyl acid contaminant exposure in eggs of an omnivorous bird*. Journal of Great Lakes Research, Vol. 48, pp 1270-1277. DOI: /10.1016/j.jglr.2022.08.010

- **Effects of neonicotinoid insecticides on amphibians**

  Focus of research: This study assessed the cumulative effects of the neonicotinoid insecticide, imidacloprid, and a natural stressor, population density, on wood frog (Rana sylvatica) behaviour. Specifically, three developmental stages were assessed for behavioural responses in the presence and absence of predation cues. Such work contributes to understanding the combined effects of anthropogenic contaminants (i.e., pesticides) and natural environmental stressors on amphibians to protect Canadian wildlife.

  Results: Wood frog behavioural responses to predation cues was unaffected by exposure to imidacloprid. However, distance travelled differed between low- and high-density treatments with the total distance travelled dependent on developmental stage. No interactive effects between imidacloprid and density were found. This work contributes to understanding the global concern for neonicotinoid insecticides on non-target aquatic vertebrates and will inform regulations for this pesticide product. This study was conducted in collaboration with Bishop's University and the University of Ottawa.

  Publication: Bouffard, J., Careau, V., Robinson, S.A., Bergeron, P. 2022. *Effects of a neonicotinoid insecticide and population density on behavior and development of wood frogs (Rana sylvatica)*. Environmental Toxicology and Chemistry, Vol. 41, Issue 12, pp. 2968-2980, DOI:10.1002/etc.5477

- **Characterizing exposure, accumulation, and potential toxicity of priority pefluoroalkyl substances, particularly long-chain perfluoro-carboxylates, to wild birds across Canada**

  Focus of Research: The domestic and international regulation of some perfluoroalkyl chemicals (e.g., PFOS), results in the introduction and use of replacement perfluoroalkyl substances. Certain replacement perfluoroalkyl acids have been subject to, or are currently undergoing risk assessment and risk management in Canada and internationally. This ECCC research, funded by the federal Chemicals Management Plan, directly supports CEPA's mandate to protect the people in Canada and the environment from harmful chemicals. The main goal of this research is to determine if wild birds in Canada are exposed to, accumulate, and/or experience any toxicity of long-chain perfluoroalkyl acids or their replacements, and if these chemical pollutants accumulate and magnify through different sections of their food webs.

  Results: This ECCC research, in collaboration with McGill University, identified that tree swallows nesting in southern Ontario were exposed to and accumulated long-chain perfluoro-carboxylic and -sulfonic chemicals. These chemical pollutants were ingested by adult females and transferred to their eggs, exposing young birds throughout their embryonic and nestling development. Tree swallows accumulated higher levels of some long-chain perfluorocarboxylic pollutants when they nested near the outfall of a large urban wastewater treatment plant. This finding suggests that effluent from such treatment plants can be an environmental source of major perfluorinated pollutants for birds. This ECCC project contributes to the risk assessment and risk management of PFAS, as environmental chemical pollutants, in Canada and internationally. Canada has nominated long-chain PFCAs to the UNEP Stockholm Convention on Persistent Organic Pollutants. Further assessments of the bioaccumulation and toxicity of these environmental pollutants to wild tree swallows, peregrine falcons, and Cooper's hawks, in Canada is ongoing through this project.

  Publications: Hopkins, K., McKinney, M.A., Letcher, R.J., Fernie, K.J. 2023. *The influence of environmental and ecological factors on the accumulation and distribution of short- and long-chain perfluoroalkyl acids in a mid-trophic avian insectivore*. Environmental Pollution, Vol, 321, 121133, DOI:10.1016/j.envpol.2023.121133

  Hopkins, K., McKinney, M.A., Letcher, R.J., Fernie, K.J. 2023. *The influence of environmental and ecological factors on the accumulation and distribution of short- and long-chain perfluoroalkyl acids in a mid-trophic avian insectivore*. Environmental Pollution, Vol, 321, 121133, DOI:10.1016/j.envpol.2023.121133

Goodchild, C.G., Karouna-Renier, N.K., Braham, R.P., Henry, P.F.P., Letcher, R.J. Fernie, K.J. 2022. *Hepatic gene expression profiling of American kestrels (Falco sparverius) exposed in ovo to three alternative brominated flame retardants (BTBPE, EHTBB, and TBPH).* Biology, Vol, 11, 1341, DOI:10.3390/biology11091341

- **Utilizing new approach methodologies (NAMs; e.g. toxicogenomics) and alternative testing strategies (e.g. early-life stage, non-animal) in supporting risk assessment of priority chemicals**

  Focus of Research: There is increasing pressure and interest from regulatory communities worldwide to develop and use new approach methodologies (NAMs) that reduce the use of animals for toxicity testing and are more efficient in order to determine the effects of an increasing number of priority chemicals. Many NAMs are still in the early stages of development so a key focus of research involves the harmonization of approaches and sharing data from case studies to come up with key guiding principles. Comparing traditional toxicity testing approaches, which use animals and are time/resource intensive, to short-term, animal-free NAMs will help determine whether data generated by the newer methods yield similar, trusted results as traditional approaches.

  Results: A combination of *in vitro*/early-life stage exposures and genomics (transcriptomics) evaluation helped in screening/prioritization of priority chemicals and determining benchmark doses/points of departure that were protective of traditionally derived effective concentrations.

  Publications: Johnson, K.J., Auerbach, S.S., Stevens, T., Barton-Maclaren, T.S., Costa, E., Currie, R.A., Dalmas Wilk, D., Haq, S., Rager, J.E., Reardon, A.J.F., Wehmas, L., Williams, A., O'Brien, J., Yauk, C., LaRocca, J.L., Pettit, S. 2022. *A transformative vision for an omics-based regulatory chemical testing paradigm.* Toxicological Sciences. Vol. 190, Issue 2, pp 127-132, DOI: 10.1093/toxsci/kfac097

  Sharin, T., Crump, D., O'Brien, J.M. 2022. *Toxicity screening of bisphenol A replacement compounds: cytotoxicity and mRNA expression in LMH 3D spheroids*. Environmental Science and Pollution Research International. Vol. 29, Issue 29, pp 44769-44778, DOI: 10.1007/s11356-022-18812-z

  Ewald, J.D., Basu, N., Crump, D., Boulanger, E., Head, J. 2022. *Characterizing variability and uncertainty associated with transcriptomic dose-response modeling.* Environmental Science and Technology. Vol. 56, Issue 22, pp 15960-15968, DOI: 10.1021/acs.est.2c04665

  Jeon, Y.S., Crump, D., Boulanger, E., Soufan, O., Park, B., Basu, N., Hecker, M., Xia, J., Head, J. 2022. *Hepatic transcriptomic responses to ethinylestradiol in two life stages of japanese quail*. Environmental Toxicology and Chemistry. Vol. 41, Issue 11, pp 2769-2781, DOI: 10.1002/etc.5464

  van der Vegt, R., Maguire, S., Crump, D., Hecker, M., Basu, N., Hickey, G. 2022. *Chemical Risk Governance: Exploring Stakeholder Participation in Canada, the USA, and the EU*. Ambio. Vol 51, Issue 7, pp 1698-1710, DOI: 10.1007/s13280-021-01671-2

- **Assessment of the toxicity of lanthanide mixtures found in aquatic ecosystems in *Hydra attenuata***

  Focus of Research: Lanthanides are rare earth elements and are used in a variety of industrial applications including electronics, aerospace, automotive and defense sectors. Previous research measured lanthanides in water in lakes near mining activities in northern Quebec. The focus of this research was to evaluate the toxicity of lanthanide mixtures at environmentally relevant concentrations using both acute (96 hours) and chronic (seven day) scenarios with the freshwater invertebrate hydrozoan species, *Hydra attenuata*. Endpoints included lethality, morphological (body structure) changes, reproduction, and head regeneration.

  Results: Overall, the mixture of rare earth elements was found to be less toxic than the sum of the toxicity for each individual element in this study. Results indicated changes in *Hydra* morphology were the most sensitive indicator of sub-lethal toxicity to lanthanide mixtures with decreased morphology index seen in both acute and chronic exposure scenarios. The diminished morphology was also found to decrease reproduction with the highest dose completely inhibiting reproduction after a short 24-hour exposure. Acute lethality of the mixture occurred at concentrations nearly 2.5 times higher than those inducing sublethal effects after a chronic exposure

of seven days. Of the elements tested in the mixture, those of lower molecular weight and higher atomic radius were found to be less toxic.

Publication: Hanana, H., Gagné, F., Trottier, S., Bouchard, P., Farley, G., Auclair, J., Gagnon, C. 2022. *Assessment of the toxicity of a mixture of five rare earth elements found in aquatic ecosystems in Hydra vulgaris*. Ecotoxicology and Environmental Safety, Vol. 241, DOI: 10.1016/j.ecoenv.2022.113793

- **Bioaccumulation and trophic magnification of emerging and legacy per- and polyfluoroalkyl substances (PFAS) in a St. Lawrence River food web**

  Focus of Research: Research on per- and polyfluoroalkyl substances (PFAS), a CEPA priority substance, in freshwater ecosystems has focused primarily on legacy compounds and little is still known on the presence of emerging PFAS. The occurrence of 60 anionic, zwitterionic, and cationic PFAS in a food web of the St. Lawrence River (Quebec, Canada) near a major metropolitan area were investigated. Water, sediments, aquatic vegetation, invertebrates, and 14 fish species were targeted for analysis.

  Results: Levels of perfluorobutanoic acid (a type of PFAS) in river water exceeded those of two legacy PFAS: perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Further, an emerging zwitterionic PFAS (6:2 FTAB), was observed for the first time in the St. Lawrence River. The highest mean PFAS concentrations were observed for the benthopelagic top predator Smallmouth bass (*Micropterus dolomieu*) and the lowest for aquatic plants. Up to 33 PFAS were detected in biotic samples, with frequent occurrences of emerging PFAS such as perfluorobutane sulfonamide (FBSA) and perfluoroethyl cyclohexane sulfonate (PFECHS). Certain PFAS were found to have highest concentrations in top predator fish in the food webs. Some novel PFAS such as zwitterionic substances were frequently detected in invertebrates (molluscs, gammarids, and insects) but not in fish, suggesting that fish have a higher clearance rate and potential for metabolism of these emerging PFAS in aquatic organisms. This study was conducted in collaboration with ECCC and Université de Montréal.

  Publication: Munoz, G., Mercier, L., Duy, S.V., Liu, J., Sauvé, S., Houde, M. 2022. *Bioaccumulation and trophic magnification of emerging and legacy per- and polyfluoroalkyl substances (PFAS) in a St. Lawrence River food web*. Environmental Pollution, Vol. 309, DOI: 10.1016/j.envpol.2022.119739

- **Metformin effects in fathead minnow**

  Focus of Research: Metformin is a prescribed drug for treating type 2-diabetes. Metformin is only partially degraded in sewage treatment plants and is released to aquatic ecosystems including rivers and lakes. The focus of this research was to evaluate the effect of metformin at environmentally relevant doses to fathead minnow, a widely distributed small-bodied fish species, using laboratory- and wild-spawned fish embryos to inform ecological risk screening.

  Results: The wild fathead minnow embryos were tested in outdoor limnocorral mesocosms while the lab-reared minnow embryos were dosed in indoor tanks with a similar light cycle and temperature profile as the outdoor mesocosm study. The fitness of wild-spawned fish larvae was impacted to a greater extent than the lab-spawned fish. In both lab and outdoor scenarios, metformin was bioavailable to fish and impacted fish development. The specific observed effects included disruption to energy regulation and visual acuity. In a second study, fathead minnow eggs and larvae were subjected to a water-borne dose of metformin over 21 days. Egg-hatching, larval survival and growth were not affected by metformin. The gut microbiome was also evaluated as it is important for homeostasis, nutrient acquisition, and disease prevention. Exposure to metformin resulted in increases in Proteobacteria in the gut microbiome of fathead minnow larvae, however, the implication of these results is not known. Proteobacteria have been linked to altered health outcomes in mammals, however it is unknown whether a similar association is present in fish. These findings represent highly representative toxicity data needed to inform regulatory decisions. This study was conducted in collaboration with ECCC and the International Institute for Sustainable Development-Experimental Lakes Area (IISD-ELA).

Publications: Nielsen, K.M., DeCamp, L., Birgisson, M., Palace, V.P., Kidd, K.A., Parrott, J.L., McMaster, M.E., Alaee, M., Blandford, N., Ussery, E.J. 2022. *Comparative effects of embryonic Metformin exposure on wild and laboratory-spawned Fathead Minnow (Pimephales promelas) populations*. Environmental Science and Technology, Vol. 56, Issue 14, pp 10193-10203, DOI: 10.1021/acs.est.2c01079

Parrott, J.L, Restivo, V.E., Kidd, K.A., Zhu, J., Shires, K., Clarence, S., Khan, H., Sullivan, C., Pacepavicius, G., Alaee, M. 2022. *Chronic Embryo-Larval Exposure of Fathead Minnows to the Pharmaceutical Drug Metformin: Survival, Growth, and Microbiome Responses*. Environmental Toxicology Vol. 41, Issue 3, pp 635-647, DOI: 10.1002/etc.5054

- **Toxicity and application of new approach methodologies (NAM) for measurement of effects from exposure to organic and inorganic complexes of rare earth elements in soil**

  Focus of research: Rare Earth Elements (REE) are naturally present in soil and used increasingly in green technologies. As a result, mining and processing have also increased, elevating the potential risk to surrounding soil environments. This study captures the effects of REE on different ecological niches occupied by soil invertebrates, as well as impacts to soil microbial activities that influence nutrient cycling. The research explores the impact of neodymium (Nd) (e.g., as an inorganic salt), and a Nd-organometallic (Nd-2-ethylhexanoate, along with it's organic moiety, 2-ethylhexanoate), to examine the influence of metal moiety on toxicity, and whether toxicity changes over time following 6 months of incubation. The study also explores toxicogenomic responses, and whether these responses can help explain the observed toxicity from traditional biological test methods. Assessing REE as organic and inorganic complexes will support the read-across of these materials for risk assessment, with genomics contributing to the development and application of new approach methodologies.

  Results: As Rare Earth Elements are increasingly used, the impact to the soil environment in areas close to mining or disposal will need to be assessed. In investigating the fate and toxicity of these substances, two different soil types were considered: an upper organic horizon, and a lower mineral horizon, both collected from a boreal forest from where REEs are most likely to be present. Results demonstrate that metal availability and toxicity differ between soil types, with less availability and toxicity in the organic-rich soil relative to the mineral soil; these differences are important in terms of fate, as although initially less bioavailable, organisms will continue to break down organic litter in the upper horizons, thus remobilizing metals through the soil profile, down to the mineral horizon. Effects were also species and function dependent, with earthworms being more affected by the REE than springtails and soil mites; in some cases, microbial activity was also significantly less over time. When comparing between the organic and inorganic complexes, the organometal was more toxic to the soil invertebrates and microbial processes, than the metal alone, suggesting that the organic moiety induced higher toxicity than the metal moiety within the complex. Similarly, with aging of the organometal in soil, toxicity reduced across species, likely due to the degradation of the organic component with time, as the metal remained relatively stable. As research progresses, effects on gene expression will be evaluated on springtails, as to date, this is generally the most genomically well-characterized soil species. The results from this study contribute toxicity data for risk assessment, as well as the read-across framework for REEs in soil. With the inclusion of new approach methodologies and gene expression exploration, the work will contribute new methods and pathways for future consideration in risk assessment.

  Publication: Biological Assessment and Standardization Section. 2023. *Toxicity and Application of New Approach Methodologies (NAM) for Measurement of Effects from Exposure to Organic and Inorganic Complexes of Rare Earth Elements in Soil*. Technical research report. Environment and Climate Change Canada, Ottawa, Ontario

7.1.1.4 Multiple approaches including non-target analysis (NTA) to understand chemical biotransformation and protein adduction in biota

- **Multiple lines of *in vitro* and *in silico* approaches to understand organophosphate ester (OPE) biotransformation/metabolism in birds and rats**

  Focus of research: This study characterized *in vitro* biotransformation of the novel organophosphate ester (OPE) using *in vitro* rat and bird microsomal assays. *In silico* modelling was used to estimate BPADP metabolites. Additional non-target metabolites were determined by high resolution NTA. OPEs are within the CEPA mandate and identified in the CEPA renewal Bill S-5, 2023, and falling under and contributing to the Controlling of Toxic Substances through A. the Chemicals Management Plan and B. Assessment of Substances.

  Results: Increased production and usage of OPEs as flame retardants and plasticizers has trended towards larger and 'novel' OPEs but there is a dearth of understanding of the environmental fate, stability, toxicokinetics, biotransformation and bioaccumulation in exposed biota. The present study characterized *in vitro* biotransformation of the novel OPE bisphenol-A bis(diphenyl phosphate) (BPADP) using Wistar-Han rat and herring gull liver based microsomal assays. BPADP was metabolized *in vitro* to bisphenol-A (BPA) and diphenyl phosphate (DPHP) and other metabolites. *In silico* modelling predicted both BPA and DPHP as rat metabolites of BPADP. Additional non-target metabolites were determined by high resolution mass spectrometry. Mean BPADP depletion and BPA and DPHP formation were faster for rats compared to birds. Additional NTA metabolites identified other metabolites and demonstrated agreement between lines of *in vitro* and *in silico* evidence. These findings add to the understanding of BPADP stability and biotransformation, and perhaps of other novel OPEs, which are factors highly applicable to hazard assessments of exposure, persistence and bioaccumulation in biota. This research paper was published October 10, 2022 and is a collaboration of ECCC research scientist Robert Letcher, ECCC employee Shaogang Chu and Carleton University graduate student (Sofia Herczegh).

  Publication: Herczegh, S.M., Chu, S.G., Letcher, R.J. 2023. *Biotransformation and metabolites of bisphenol-A bis(diphenyl phosphate): in vitro, in silico, and non-target screening in rat and bird liver microsomal models.* Chemosphere, Vol. 310, Article #136796**,** DOI: 10.1016/j.chemosphere.2022.136796

- **Bottoms-up proteomics and NTA of adducts of histones incubated *in vitro* with the herbicide atrazine**

  Focus of research: The present research used a bottom-up proteomics approach that optimized sample preparation methodology and incorporated NTA using high resolution mass spectrometry. This approach was applied to identify protein adduction *in vitro* with a model compound, the broad spectrum herbicide, atrazine. Pesticides including atrazine are within the CEPA mandate and identified in the CEPA renewal Bill S-5, 2023, and falling under and contributing to the Controlling of Toxic Substances through A. the Chemicals Management Plan and B. Assessment of Substances.

  Results: Histones are the major protein components of chromatin in eukaryotic cells and an important part of the epigenome. Histones affect most DNA-related events, including transcription, replication, and chromosome segregation, and play a key role in controlling DNA expression. Recent evidence has shown that alteration of histones by chemical contaminants might conceivably disturb their normal function. In the present study, whole histones of calf thymus or human histone H3.3 were incubated with atrazine *in vitro*. After solvent-based protein precipitation, the protein was digested to peptides and NTA with high-resolution mass spectrometry. The results showed that calf thymus histone H3.1 and human histone H3.3 proteins were adducted with atrazine. It was confirmed also that the adduction position was at its cysteine 110 residue. Time- and concentration-dependent assays also confirmed the non-enzymatic modification of histone H3.3 by atrazine *in vitro*. The potential exists that atrazine and its metabolites can undergo adduction with histone proteins which may lead to the alteration of histones that subsequently disturbs their normal function in DNA. This research paper was published January 20, 2023 and is a collaboration of ECCC research scientist Robert Letcher and ECCC employee Shaogang Chu.

  Publication: Letcher, R.J., Chu, S.G. 2023. *Bottom-up proteomics analysis for adduction of the broad spectrum herbicide atrazine to histone.* Analytical and Bioanalytical Chemistry, Vol. 415, pp. 1497–1504. DOI: 10.1007/s00216-023-04545-6

7.1.1.5 Nanomaterials

- **Influence of size, coating and aging, on the fate and effects of metal oxide nanomaterials in soils**

  Focus of research: Soils are critical to environmental processes and provide services that support agricultural production, resources for other species, and water filtration. However, soils are also exposed to chemical pollution, including nanomaterials that enter through different pathways. The study evaluated the fate, bioaccumulation, and toxicity of metal oxide nanomaterials (e.g., cerium and copper) to the soil environment, including impacts to soil invertebrate reproduction and microbial nutrient cycling. Different properties of nanomaterials can influence their fate and effect in soil, therefore, different coatings and sizes, as well as metal availability and uptake were investigated. Finally, the study evaluates the influence of different soil properties on the fate and effects of these nanomaterials in soil. Assessing different sizes, coatings and metal availability in different soil types will support the read-across and integration of soil systems within the risk assessment framework for nanomaterials.

  Results: Soils are important to include in the assessment of chemical pollution in the environment, which also include nanomaterials. Nanomaterials can enter soils through deposition from air, the application of sludges to agricultural fields as a nutrient amendment, or direct leaching from products that contain them (e.g., pressure treated wood). The evaluation of nanomaterials involves many measurements to look at total, bioavailable and nano-particulate metal to see how nanomaterials behave, change, are taken up or effect different soil processes (e.g., soil organism survival, reproduction, and microbial processes). The results to date suggest that metal oxide nanomaterials dissolve in soils over time, releasing metal ions, which then become available to plants, soil organisms and microorganisms for uptake. The rate of dissolution depends on the metal oxide of interest, the soil type and e.g., if sludges are present in the soil, but toxic effects seem to be predictable by the soluble metal ion in soil, except when nanomaterials are present in very small concentrations. In this case, the nano-particulates are likely more dispersed and can be taken up the organism, as seen through copper oxide exposures. For other metal oxides, e.g., cerium oxide, very few effects were observed, with toxicity also predictable by the soluble ion. As the study progresses, the influence of nanomaterial coating and size, including different soil properties will be investigated to see if these parameters can serve as a predictor of toxicity. The results from this study will fill data gaps for the risk assessment of metallic nanomaterials in soil and will support the development of prediction models for future use. Given the type of metal oxides evaluated, the data will also contribute to read-across frameworks for nanomaterials.

  Publication: Samarajeewa, A., Velicogna, J., Schwertfeger, D., Meier, M., Subasinghe, R., Princz, J., Scroggins, R., Beaudette, L. 2023. *Cerium oxide nanoparticles ($NCeO_2$) exert minimal adverse effects on microbial communities in soils with and without biosolids amendment*. Environmental Science and Pollution Research, Vol. 30, pp 72336-72353, DOI: 10.1007/j.espr.2023.s11356-023-27313-6

- **Toxicity of freshwater invertebrates to silver nanoparticles**

  Focus of Research: Nanomaterials are manufactured substances within the nanoscale. Currently nanosilver is used in textiles, laundry detergents, soaps, disinfectant sprays, bed sheets, and in water filtration. The focus of this research was to determine the toxicity of silver nanoparticles to aquatic invertebrates using *Hydra vulgaris*, an aquatic hydrozoan, and *Dreissena* mussels as test organisms. *Hydra vulgaris* were exposed under acute (24 hours) and chronic (96 hours) conditions and endpoints included lethality and morphology. Wild-caught mussels were transported to the lab and exposed to nanoparticle suspensions for 96 hours. Oxidative stress and neural activity were monitored as endpoints in mussels.

  Results: Mortality was observed in *Hydra* exposed to silver nanospheres but not to the cubic or prismatic shapes of silver nanoparticles. Sublethal shape-dependent toxic effects on morphology of *Hydra* were observed in which the nanosphere was most toxic followed by prisms but no sublethal effects were noted in the *Hydra* exposed to cubic silver nanoparticles. In mussel experiments, the condition factor of the organisms was significantly higher in the highest treatment concentration of cubic nanosilver whereas no effect on condition factor was observed for spherical, prismatic and ionic silver treatments. Oxidative stress in mussels exposed to spheric and cubic nanosilver

in intermediate concentration treatments was noted whereas no effect at the highest concentrations were observed. A decrease in neural activity of mussels was observed in most types of silver with the highest effect corresponding to prism, followed by cube and lastly spherical nanosilver. Transmission electron microscopy was used to determine properties of the different shapes including circularity, boxivity, elongation, aspect ratio, surface area, and surface-to-volume ratio. Aspect ratio was calculated by dividing length by thickness. Nanoprisms have the lowest aspect ratio, which may translate to greater cellular uptake. However, the leaching of silver ions from silver nanoparticles is also thought to be a mechanism of toxicity but further study is required to understand shape-specific leaching rates from silver nanoparticles. Taken together, these results indicate that all forms of silver are not equally toxic and that the geometry of silver nanoparticles is a relevant factor.

Publications: Auclair, J., Gagné, F. 2022. *Shape-Dependent Toxicity of Silver Nanoparticles on Freshwater Cnidarians.* Nanomaterials Vol. 12, Issue 18, pp 3107-3115, DOI: 10.3390/nano12183107

Auclair, J., Peyrot, C., Wilkinson, K.J., Gagné, F. 2022. *The Influence of Silver Nanoparticle Form on the Toxicity in Freshwater Mussels.* Applied Sciences Vol. 12*,* Issue 3, pp 1429-1443, DOI: 10.3390/app12031429

7.1.1.6 Chemical substances in the atmosphere

- **Atmospheric mercury in Ontario and the Canadian Arctic**

  Focus of Research: Evaluated the variability of atmospheric mercury (Hg) isotopes across Ontario and the Arctic and assessed the impact of global sources and sinks of Hg emissions, while highlighting the potential impact of climate change on mercury re-emission in the Arctic environment.

  Results: Ontario-wide variations in atmospheric gaseous elemental mercury (GEM) were measured, showing that both sources (urban/industrial emissions) and sinks (vegetation uptake) contribute to the spatial and temporal patterns of the residual atmospheric GEM pool. This study of GEM in Ontario demonstrates that boreal forests can play an important role in driving lower atmospheric GEM levels and changing the isotopic composition of GEM.

  The analysis from 10 circumpolar air monitoring stations, comprising of high-Arctic and sub-Arctic sites, indicated that atmospheric Hg concentrations have decreased across the Arctic over the last 20 years, though not uniformly., Mercury models suggest that changes in meteorology amplified the impact of global human generated emissions on Hg deposition in the Arctic leading to elevated modeled Arctic GEM levels in 2015 compared to 2010, contrary to observed declines at most monitoring sites. This suggests that the models overestimate the impact of rising Hg emissions and underestimate or omit the effect of some Hg removal processes, such as uptake by vegetation.

  During Arctic springtime, atmospheric elemental mercury is deposited to the cryosphere (snow and ice). This is followed by a summertime atmospheric mercury peak that is believed to mostly come from re-emission from the Arctic Ocean. However, Hg isotope observations suggest that the summertime peak is caused by the re-emission of the Hg deposited to the cryosphere during spring, and not by emission of terrestrial Hg inputs to the Arctic Ocean via river run-off and coastal erosion. These findings imply that the potential release of Hg from melting permafrost caused by climate change may have less impact on the global atmosphere than previously thought; however, in this case the mercury would remain in the marine ecosystem, possibly affecting food webs.

  Publications: Szponar, N., Su, Y., Stupple, G., McLagan, D. S., Pilote, M., Munoz, A., et al. 2023. *Applying passive air sampling and isotopic characterization to assess spatial variability of gaseous elemental mercury across Ontario, Canada*. Journal of Geophysical Research: Atmospheres, 128, e2022JD037361, DOI: 10.1029/2022JD037361

  MacSween, K., Stupple, G., Aas, W., Kyllönen, K., Pfaffhuber, K.A., Skov, H., Steffen, A., Berg, T., Mastromonaco, M.N. (2022). Updated trends for atmospheric mercury in the Arctic: 1995–2018. Sci. Total Environ., 837, art. no. 155802. DOI: 10.1016/j.scitotenv.2022.155802.

Dastoor, A., Wilson, S.J., Travnikov, O., Ryjkov, A., Angot, H., Christensen, J.H., Steenhuisen, F., Muntean, M. 2022. *Arctic atmospheric mercury: Sources and changes.* Science of the Total Environment, 839, art. no. 156213. DOI: 10.1016/j.scitotenv.2022.156213

Araujo, B.F., Osterwalder, S., Szponar, N. et al. 2022. *Mercury isotope evidence for Arctic summertime re-emission of mercury from the cryosphere*. Nat Commun 13, 4956. DOI: 10.1038/s41467-022-32440-8

- **Organic flame retardants and other priority substances**

  Focus of Research: Investigation into the emissions and fates of organophosphate ester (OPE) flame retardants, and the assessment of emission trends of per- and polyfluoroalkyl substances (PFAS) and volatile methyl siloxane (VMS) priority substances.

  Results: Estimates of the atmospheric emissions and fate of OPEs from 19 major cities around the world suggest that OPE emissions appear to be driven more by diffuse processes (i.e., OPEs in products) rather than manufacturing processes and, depending on the built environment and climate of the city considered, the same compound can behave as a mobile or a bioaccumulative chemical. Specifically, sparse cities, with fewer depositional surfaces, and densely urbanized cities are observed to mobilize OPEs by air advection (transfer or transport) and water advection (transfer or transport), respectively. By contrast, densely vegetated cities are observed to promote OPE deposition and transformation. Moreover, in cities with a low-deposition climate (i.e., warmer, windier, and drier), advection via air dominates, whereas in cities with a high-deposition climate (i.e., cooler, wetter, and calmer), water advection and vegetation deposition dominate. This study highlights that processes governing OPE emissions and fate in urban areas have significant implications for human and ecosystem exposure. Therefore, the results suggest that urban design choices could support policies aimed at reducing chemical releases to the broader environment without increasing exposure for urban residents.

  Atmospheric concentrations and trends of PFAS and VMS measured at 41 passive sampling monitoring sites across the globe from 2009-2017. In general, VMS and neutral PFAS showed stable or declining levels, while several ionizable PFAS showed increasing trends. In particular, the increasing trends of perfluorooctanesulfonic acid (PFOS), which was the first PFAS listed as a Persistent Organic Pollutant (POP) under the Stockholm Convention on POPs in 2009, indicates their continuous emissions via direct or indirect sources. This data helps to establish a baseline against which future trends and regulation efforts can be evaluated, such as under the Effectiveness Evaluation process of the Stockholm Convention on POPs.

  Publications: Rodgers, T.F.M., Giang, A., Diamond, M.L. et al. 2023. *Emissions and fate of organophosphate esters in outdoor urban environments.* Nature Communications, Vol. 14, Issue 1, 1175, DOI: 10.1038/s41467-023-36455-7

  Saini, A., Chinnadurai, S., Schuster, J. K., Eng, A., & Harner, T. 2023. *Per- and polyfluoroalkyl substances and volatile methyl siloxanes in global air: Spatial and temporal trends.* Environmental Pollution, Vol. 323, 121291, DOI: 10.1016/j.envpol.2023.121291

- **Polycyclic aromatic hydrocarbons (PAHs) and polycyclic aromatic compounds (PACs)**

  Focus of Research: Alkylated polycyclic aromatic hydrocarbons (alkyl-PAHs), dibenzothiophenes (DBTs), and unsubstituted polycyclic aromatic hydrocarbons (PAHs) are naturally present in fossil fuels and may be good indicators of pollution from petroleum-based emissions, such as those from traffic

  Results: Analysis of alkyl-PAH, DBT, and PAH emissions on ambient air quality revealed that alkyl-PAHs represent the majority of the PACs in the air at all ambient air monitoring sites and were most elevated at the high-traffic impacted near-road site at Highway 401 in Toronto, which was also accompanied by the highest unsubstituted PAH concentrations. The research supports observations that urban sites are influenced by mixed sources of PACs, with alkyl-PAHs originating mostly from petroleum related (petrogenic) emissions such as traffic while unsubstituted PAHs, in addition to petrogenic sources, are also originating from industrial processes and activities. These findings will assist in estimating contributions of alkylated species to traffic and urban related

emissions and will lead to better understanding and quantifying the contribution of emissions from the transportation sector in Canada

Publication: Wnorowski A., Harnish D., Jiang Y., Celo V., Dabek-Zlotorzynska E., Charland J.-P. 2022. *Assessment and Characterization of Alkylated PAHs in Selected Sites across Canada*. Atmosphere. Vol. 13, Issue 8, 1320, DOI: 10.3390/atmos13081320

7.1.2 Health Canada research

HC funded CMP Research and Monitoring and Surveillance projects in 2022-2023. These projects addressed departmental and international priorities and covered a number of subjects such as:

- the development of new methods for detection of chemicals and assessment of toxicity
- the characterization of chemical exposures to people in Canada and their homes
- the characterization and toxicological response to nanomaterials , microplastics and products of biotechnology
- new approach methodologies
- carcinogenic and genetic toxicity assessment
- the effects of chemicals on human health
- hazard characterization

7.1.2.1 Chemical substances in Canadians

- **National Biomonitoring Program under the Canadian Health Measures Survey (CHMS)**

Focus of Research: The Canadian Health Measures Survey (CHMS) is a national survey led by Statistics Canada, in partnership with Health Canada and the Public Health Agency of Canada. The survey includes a biomonitoring component that measures environmental chemicals or their metabolites in blood, urine and/or hair samples. This component is funded and led by Health Canada's National Biomonitoring Program. Since 2007, the National Biomonitoring Program has established baseline concentrations for over 250 environmental chemicals in the Canadian population supporting the identification of risk assessment priorities, characterization of exposures in risk assessments, performance measurement of risk management actions, while also serving as the basis of numerous scientific research studies.

Results: In 2022-2023, biomonitoring data from the CHMS was published in three online dashboards. In each of these dashboards, the inclusion of CHMS data has a twofold outcome. Firstly it increases access to the CHMS data and, secondly, it facilitates comparison of CHMS data with other human biomonitoring data. The AEPHIN dashboard presents CHMS data from cycles 1 to 6 alongside a prairies dataset from the CHMS which includes averages of results from the combined biomonitoring dataset of CHMS cycles 1 to 5 for the provinces of Alberta, Saskatchewan, and Manitoba. The prairies dataset is representative of the population of the three provinces. The IPCHEM dashboard presents CHMS data from cycles 1 to 6. The integration of Canada's national human biomonitoring data onto the platform represents the first country outside of the EU to do so. This initiative provides policy and research communities the ability to readily compare CHMS data with other international/ European datasets. The HB2GV dashboard is a curated international database of human biomonitoring guidance values that includes a comparison feature where users can import results from the CHMS directly into a figure presenting the applicable guidance values.

Publications: AEPHIN (Alberta Environmental Public Health Information Network). 2022. *Human Biomonitoring of Environmental Chemicals in Canada and the Prairies*. Available: http://aephin.alberta.ca/human-biomonitoring/

European Commission. 2022. *IPCHEM – the Information Platform for Chemical Monitoring.* Available: https://ipchem.jrc.ec.europa.eu/

Nakayama, S.F., St-Amand, A., Pollock, T., Apel, P., Bamai, Y.A., Barr, D.B., Bessems, J., Calafat, A.M., Castaño, A., Covaci, A., Duca, R.C., Faure, S., Galea, K.S., Hays, S., Hopf, N.B., Ito, Y., Jeddi, M.Z., Kolossa-Gehring, M., Kumar, E., LaKind, J.S., López, M.E., Louro, H., Macey, K., Makris, K.C., Melnyk, L., Murawski, A., Naiman, J., Nassif, J., Noisel, N., Poddalgoda, D., Quirós-Alcalá, L., Rafiee, A., Rambaud, L., Silva, M.J., Ueyama, J., Verner, M.A., Waras, M.N., Werry, K. 2022. *Interpreting biomonitoring data: Introducing the international human biomonitoring (i-HBM) working group's health-based guidance value (HB2GV) dashboard*. International Journal of Hygiene and Environmental Health, Vol. 247, 114046, DOI: 10.1016/j.ijheh.2022.114046

Singh, K., Blechinger, S., Pelletier, L., Karthikeyan, S., St-Amand, A., Liberda, E.N., Chan, H.M. 2023. *Characterizing variability in total mercury hair:blood ratio in the general Canadian population*. Environmental Research, Vol. 224, 115491, DOI: 10.1016/j.envres.2023.115491

- **The Maternal-Infant Research on Environmental Chemicals (MIREC) Research Platform**

Focus of Research: The MIREC Research Platform is designed to obtain pan-Canadian data on maternal, fetal, and childhood exposure to priority environmental chemicals and potential adverse health effects on pregnancy, as well as newborn and infant/child growth and development. It encompasses the original MIREC Study of pregnant women and their infants and follow-up studies in the children(MIREC-Infant Development: MIREC-ID; MIREC-Child Development at ages 3-5: MIREC-CD3 and MIREC-CD Plus; MIREC – Pubertal Timing, Endocrine and Metabolic Function: MIREC-ENDO). The Platform also includes a repository of MIREC data and biospecimens, the MIREC Biobank, for additional research on the health of mothers and their children.

Results: In 2022-2023, 13 MIREC Research Platform papers were published, nine of which were co-authored by HC. These studies investigated prenatal and lactational exposure to multiple chemicals and nutrients including metals, PFAS, bisphenol A, herbicides, and vitamin D. HC's MIREC team led a publication which provides the first pan Canadian biomonitoring data in pregnant women for the herbicides Glyphosate and Glufosinate and their metabolites. Another Health Canada led publication looked at the complex interplay between nutrition and toxic metals exposure in relation to pre-term birth. The MIREC Research Platform continues to generate new knowledge on early life and cumulative exposure to environmental chemicals and potential health risks in populations with unique vulnerability or susceptibility to chemical exposures, including pregnant women, fetuses, infants, and children. The MIREC Research platform contributes to risk assessment and management of chemicals both in Canada and internationally.

Publications: Ashley-Martin, J., Fisher, M., Belanger, P., Cirtiu, C.M., Arbuckle, T.E. 2022. *Biomonitoring of inorganic arsenic species in pregnancy*. Journal of Exposure Science and Environmental Epidemiology, DOI: 10.1038/s41370-022-00457-2

Ashley-Martin, J., Huang, R., MacPherson, S., Brion, O., Owen, J., Gaudreau, E., Bienvenu, J.F., Fisher, M., Borghese, M.M., Bouchard, M.F., Lanphear, B., Foster, W.G., Arbuckle, T.E. 2022. *Urinary concentrations and determinants of glyphosate and glufosinate in pregnant Canadian participants in the MIREC study*. Environmental Research, Vol., 217, 114842, DOI: 10.1016/j.envres.2022.114842

Fisher, M., Marro, L., Arbuckle, T.E., Potter, B.K., Little, J., Weiler, H., Morisset, A.S., Lanphear, B., Oulhote, Y., Braun, J.M., Kumarathasan, P., Walker, M., Borghese, M.M., Ashley-Martin, J., Shutt, R., Fraser, W.D. 2023. *Association between toxic metals, vitamin D and preterm birth in the Maternal-Infant research on environmental chemicals study*. Paediatric and Perinatal Epidemiology, Vol. 37, Issue 5, pp 4447-457, DOI: 10.1111/ppe.12962

Krzeczkowski, J.E., Hall, M., McGuckin, T., Lanphear, B., Bertinato, J., Ayotte, P., Chevrier, J., Goodman, C., Green, R., Till, C. 2022. *Iodine status in a large Canadian pregnancy cohort*. American Journal of Obstetrics and Gynecology, Volume 5, Issue 1, 100784, DOI: 10.1016/j.ajogmf.2022.100784

Patti, M.A., Braun, J.M., Arbuckle, T.E., MacFarlane, A.J. 2022. *Associations between folic acid supplement use and folate status biomarkers in the first and third trimesters of pregnancy in the Maternal-Infant Research on*

Environmental Chemicals (MIREC) Pregnancy Cohort Study. The Americain Journal of Clinical Nutrition; Vol. 116, Issue 6, pp 1852-1863, DOI: 10.1093/ajcn/nqac235

Patti, M.A., Kelsey, K.T., MacFarlane, A.J., Papandonatos, G.D., Arbuckle, T.E., Ashley-Martin, J., Fisher, M., Fraser, W.D., Lanphear, B.P., Muckle, G., Braun, J.M. 2022. *Maternal Folate Status and the Relation between Gestational Arsenic Exposure and Child Health Outcomes*. International Journal of Environmental Research and Public Health, Vol. 19, Issue 18, DOI: 10.3390/ijerph191811332

Rawn, D.F.K., Quade, S.C., Corrigan, C., Ménard, C., Sun, W.F., Breton, F., Arbuckle, T.E., Fraser, W.D. 2023. *Differences in mirex [dechlorane] and dechlorane plus [syn- and anti-] concentrations observed in Canadian human milk.* Chemosphere, Vol. 316, 137784, DOI: 10.1016/j.chemosphere.2023.137784

West, Z., Demchenko, I., Clark, L., White, M., MacFarlane, A.J., Fraser, W.D., Arbuckle, T.E., Connor, K.L.. 2022. *MIREC Study Group. Relationships between maternal body mass index and child cognitive outcomes at 3 years of age are buffered by specific early environments in a prospective Canadian birth cohort*. Journal of Developmental Origins of Health and Disease, Vol., Issue 1, pp 42-52, DOI: 10.1017/S2040174422000228

Yonkman, A.M., Alampi, J.D., Kaida, A., Allen, R,W., Chen, A., Lanphear, B.P., Braun, J.M., Muckle, G., Arbuckle, T.E., McCandless, L.C. 2023. *Using Latent Profile Analysis to Identify Associations Between Gestational Chemical Mixtures and Child Neurodevelopment*. Epidemiology, Vol. 34, Issue 1, pp 45-55, DOI: 10.1097/EDE.0000000000001554

- **Targeted human biomonitoring study to assess Canadian children's DEET exposure during protective use**

  Focus of Research: N,N-diethyl-meta-toluamide (DEET) is an ingredient found in consumer insect repellents and is approved by Canadian government agencies for protection against biting insects. Most research on DEET exposure and toxicokinetics has focused on adult populations, with little data from vulnerable populations, including children. An observational exposure human biomonitoring study was conducted at three overnight summer camps in Ontario, Canada, through July and August 2019.

  Results: Over the course of 24 hours while at camp, children reported when they were using bug spray and the areas of their bodies to which it was applied (e.g., arms, legs, hair, clothing, etc.). To estimate the amount of bug spray used, the change in the mass of each child's bug spray container was measured. Children also provided multiple spot urine samples (up to five samples) for measurement of DEET and DEET metabolites in the children's urine.

  In total, 389 urine samples were collected from 124 children. Children excreted only a small proportion of the estimated amount of applied DEET as DEET and metabolites. Children who used more insect repellent had higher concentrations of DEET and metabolites in their urine following DEET use. DEET and DEET metabolite concentrations were still detectable 22 hours after application. Results suggest that children's typical use of DEET-based insect repellents results in only a small percentage of absorption and excretion of applied DEET. The results of the study suggest that toxicokinetics for DEET absorption, metabolism and excretion may be similar to previous studies in adults where urinary concentrations of DEET and metabolites increased following DEET application, and eventually decreased over 24 to 48 hours.

  Publications: Gibson, J.C., Marro, L., Borghese, M.M., Brandow, D., Remedios, L., Fisher, M., Malowany, M., Kieliszkiewicz, K., Lukina, A.O., Irwin, K. 2022. *Development of an observational exposure human biomonitoring study to assess Canadian children's DEET exposure during protective use*. PLoS One, Vol. 17, Issue 8, e0268341, DOI: 10.1371/journal.pone.0268341

  Gibson, J.C., Marro, L., Brandow, D., Remedios, L., Fisher, M., Borghese, M.M., Kieliszkiewicz, K., Lukina, A.O., Irwin, K. 2022. *Biomonitoring of DEET and DCBA in Canadian children following typical protective insect repellent use*. International Journal of Hygiene and Environmental Health, Vol. 248, 114093, DOI: 10.1016/j.ijheh.2022.114093

7.1.2.2 Methods

- **Development of non-targeted methods for use of human biomonitoring data in chemical risk assessment**

  Focus of Research: Non-targeted analysis (NTA) encompasses a rapidly evolving set of mass spectrometry techniques aimed at characterizing the chemical composition of complex samples, identifying unknown compounds, and/or classifying samples, without prior knowledge regarding the chemical content of the samples. However due to the lack of standards and suitable libraries, accurate assignment of unknown chemicals still remains challenging without authentic standards for confirmation, which impedes unambiguous assignment of unknown metabolites such as those of commonly used plasticizers and their alternatives in human samples. Therefore, it is necessary to develop prioritization tools to improve the confidence of structure assignments. Common behaviours of chemicals with similar structural skeletons in mass spectrometry analyses can be used to develop filters to recognize, prioritize, and classify candidate molecules, for assigning chemical formulas, and for elucidating structures in NTA of unknown metabolites. The goal of this research is to develop a prioritization tool to rapidly screen and prioritize candidate unknown chemicals in non-targeted analysis.

  Results: HC conducted research on specific applications of NTA approaches and methods, including the development of a prioritization tool to increase the identification confidence in NTA and application of this tool to screen for and prioritize metabolites of phthalates and alternatives in human urine. The findings indicate that the structural similarity of phthalate metabolites gives three typical common fragment ions, which can be used as a filter to prioritize candidate precursor ions as potential phthalate metabolites. The methodology developed in this study allowed for prioritization of eight new substances in human urine, one of which was tentatively identified as a new, unreported breakdown product of phthalates. Future improvement in this field is required and could ultimately lead to a more cost-effective and efficient methods to assess human exposure to emerging or unknown chemicals.

  Publications: Black, G., Lowe, C., Anumol, T., Bade, J., Favela, K., Feng, Y.L., Knolhoff, A., Mceachran, A., Nuñez, J., Fisher, C., Peter, K., Quinete, N.S., Sobus, J., Sussman, E., Watson, W., Wickramasekara, S., Williams, A., Young, T. 2022. *Exploring chemical space in non-targeted analysis: a proposed ChemSpace tool*. Analytical and Bioanalytical Chemistry. Vol. 415, Issue 1, pp 35-44. DOI: 10.1007/s00216-022-04434-4

  Feng, Y.L. 2022. *Chromatography High-Resolution Mass Spectrometry in Food and Environmental Chemistry*. Mass Spectrometry in Food and Environmental Chemistry. The Handbook of Environmental Chemistry, Vol. 119, pp 149-185. DOI: 10.1007/698_2022_892

  Feng, Y.L., Baesu, A. 2023. *Influence of data acquisition modes and data analysis approaches on non-targeted analysis of phthalate metabolites in human urine*. Analytical and Bioanalytical Chemistry. Vol. 415, Issue 2, pp 316-415, DOI: 10.1007/s00216-022-04407-7

  Feng, Y.L., Singh, R., Chao A, Li Y. 2022. *Diagnostic Fragmentation Pathways for Identification of Phthalate Metabolites in Nontargeted Analysis Studies*. Journal of the American Society for Mass Spectrometry; Vol. 33, Issue 6, pp 981-995, DOI: 10.1021/jasms.2c00052

- **Development of novel methods to identify and assess endocrine toxicity**

  Focus of Research: Concern related to the impact of chemical exposures on the endocrine system continues to grow. Over the past decades, Canada under CEPA, as well as other international governments, have regulated the production and use of chemicals shown to act as endocrine disruptors. Consequently, this has led to an increased use of alternative chemicals to address market needs and the potential for regrettable substitution. One such example is bisphenol A (BPA) for which concerns over its effects on human health led to the implementation of regulatory measures to reduce the risks; this action resulted in a rise in the use of BPA alternatives. Under the Chemicals Management Plan (CMP), certain bisphenols and related substances were identified as priorities for further consideration, however many of these chemicals are lacking toxicity data to support assessment. To demonstrate the utility of non-animal test methods, or New Approach Methods (NAM),

to address data gaps, this effort examined 25 BPA alternatives using predictive models and high throughput transcriptomics to provide an integrated assessment of estrogenic activity.

Results: The investigation demonstrated that several approaches may be considered for establishing robust and reproducible endpoints to derive NAM-based effect levels for bisphenols and related chemical substances. The majority of bisphenol alternatives evaluated showed potential to alter the endocrine system as illustrated using transcriptomic analyses and computer model predictions. Further, comparing in vitro NAM-based effect levels with those derived from animal models reaffirmed the protective nature of the approach when considered in applications to facilitate human health risk assessment of data-poor chemicals. This project contributes to a global effort to reduce animal testing and provides specific data that can be used in a screening strategy to identify chemicals with the potential for endocrine effects and contribute to the weight of evidence assessment used in regulatory decisions for chemical risk assessment.

Publications: Anthony Reardon, Matthew Gagne, Reza Farmahin, Shamika Wickramasuriya, Sean Collins, Marc Beal, Andrew Williams, Karen Leingartner, Andrea Rowan-Carroll, Matthew Meier, Andy Nong, Ella Atlas, Carole Yauk, Tara Barton-Maclaren. OECD *Case Study on the use of Integrated Approaches to Testing and Assessment for potential Systemic Toxicity and Estrogen Receptor Activation of a Group of Bisphenols and Select Alternatives* (Seventh Review Cycle 2021). www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/cbc/mono(2022)43&doclanguage=en

Collins S.P., Barton-Maclaren T.S. *Novel machine learning models to predict endocrine disruption activity for high-throughput chemical screening*. Front Toxicol. 2022 Sep 20;4:981928. DOI: 10.3389/ftox.2022.981928. PMID: 36204696; PMCID: PMC9530987

Matteo G., Leingartner K., Rowan-Carroll A., Meier M., Williams A., Beal M.A., Gagné M., Farmahin R., Wickramasuriya S., Reardon A.J..F, Barton-Maclaren .T, Christopher Corton J., Yauk C.L., Atlas E. *In vitro transcriptomic analyses reveal pathway perturbations, estrogenic activities, and potencies of data-poor BPA alternative chemicals*. Toxicol Sci. 2023 Feb 17;191(2):266-275. DOI: 10.1093/toxsci/kfac127. PMID: 36534918; PMCID: PMC9936204

- **Development of a non-animal testing and assessment strategy for genotoxicity**

  Focus of Research: Traditionally, chemical toxicity testing has been carried out using mainly animal bioassays that cover a range of endpoints. However, over the past two decades there has been a global shift away from the use of animals for toxicity testing. In 2023, legislation was approved to modernize CEPA, which encourages the development and incorporation of new approach methods (NAMs); that is, toxicity testing approaches that do not use animals. NAMs have the potential to increase the throughput of chemical testing, while simultaneously increasing the human relevance and mechanistic data obtained. Genetic toxicity is known to be mechanistically related to a host of adverse effects including cancer and heritable genetic diseases and disorders. Consequently, genetic toxicity assessment is a key component of human health risk assessment. The main goals of this work are to develop and deploy a novel NAM-based testing platform for effective assessment of genetic toxicity and to apply a computational approach to quantitative cell-based genetic toxicity data to estimate human equivalent doses that can serve as protective points of departure (PODs) to support human health risk assessment.

  Results: Several genotoxicity NAMs have been validated and demonstrated to be predictive of animal bioassay outcomes. An integrated NAM-based genotoxicity testing strategy has been shown to be effective for detecting genetic toxicity, while also providing human-relevant mechanistic insight regarding the mode-of-action. Furthermore, recent studies have demonstrated that NAM-based assessment of genetic toxicity can provide protective PODs to support human health risk assessment. This project contributes to a global effort to reduce animal testing and can be deployed to assess genetic toxicity of chemicals that currently lack health effects data. This NAM-based assessment strategy can be used for hazard identification in a screening strategy, and results can also be combined with computational methods to provide NAM-based PODs, which can be compared with human exposure estimates for prioritization, or to support assessments.

Publications: Kuo B., Beal M.A., Wills J.W., White P.A., Marchetti F., Nong A., Barton-Maclaren T.S., Houck K., Yauk C.L. *Comprehensive interpretation of in vitro micronucleus test results for 292 chemicals: from hazard identification to risk assessment application*. Arch Toxicol. 2022 Jul;96(7):2067-2085. DOI: 10.1007/s00204-022-03286-2. Epub 2022 Apr 21.PMID: 35445829

Fortin A.V., Long A.S., Williams A., Meier M.J., Cox J., Pinsonnault C., Yauk C..L, White .PA. *Application of a new approach methodology (NAM)-based strategy for genotoxicity assessment of data-poor compounds.* Front Toxicol. 2023 Jan 23;5:1098432. DOI: 10.3389/ftox.2023.1098432. PMID: 36756349; PMCID: PMC9899896

Beal M.A., Audebert M., Barton-Maclaren T., Battaion H., Bemis J..C, Cao X., Chen C., Dertinger S.D., Froetschl R., Guo X., Johnson G., Hendriks G., Khoury L., Long A.S., Pfuhler S., Settivari R.S., Wickramasuriya S., White P. *Quantitative in vitro to in vivo extrapolation of genotoxicity data provides protective estimates of in vivo dose*. Environ Mol Mutagen. 2023 Feb;64(2):105-122. DOI: 10.1002/em.22521. Epub 2022 Dec 22. PMID: 36495195

- **The contribution of larval zebrafish transcriptomics to chemical risk assessment**

  Focus of Research: A major goal under CEPA is to support the development and use of scientifically justified alternative methods in Canada to support the data needs for risk assessment. While these toxicity data are historically obtained using rodents, in response to international efforts to eliminate animal testing, HC is collaborating with the National Research Council (NRC) of Canada to develop a New Approach Method by refining existing NRC zebrafish models.

  The zebrafish model using embryonic or larval zebrafish evaluates whole body general toxicity which currently cannot be done using testing on isolated single cell types. The experimental model includes non-lethal indicators such as behavioural, toxicokinetic and transcriptomic responses to assess signs of toxicity at levels below those which cause visible toxicity following chemical exposure at lower concentrations. In this paper, the predictive power of zebrafish transcriptomics is demonstrated using two chemicals; Raloxifene and Resorcinol.

  Results: Raloxifene exposure produced darkening of the liver and malformation of the nose/mandible, while Resorcinol exposure produced increased fish movement. Analysis of gene expression during treatment showed a correlation between gene expression and the visible phenotypic effects and benchmark dose calculations determined that the transcriptomic Point of Departure (POD) occurred at concentrations below those which caused observable physical signs of toxicity. Correlating gene expression with physical (phenotypic) effects strengthens confidence in evaluation of chemical toxicity, thereby showing that the larval zebrafish transcriptomics model represents a significant advancement in chemical risk assessment. This research represents a significant step toward an end goal of validating regulatory acceptance of a modern toxicity test, while respecting the 3Rs (reduce, refine and replace animal testing) and maintains a whole-organism test, to accurately reflect organism responses to test chemicals.

  Publication: Morash M.G., Kirzinger M.W., Achenbach J.C., Venkatachalam A.B., Cooper J.P., Ratzlaff D.E., Woodland C.L.A., Ellis L.D. *The contribution of larval zebrafish transcriptomics to chemical risk assessment.* Regul Toxicol Pharmacol. 2023 Feb;138:105336. DOI: 10.1016/j.yrtph.2023.105336. Epub 2023 Jan 13. PMID: 36642323

- **Long and short duration exposures to the Selective Serotonin Reuptake Inhibitors (SSRIs) Fluoxetine, Paroxetine and Sertraline at environmentally relevant concentrations lead to adverse effects on zebrafish behaviour and reproduction**

  Focus of Research: Recognizing that the science of assessing cumulative effects is still evolving, amendments to CEPA require that the Ministers consider available information about the cumulative effects on the environment and health that may result from exposure to a substance in combination with exposure to other substances when conducting and interpreting the results of risk assessments. To support the emerging science of cumulative effects and risk assessment, the effect of low, environmentally relevant, concentrations of substances that are known to exert their effect through the same biological mechanistic mode of action is being studied. The zebrafish model using embryonic or larval zebrafish evaluates whole body general toxicity which currently cannot be done using testing on isolated single cell types. This experimental model includes subtle non-lethal behavioural responses to assess signs of toxicity from chemical exposure at low concentrations.

Selective serotonin reuptake inhibitors (SSRIs) are currently the most prescribed class of psychotropic medications. Their increased global manufacture and use have become a growing concern for aquatic toxicologists and environmental biologists, who assess both the direct and indirect effects of these substances on the environment and on human health. In order to assess the potential impact of environmentally relevant levels of SSRIs on fish development, behaviour and reproduction, juvenile and adult zebrafish were exposed to a select group of SSRIs using two separate exposure scenarios, including one for short and another for long term duration.

Results: In the first scenario, juvenile zebrafish were exposed to Fluoxetine (Prozac), Paroxetine (Paxil), Sertraline (Zoloft) or a mixture of the three, beginning at levels found in the environment (10 µg/L) for 135 days (long-term exposure) beginning at 5 days post fertilization (dpf). In the second scenario, adult zebrafish were exposed to matching concentrations of the same SSRIs for 35 days (short-term exposure). The long-term exposure scenario proved to have little to no obvious effect on growth or development at lower than lethal concentrations (10 and 100 µg/L). However, both the stress/anxiety response (novel tank tests) and reproduction were dramatically reduced. Importantly, the short-term exposure of reproductively mature fish led to similar negative effects on both the stress response and reproduction. Following both the short and long duration exposure scenarios, a 2-week washout period led to a small reduction in the negative effects. These findings highlight the potential for SSRIs to negatively impact zebrafish populations and may be used to inform potential effects on other fish species in the environment.

Publication: Venkatachalam A.B., Levesque B., Achenbach J.C., Pappas J.J., Ellis L.D. *Long and Short Duration Exposures to the Selective Serotonin Reuptake Inhibitors (SSRIs) Fluoxetine, Paroxetine and Sertraline at Environmentally Relevant Concentrations Lead to Adverse Effects on Zebrafish Behaviour and Reproduction*. Toxics. 2023; 11(2):151. DOI:10.3390/toxics11020151

- **Evaluation of the uptake, metabolism, and secretion of toxicants by zebrafish larvae**

  Focus of Research: A major goal under CEPA is to support the development and use of scientifically justified alternative methods in Canada to support the data needs for risk assessment. The zebrafish model using embryonic or larval zebrafish evaluates whole body general toxicity which currently cannot be done using testing on isolated single cell types.

  Zebrafish larvae have typically been used as a rapid model to test both the bioactivity and toxicity of known and new compounds, making them a promising whole organism New Approach Method in the international push to end animal testing. Larvae are generally exposed to the chemicals being tested in an unchanging environment and the concentration-response patterns are calculated based on the initial concentrations of the compounds in the water with the larvae. This approach rarely takes into account the absorption, distribution, metabolism, and excretion of the compounds being tested, which can have a significant effect on the toxicokinetic profiles of the compounds and thus impact how well the model can predict the result. In this study, the toxicokinetic profile of 5 known toxic substances was studied, 3 phenolic compounds, along with thiabendazole and 3,4-dicholoronalanine, at 6, 8, 24, 72, and 120 h postfertilization in order to match the exposure timelines of a standard *in vitro* fish embryo toxicity test.

  Results: It was shown that in addition to bioaccumulation effects, the compounds were all actively metabolized and excreted by the larvae. Importantly, comparisons between the toxicants revealed that the patterns of uptake and metabolism were varied and could often partially explain the differences in their concentration-response patterns. The findings of this study are significant as they highlight the requirement for an assessment of the stability and toxicokinetic profile of chemicals tested using standard zebrafish larval toxicity assays in order to better understand and compare their toxicity profiles.

  Publication: Achenbach J.C., Hui J.P.M., Berrue F., Woodland C., Ellis L.D. *Evaluation of the Uptake, Metabolism, and Secretion of Toxicants by Zebrafish Larvae*. Toxicol Sci. 2022 Nov 23;190(2):133-145. DOI: 10.1093/toxsci/kfac102. PMID: 36155823

- **Application of a new approach methodology (NAM)-based strategy for genotoxicity assessment of data-poor compounds**

  Focus of Research: A major goal under CEPA is to support the development and use of scientifically justified alternative methods in Canada to support the data needs for risk assessment. The conventional battery for genotoxicity testing is not well suited to assessing the large number of chemicals needing evaluation. Traditional *in vitro* tests lack high volume throughput, provide little mechanistic information, and have poor specificity in predicting *in vivo* genotoxicity. NAMs aim to accelerate the pace of hazard assessment and reduce reliance on *in vivo* tests that are long resource-intensive. As such, high-throughput transcriptomic and flow cytometry-based assays have been developed for modernized *in vitro* genotoxicity assessment. This includes: the TGx-DDI transcriptomic biomarker (i.e., 64-gene expression signature to identify DNA damage-inducing (DDI) substances), the MicroFlow® assay (i.e., a flow cytometry-based micronucleus (MN) test), and the MultiFlow® assay (i.e., a multiplexed flow cytometry-based reporter assay that yields mode of action (MoA) information). The objective of this study was to investigate the usefulness of the TGx-DDI transcriptomic biomarker, multiplexed with the MicroFlow® and MultiFlow® assays, as an integrated NAM-based testing strategy for screening data-poor compounds prioritized under CEPA by HC's New Substances Assessment and Control Bureau.

  Results: Human lymphoblastoid TK6 cells were exposed to 3 control and 10 data-poor substances, using a 6-point concentration range. Gene expression profiling was conducted using the targeted TempO-Seq™ assay, and the TGx-DDI classifier was applied to the dataset. Classifications were compared with those based on the MicroFlow® and MultiFlow® assays. Benchmark Concentration (BMC) modeling was used for potency ranking. The results of the integrated hazard calls indicate that five of the data-poor compounds were genotoxic *in vitro*, causing DNA damage *via* a clastogenic MoA, and one *via* a pan-genotoxic MoA. Two compounds were likely irrelevant positives in the MN test; two are considered possibly genotoxic causing DNA damage *via* an ambiguous MoA. BMC modeling revealed nearly identical potency rankings for each assay. This ranking was maintained when all endpoint BMCs were converted into a single score using the Toxicological Prioritization (ToxPi) approach. Overall, this study contributes to establishing a modern approach for effective genotoxicity assessment and chemical prioritization for further regulatory review. We conclude that the integration of TGx-DDI, MicroFlow®, and MultiFlow® endpoints is an effective NAM-based strategy for genotoxicity assessment of data-poor compounds.

  Publication: Fortin A.-M.V., Long A.S., Williams A., Meier M.J., Cox J., Pinsonnault C., Yauk C.L. and White P.A. (2023) *Application of a new approach methodology (NAM)-based strategy for genotoxicity assessment of data-poor compounds*. Front.Toxicol. 5:1098432. DOI: 10.3389/ftox.2023.1098432

7.1.2.3 Exposure characterization

- **Influence of house characteristics on exposures to chemicals in settled indoor dust**

  Focus of Research: The Canadian House Dust Study (CHDS; 2007-2010), a national study involving the collection of dust samples from urban households, provides insight into the presence of chemicals of concern in Canadian households, and the levels to which people in Canada are typically exposed. This research supports risk assessment and risk management actions under the Chemicals Management Plan, and the *Canadian Environmental Protection Act*. The present study examines associations between house characteristics and chemical contaminants in CHDS samples to identify potential indoor sources of a wide range of synthetic organic compounds and metal(loid)s.

  Results: The use of room deodorizers/air fresheners and the presence of cats in the home were associated with a wide variety of synthetic organic compounds in the settled dust. Components of heating appliances and heat distribution systems appeared to contribute heat-resistant chemicals such as flame retardants and related metal(loid)s to settled dust. Hardwood flooring, a manufactured wood product, was identified as a source for a variety of metal(loid)s, plasticizers, flame retardants and organochlorine pesticides. Carpets displayed a dual role as both source and sink of dust-borne contaminants. The surface covered with carpet increased with the house construction date and positively correlated with dust concentrations of plasticizers, halogenated flame retardants,

bromide and boron. As numbers of children in the home increased, dust concentrations of numerous flame retardants and plasticizers increased, likely related to their use in children's toys and other products.

These findings help refine exposure assessment and assist in the development and prioritization of mitigation strategies. Future monitoring of Canadian house dust may provide additional data to identify changing patterns of chemical exposure in Canadian homes as different chemicals are used for building materials and consumer products in the future.

Publication: Rasmussen, P.E., Kubwabo, C., Gardner, H.D., Levesque, C., Beauchemin, S. 2022. *Relationships between House Characteristics and Exposures to Metal(loid)s and Synthetic Organic Contaminants Evaluated Using Settled Indoor Dust*. International Journal of Environmental Research and Public Health, Vol. 19, Issue 16, DOI: 10.3390/ijerph191610329

7.1.2.4 Toxicity characterization

- **Establishing a quantitative framework for regulatory interpretation of genetic toxicity dose-response data: margin of exposure case study of 48 compounds with both *in vivo* mutagenicity and carcinogenicity dose-response data**

  Focus of Research: Under CEPA, HC is responsible for management of the health risks associated with exposures to new and existing chemicals. This requires information pertaining to a chemical's genetic toxicity (i.e., its ability to induce genetic damage), and its carcinogenicity (i.e., its ability to induce cancer). Previous analyses showed that the extent to which a chemical can cause genetic mutations in experimental animals (i.e., mutagenic potency) is comparable to its ability to induce cancer (i.e., carcinogenic potency). Both carcinogenic and mutagenic potency can be used to calculate margin of exposure (MOE) values; the ratio of the exposure level below which harm is not expected to the estimated level of human exposure. The MOE is a common metric used to prioritize substances for risk management; low values (e.g., values below 10,000) indicate a necessity for concern.

  This work extended previous analyses by using human exposure data for 48 compounds to calculate carcinogenicity- and genotoxicity-derived (MOE) values. Genotoxicity-derived MOE values were then critically compared to carcinogenicity-derived MOE values, with the comparison indicating alignment of concomitant regulatory decision-making.

  Results: Using both approaches, MOEs for 16 of the 48 compounds were below 10,000; consequently, they would be prioritised for regulatory actions. Of these, 15 were highlighted using genotoxicity-derived MOEs; only 13 were highlighted using carcinogenicity-derived MOEs. Of the 15 compounds, 12 were highlighted by both types of MOE values. The results indicate that regulatory decisions based on in vivo genotoxicity dose-response data would be consistent with those based on carcinogenicity dose-response data; in some cases, genotoxicity-based decisions would be more conservative.

  Routine use of the MOE approach necessitates reliable human exposure estimates; moreover, consensus regarding appropriate approaches for quantitative interpretation of genetic toxicity data. Going forward, and in the increasing absence of carcinogenicity data, in vivo genotoxicity data can be considered for chemical prioritization.

  Publication: Chepelev, N., Long, A.S., Beal, M., Barton-Maclaren, T., Johnson, G., Dearfield, K.L., Roberts, D.J., van Benthem, J., White, P. 2023. *Establishing a quantitative framework for regulatory interpretation of genetic toxicity dose-response data: Margin of exposure case study of 48 compounds with both in vivo mutagenicity and carcinogenicity dose-response data*. Environmental and Molecular Mutagenesis, Vol. 64, Issue 1, pp 4-15, DOI: 10.1002/em.22517

7.1.2.5 Nanomaterials and microplastics

- **The high-throughput *in vitro* CometChip assay for the analysis of metal oxide nanomaterial induced DNA damage**

  Focus of Research: Under CEPA, HC is responsible for the assessment and management of the health risks associated with exposures to new and existing chemicals, including technology-enabled materials such as nanomaterials (NM), materials in the size range of 1-100 nanometers. This includes investigation of a material's potential to induce genetic toxicity (i.e., its ability to induce damage to DNA and consequently, cancer).

  NM exhibit unique size associated properties that alter their biological behaviour and consequently, their toxic potential. This implies that substances on the current Domestic Substances List (DSL) may have to undergo reassessments, if they are produced and used as NM. The numerous sizes and combinatorial properties that they exhibit makes it challenging to assess them one by one, necessitating the application of novel approach methodologies (NAMs) for toxicity testing. In this study, several individual metal oxide nanomaterials (MONMs, one of the most highly utilized classes of NM worldwide, with applications in diverse sectors) from the DSL were assessed for their potential to induce DNA damage. Specifically, metal oxides of different sizes (nano vs macro), chemical composition (copper, zinc and titanium), surface properties (surface coating) and solubility (ability to dissolve in aqueous solution, low solubility to 100% soluble), were assessed. A novel high-throughput CometChip assay methodology, which allows the assessment of up to 96 samples at once and quantifies the amount of DNA breaks caused by the material, was optimized and applied.

  Results: Results showed that some MONPs are potent inducers of DNA damage. For some, nanoparticulate form contributed to the toxicity, and for others, it was the soluble metal ions or their crystal phase, which was detrimental. The results of this DNA damage screening were used to inform HC's NM risk assessment processes.

  Moving forward, the high throughput technique optimized can be routinely used to prioritize NM for further genotoxicity testing.

  Publication: Boyadzhiev, A., Solorio-Rodriguez, S.A., Wu, D., Avramescu, M.L., Rasmussen, P., Halappanavar, S. 2022. *The High-Throughput In Vitro CometChip Assay for the Analysis of Metal Oxide Nanomaterial Induced DNA Damage*. Nanomaterials (Basel), Vol. 12, Issue 11, Article 1844, DOI: 10.3390/nano12111844

7.2 Air pollutants and greenhouse gases

Air quality research:

- helps quantify priority air pollutants and determine trends
- improves and validates air quality predictions both in the near term and into the future within the national and global context
- enhances understanding of the impacts of air pollution on people in Canada and the environment
- tackles emerging issues
- develops and refines tools to communicate the health impacts of air pollution
- underpins and informs evidence-based policy and regulatory development including the setting of Canadian Ambient Air Quality Standards and Residential Indoor Air Quality Guidelines

7.2.1 Environment and Climate Change Canada research

Ongoing research continued on a wide range of air pollutants, including short-lived climate pollutants, ammonia, nitrogen oxides (NO_x), sulphur dioxide (SO_2), volatile organic compounds (VOCs), ozone, and particulate matter/aerosols. A sample of the research papers on the topics of air pollutants and GHGs published in peer-reviewed scientific journals in 2022-2023 is referenced below.

- **Impact of tropospheric and stratospheric temperatures on the tropopause**

  Focus of Research: The tropopause is the transition between the troposphere and the stratosphere above it. Human activities have brought about substantial changes in tropospheric warming and stratospheric warming, both of which tend to raise the tropopause height (H). Thus, changes in H provide a valuable indicator of human related climate change. This research used radiosonde balloon observations over the Northern Hemisphere to develop profiles of tropospheric temperature (TTRO) and stratospheric temperature (TSTR), and tropopause height (H) for the periods 1980-2000 and 2001-2020.

  Results: The tropopause was found to have risen at roughly the same rate in both periods. It is estimated that after 2000, tropospheric warming played a dominant role (~80%) in raising the tropopause, while before 2000, tropospheric warming and stratospheric cooling contributed almost equally to tropopause rise. This conforms to expected effects of human activities – before 2000 ozone destruction by ozone depleting substances (ODS) contributed to TSTR decline; since 2001 the reduction in ODS use following the implementation of the Montreal Protocol in the early 1990s has resulted in a warmer stratosphere. Similarly, the accelerating rate of climate change has resulted in more rapid warming of the troposphere since 2001. As our understanding of the impact of rising tropopause on climate and weather is rather limited, further studies are warranted to determine the long-term impacts of tropopause rise.

  Publications: Liu, J. et al. 2022. *The troposphere is expanding due to anthropogenic climate change.* CMOS BULLETIN. https://bulletin.cmos.ca/the-troposphere-is-expanding-due-to-anthropogenic-climate-change/

  Meng, L. et al. 2021. *Continuous rise of the tropopause in the Northern Hemisphere over 1980–2020*. Sci. Adv.7, eabi8065, DOI: 10.1126/sciadv.abi8065.

- **Measuring the effect of fine particulate matter on human health**

  Focus of Research: Redox-active substances in fine particulate matter (PM) contribute to inhalation health risks through their potential to generate reactive oxygen species (ROS) in epithelial lung lining fluid (ELF). The potential of PM to cause oxidative stress can be estimated utilizing oxidative potential (OP) assays, which quantify ROS formation or antioxidant consumption. Recent work by ECCC compared the OP of redox-active substances loaded in ELF via air–liquid interface (ALI) mixing to OP determined by the commonly used bulk mixing technique.

  Results: The resulting oxidative potential of the nanoparticle-coated redox-active compounds loaded into ELF via ALI were found to exceed the OP resulting from bulk mixing. This suggests that the OP of PM, as determined in acellular assays by bulk mixing of samples, might be underestimating the effective OP exerted in the human lung upon inhalation.

  Publication: Baumann, K., Wietzoreck, M., Shahpoury, P. et al. 2023. *Is the oxidative potential of components of fine particulate matter surface-mediated?* Environ Sci Pollut Res Vol. 30, pp 16749–16755, DOI : 10.1007/s11356-022-24897-3

- **Emissions inventory in the Alberta oil sands region**

  Focus of Research: The Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring (JOSM) program is studying the cumulative effects of oil sands development through environmental monitoring and research of contaminants. Using data from the JOSM air emissions inventory, this study developed an emission inventory for 29 elements in fine and coarse particulate matter ($PM_{2.5}$ and $PM_{2.5\text{-}10}$ respectively) in the Athabasca Oil Sands Region in northern Alberta. Using this emission inventory as input, a dispersion model was used to simulate reasonable element concentrations in both $PM_{2.5}$ and $PM_{2.5\text{-}10}$.

  Results: The model showed that for both $PM_{2.5}$ and $PM_{2.5\text{-}10}$, the spatial distribution of airborne particulate elements was strongly related to oils sands surface mining activities. The study also found discrepancies between the model and actual measurements of these elements in the oil sands region, suggesting further improvements to the model such as including background element concentrations and wildfire emissions. The modeled concentrations generated from this study will be used to produce maps of atmospheric deposition fluxes of particulate elements for assessment of cumulative ecosystem effects in the oil sands region.

  Publications: Yang, F., Cheng, I., Xiao, R., Qiu, X., & Zhang, L. 2023. *Emissions database development and dispersion model predictions of airborne particulate elements in the Canadian Athabasca oil sands region*. Environmental Research, Vol. 220, 115223, DOI: 10.1016/j.envres.2023.115223

- **Boreal forest wildfire emissions**

  Focus of Research: Wildfire impacts on air quality and climate are expected to be exacerbated by climate change with the most pronounced impacts in the boreal forest biome, which includes 75% of Canada's forested land. In this study, airborne measurements of 193 compounds from 15 instruments, including 173 non-methane organics compounds (NMOG), were used to provide the most detailed characterization to date of boreal forest wildfire emissions.

  Results: Measurements showed a large diversity of air pollutants, highlighting the complexity of wildfire emissions and expanding the range of volatile organic compounds typically reported for these emissions. Despite the large number of compounds assessed, a large portion of organic species were unidentified; further research is needed to fully characterize these emissions. These aircraft-derived measurements improve understanding of wildfire emissions chemical composition and can support reliable model predictions of pollution from boreal forest wildfires.

  Publication: Hayden, K. L., Li, S.-M., Liggio, J., Wheeler, M. J., Wentzell, J. J. B., Leithead, A., Brickell, P., Mittermeier, R. L., Oldham, Z., Mihele, C. M., Staebler, R. M., Moussa, S. G., Darlington, A., Wolde, M., Thompson, D., Chen, J., Griffin, D., Eckert, E., Ditto, J. C., He, M., and Gentner, D. R. 2022. *Reconciling the total carbon budget for boreal forest wildfire emissions using airborne observations*, Atmos. Chem. Phys., Vol. 22, pp 12493–12523, DOI: 10.5194/acp-22-12493-2022

- **Air pollution and climate change in the Arctic**

  Focus of Research: Air quality and climate change are often treated as separate environmental issues, even though there are close connections between the two. This study modelled future green-house gas (GHG) and air pollutant emission scenarios by comparing the impacts of sulfur, black carbon (BC), and methane emission reductions on radiatively forced temperature changes in the Arctic

  Results: Because sulfur dioxide undergoes chemical processes in the atmosphere that lead to compounds that scatter incoming solar ultraviolet radiation, sulfur emissions have a cooling effect on the atmosphere that partly offsets the warming caused by GHGs. Results reveal that reductions in sulfur emissions would be a significant contributor to Arctic warming in the next few decades; however, it also shows that increased reductions in emissions of BC and methane would decrease Arctic warming, thus offsetting the decreased cooling. This also suggests that ambitious global reductions of methane and BC could lead to short-term Arctic climate benefits by 2050, but current emission reduction targets for BC will not be enough to realize the full potential benefit.

Publication: Von Salzen, K., Whaley, C.H., Anenberg, S.C. et al. 2022. *Clean air policies are key for successfully mitigating Arctic warming.* Commun Earth Environ Vol. 3, 222, DOI: 10.1038/s43247-022-00555-x

- **Sulfur dioxide (SO_2) and nitrogen oxides (NO_x)**

  Focus of Research: Sulfur oxide and nitrogen oxide pollutants have significant impacts on the environment, health, atmospheric chemistry, and climate, and therefore are listed on Schedule 1 of CEPA. Studies conducted by ECCC on these pollutants involved monitoring sulfur dioxide (SO_2) emission levels and evaluating sulfur and nitrogen wet and dry deposition.

  Results: SO_2 measurements from three satellite instruments were used to update and extend the previously developed global catalogue of large SO_2 emission sources. The catalogue data show an approximate 50% decline in global SO_2 emissions between 2005 and 2021, although emissions were relatively stable during the last 3 years. The version 2 catalogue updates the emission estimates to improve SO_2 emission inventories used in air quality and climate models.

  Data at 15 Canadian rural sites from 2000-2018 showed that nitrogen and sulfur deposition decreased significantly at the sites over this period, with the greatest decline observed in southeastern Canada due to regional reductions in SO_2 and NO_x emissions. While 36% of assessed sites exceeded their terrestrial critical loads at the beginning of the study period, and 40% of assessed sites exceeded their aquatic critical loads, this trended steadily downwards and no sites exceeded their critical loads in the latter years of the study period. Overall, the study shows a positive trend, with N and S deposition and the impact on ecosystems declining at the assessed sites. Nevertheless, progress is uneven across the country, particularly in western Canada and the prairie provinces where SO_2 and NO_x emissions reductions are modest and NH_3 emissions are rising.

  Publications: Cheng, I., Zhang, L., He, Z., Cathcart, H., Houle, D., Cole, A., Feng, J., O'Brien, J., Macdonald, A. M., Aherne, J., and Brook, J. 2022. *Long-term declines in atmospheric nitrogen and sulfur deposition reduce critical loads exceedances at multiple Canadian rural sites, 2000–2018*, Atmos. Chem. Phys., Vol. 22, pp 14631–14656, DOI: 10.5194/acp-22-14631-2022

  Fioletov, V. E., McLinden, C. A., Griffin, D., Abboud, I., Krotkov, N., Leonard, P. J. T., Li, C., Joiner, J., Theys, N., and Carn, S. 2023. *Version 2 of the global catalogue of large anthropogenic and volcanic SO2 sources and emissions derived from satellite measurements*, Earth Syst. Sci. Data, Vol. 15, pp 75–93, DOI: 10.5194/essd-15-75-2023

- **Transportation-related emissions**

  Focus of Research: The main objective was to characterize the emissions generated by transportation, and to investigate different mechanisms (i.e., fuel blends and filters) that could be used to reduce these air pollutants.

  Results: Extracts of passive air samplers deployed in 18 major cities that comprise the Global Atmospheric Passive Sampling Network (GAPS-Megacities) were analyzed for various tire-derived contaminants. This study presents some of the earliest data on airborne concentrations of chemicals associated with tire-wear and the results show that these chemicals are ubiquitous in major urban environments. It also demonstrated that passive sampling is a viable technique for monitoring airborne tire-wear contamination.

  Traffic-related air pollutants (TRAP) were measured at near-road sites along a busy highway to provide insights into the influence of wintertime meteorology on exposure to TRAP near major roads. The study found that the influence of traffic emissions extended beyond 150 m from the roadside, indicating people living near roads are impacted by traffic emissions half of the time or more, temperatures below −5 °C increased near-road concentrations of nitrogen oxide (NO_x) and ultrafine particles, and air stagnation widened the near-road area affected by poor air quality.

  A research study evaluated the effectiveness of gasoline particulate filters (GPFs) on reducing gaseous and particle phase pollutants from gasoline vehicles. It found that GPFs are effective at mitigating black carbon and

particulate matter emissions, including during passive regeneration. A second study compared aerosol emissions from a gasoline direct injection (GDI) vehicle and a port fuel injection (PFI) vehicle, with and without a GPF. Without a GPF, emissions of elemental carbon (EC) and organic carbon (OC) particles were greater for the GDI test vehicle than the PFI vehicle. With a GPF, the GDI vehicle saw a >98% decrease in EC emissions, but OC emissions increased, suggesting that oxidation and condensation of gas phase organic compounds occurs as the exhaust passes through the GPF.

Publications: Chan, T.W., Hendren, J., Brezny, R., Gunter, G.C., Lax, D., Kubsh, J. 2022. *Assessment of particle and gaseous emissions and reductions from gasoline direct injection passenger car and light-duty truck during passive regeneration*, Science of the Total Environment, Vol. 843, art. no. 156994, DOI: 10.1016/j.scitotenv.2022.156994

Jeong, C.-H., Hilker, N., Wang, J.M., Debosz, J., Healy, R.M., Sofowote, U., Munoz, T., Herod, D., Evans, G.J. 2022 *Characterization of winter air pollutant gradients near a major highway*. Science of the Total Environment, Vol. 849, art. no. 157818, DOI: 10.1016/j.scitotenv.2022.157818

Johannessen, C., Saini, A., Zhang, X., & Harner, T. 2022. *Air Monitoring of tire-derived chemicals in global megacities using passive samplers*. Environmental Pollution, Vol. 314, 120206, DOI: 10.1016/j.envpol.2022.120206

Ma, M., Rivellini, L.-H., Kasthuriarachchi, N., Zhu, Q., Zong, Y., Yu, W., Yang, W., Kraft, M., & Lee, A. K. Y. 2023. *Effects of polyoxymethylene dimethyl ether (PODEn) blended fuel on diesel engine emission: Insight from soot-particle aerosol mass spectrometry and aethalometer measurements*. Atmospheric Environment: X, Vol. 18, 100216, DOI: 10.1016/j.aeaoa.2023.100216

Zhang, J., Liggio, J., Chan, T.W., Huang, L., Brook, J.R. 2022. *Gasoline Direct Injection Engine Emissions of OC and EC: Laboratory Comparisons with Port Fuel Injection Engine*. Aerosol Air Qual. Res. Vol. 22, 220032, DOI: 10.4209/aaqr.220032

7.2.2 Health Canada research

In 2022-2023, HC continued to research the health impacts of human exposure to indoor and outdoor air pollutants in order to provide guidance to governments, industries, other organizations and individuals on how to address air pollution. HC scientists published articles in peer reviewed scientific journals. These publications addressed issues such as:

- the implications of air pollution exposure on the severity of COVID-19 in Ontario
- the effect of short-term exposure to air pollutants on emergency room visits and hospital admissions for diseases of cardiovascular, respiratory, nervous, metabolic, and immune systems
- the effect of long-term exposure and exposure during pregnancy and early life to air pollution at on mortality, gestational diabetes, and respiratory and allergic diseases in children
- the risks associated with exposure to traffic-related air pollution (TRAP) and asthma development in childhood
- the associations between residential exposure to wildfires and the incidence of several cancer outcomes (lung cancer, brain cancer, non-Hodgkin lymphoma, multiple myeloma, and leukaemia) in Canada
- the influences of short-term air pollution exposure and extreme ambient temperatures on suicide, and on mental and behavior disorders related emergency department visits and how these associations are modified by vulnerability factors

7.2.2.1 Role of stress in health effects of air pollutants

- **Air pollution and COVID-19**

  Focus of Research: Many studies have shown that ambient air pollution is associated with a wide range of adverse health effects, including increased risk of respiratory infection. Studies from Canada, the United States and Europe suggest that both short and long-term exposure to air pollution may increase the incidence of, and mortality from, COVID-19, a primarily respiratory illness. As COVID-19 is currently at the forefront of public health, identifying determinants of COVID-19 severity is important for prevention and intervention. This research investigates the links between long-term exposure to 3 common ambient air pollutants ($PM_{2.5}$, NO_2, O_3) and key indicators of COVID-19 severity, including hospital admission, intensive care unit (ICU) admission and death, using a large prospective cohort of people with confirmed SARS-CoV-2 infection in Ontario, Canada, in 2020.

  Results: Among the 151 105 people with confirmed SARS-CoV-2 infection in Ontario in 2020, HC found empirical evidence that chronic exposure to air pollution may contribute to severe outcomes after SARS-CoV-2 infection, particularly exposure to O_3. These results suggest that air pollution may play a role in the severity of COVID-19 disease. However, uncertainty still remains in the mechanisms of how long-term air pollution might affect COVID-19 severity. More research is needed to understand the mechanisms.

  Publication: Chen, C., Wang, J., Kwong, J., Kim, J., van Donkelaar, A., Martin, R.V., Hystad, P., Su, Y., Lavigne, E., Kirby-McGregor, M., Kaufman, J.S., Benmarhnia, T., Chen, H. 2022. *Association between long-term exposure to ambient air pollution and COVID-19 severity: A prospective cohort study*. Canadian Medical Association Journal, Vol. 194, Issue 20, pp E693-E700, DOI: 10.1503/cmaj.220068

7.2.2.2 Associations between air pollution and health outcomes

- **Ambient (outdoor) air pollution and adverse health outcomes**

  Focus of Research: HC is responsible for the assessment and management of health risks to people in Canada arising from exposure to various outdoor air pollutants arising from emissions and road traffic. Ambient air pollution is a significant global public health concern, affecting millions of people and responsible for a growing range of adverse health effects, from cardiovascular and respiratory diseases to increased overall mortality. HC conducted epidemiological studies on how short-term (days) and long-term (years) exposure to outdoor air pollutants, including carbon monoxide (CO), fine particulate matter ($PM_{2.5}$), reactive oxidants, sulfur dioxide (SO_2), ozone (O_3), and nitrogen dioxide (NO_2), have impacted on the health of the Canadian population. The health outcomes studied include cardiovascular, respiratory, immune and nervous systems.

  Results: Short-term exposure to outdoor air pollution may result in increased emergency room visits and hospital admissions for diseases not only of cardiovascular and respiratory systems but also of nervous system, metabolic system, and immune systems. Long-term exposure and exposure during pregnancy and early life to air pollution at even low concentrations were found to be associated with increased mortality, gestational diabetes and respiratory and allergic diseases in children. Statistical methods such as mediation and causal inferences were used to elucidate evidence on causal relations between exposure to air pollution and health outcomes.

  Publications: Abdul-Fatah, A., Gao, J.L., Stieb, D.M. 2022. *Comment on "Effect of exposure to ambient $PM_{2.5}$ pollution on the risk of respiratory tract diseases: a meta-analysis of cohort studies"*. Journal of Biomedical Research, Vol. 36, Issue 6, pp 446-447, DOI: 10.7555/jbr.36.20220091

  Gao, J.L., Abdul-Fatah, A., Stieb, D.M. 2022. *Comments on "Ambient fine particulate matter of diameter ≤2.5 μm and risk of hemorrhagic stroke: a systemic review and meta-analysis of cohort studies," by Yang, Mingfei et al. (doi: 10.1007/s11356-021-13074-7)*. Environmental Science and Pollution Research, Vol. 29, Issue 59, pp 89803-89804, DOI: 10.1007/s11356-022-23797-w

Huang, G., Brown, P., Shin, H.H. 2023. *Multi-pollutant case-crossover models of all-cause and cause-specific mortality and hospital admissions by age group in 47 Canadian cities*. Environmental Research, Vol. 225, Article 115598, DOI: 10.1016/j.envres.2023.115598

Kendzerska, T., Szyszkowicz, M., Alvarez, J.V., Mallick, R., Carlsten, C., Ayas, N., Laratta, C.R., Jovic, B., Orach, J., Smith-Doiron, M., Dales, R. 2022. *Air pollution and the effectiveness of positive airway pressure therapy in individuals with sleep apnea: A retrospective community-based repeated-measures longitudinal study*. Chest, Vol. 162, Issue 5, pp 1176-1187, DOI: 10.1016/j.chest.2022.07.017

Korsiak, J., Lavigne, E., You, H., Pollitt, K., Kulka, R., Hatzopoulou, M., Evans, G., Burnett, R.T., Weichenthal, S. 2022. *Air pollution and pediatric respiratory hospitalizations: Effect modification by particle constituents and oxidative potential*. American Journal of Respiratory Critical Care Medicine, Vol. 206, Issue 11, pp 1370-1378, DOI: 10.1164/rccm.202205-0896oc

Lukina, A.O., Burstein, B., Szyszkowicz, M. 2022. *Urban air pollution and emergency department visits related to central nervous system diseases*. PLoS One, Vol. 17, Issue 6, Article e0270459, DOI: 10.1371/journal.pone.0270459

Szyszkowicz, M. 2022. *Concentration–response functions as an essence of the results from lags*. International Journal of Environmental Research and Public Health, Vol. 19, Issue 13, Article 8116, DOI: 10.3390/ijerph19138116

Szyszkowicz, M. 2022. *Urban air pollution and mental, eye, digestive, and musculoskeletal health problems in Toronto, Canada*. Hygiene and Environmental Health Advances, Vol. 3, Article 100008, DOI: 10.1016/j.heha.2022.100008

Szyszkowicz, M., Lukina A., Dinu T. 2022. *Urban air pollution and emergency department visits for neoplasms and outcomes of blood Forming and metabolic systems*. International Journal of Environmental Research and Public Health, Vol. 19, Issue 9, Article 5603, DOI: 10.3390/ijerph19095603

Szyszkowicz, M., Thomson, E.M., de Angelis, N., Lavoie, C., Nguyễn, T.C. 2022. *Urban air pollution and emergency department visits for injury in Edmonton and Toronto, Canada*. Hygiene and Environmental Health Advances, Vol. 4, Article 100020, DOI: 10.1016/j.heha.2022.100020

Verschoor, C.P., Cakmak, S., Lukina, A.O., Dales, R.E. 2022. *Activity-related dyspnea in older adults participating in the Canadian Longitudinal Study on Aging*. Journal of General Internal Medicine, Vol. 37, Issue 13, pp 3302-3309, DOI: 10.1007/s11606-021-07374-4

7.2.2.3 Indoor air pollution and health

Canadians spend 90% of their time indoors. Indoor environmental quality affects the health of occupants. Exposure to pollutants is determined primarily by indoor sources, infiltration from outdoors and ventilation. This research investigates exposure to pollutants in indoor environments and the associated health implications.

- **Indoor air pollution and health**

  Focus of Research: Canadians spend 90% of their time indoors. Indoor environmental quality affects the health of occupants. Exposure to pollutants is determined primarily by indoor sources, infiltration from outdoors and ventilation. This research investigates exposure to pollutants in indoor environments and the associated health implications.

  Results: Two papers published this year addressed different aspects of indoor air quality. One addresses cooking as a major indoor source of airborne pollutants. It presents the results of a Canadian survey of cooking methods and kitchen fans and perceptions and attitudes towards fan use. It evaluates the potential of education strategies to reduce pollutant levels in the home. The second study is one of a series of reports of a collaborative investigation of the effect of indoor environmental quality on health of children in the Sioux Lookout Zone in

Northern Ontario. This paper investigated relationships between environmental conditions and participating children's treatment for skin conditions. Most indicators of indoor environment quality were not associated with skin infections or eczema although an inverse association between mold and medical visits for eczema is consistent with suggestions that exposure to high levels of mold and other microbial products at a young age may reduce the risk of subsequent atopic diseases such as eczema. The greatest number of skin infections were observed for indoor temperatures from 24-25C with lower incidence at both lower and higher temperatures. A previous paper addressed respiratory health and additional papers are in preparation.

Publications: Schreiber, Y., Mallach, G., Barrowman, N., Tsampalieros, A., Kelly, L., Gordon, J., McKay, M., Wong, C.L. and Kovesi, T., 2023. *Skin morbidity in Indigenous children in relation to housing conditions in remote communities in Northwestern Ontario, Canada*. Clinical and Experimental Dermatology, 48(3), pp.218-224. DOI: 10.1093/ced/llac082

Sun, L. and Singer, B.C., 2023. *Cooking methods and kitchen ventilation availability, usage, perceived performance and potential in Canadian homes*. Journal of Exposure Science & Environmental Epidemiology, pp.1-9. DOI:10.1038/s41370-023-00543-z.

7.2.2.4 Air pollution from source sectors (transportation, industry residential heating etc.)

- **Traffic-related air pollution and health outcomes**

  Focus of Research: Numerous studies show that the prevalence of childhood asthma has increased dramatically since the 1950s. Although there is sufficient evidence that ambient air pollution can exacerbate pre-existing asthma, the role of air pollution exposure in the initial development of asthma is as yet contested. Some publications have reported positive associations between traffic-related air pollution (TRAP) and the incidence and prevalence of asthma and wheeze. The question of whether children's exposure to TRAP contributes to their development of asthma is unresolved. HC conducted a systematic review and performed meta-analyses to analyze the association between TRAP and asthma development in childhood.

  Results: Forty-one studies met our eligibility criteria. Overall, there was notable variability in asthma definitions, TRAP exposure assessment and confounder adjustment. Based on this updated evidence base, we believe there is now sufficient evidence to support an association between the exposure to TRAP and the development of childhood asthma. The high degree of consistency in findings and conclusions of the individual studies, the results of the meta-analysis, and considerable support from the existing literature reinforce the hypothesis that childhood exposure to TRAP contributes to their development of asthma. Future meta-analyses would benefit from greater standardization of study methods including exposure assessment harmonization, outcome harmonization, confounders' harmonization and the inclusion of all important confounders in the individual analyses (e.g. socioeconomic status, environmental tobacco smoke exposure, and heredity). Future synthesis could also explore different exposure windows comparing effects of early life to later childhood exposures and possibly prenatal exposures.

  Publication: Yu, C., Seenundun, S., Matz, C.J., Stieb, D.M. 2022. *Comment on: Han K, Ran Z, Wang X, Wu Q, Zhan N, Yi Z, Jin T. Traffic-related organic and inorganic air pollution and risk of development of childhood asthma: A meta-analysis. Environ Res. 2021;194:110493. doi: 10.1016/j.envres.2020.110493.* Environmental Research, Vol. 214(Pt 3), Article 113922, DOI: 10.1016/j.envres.2022.113922

7.2.2.5 Wildfire smoke

- **Effect of wildfires on human health**

  Focus of Research: Wildfires emit many carcinogenic pollutants that contaminate air, water, terrestrial and indoor environments. However, little is known about the relationship between long-term exposure to wildfires smoke and cancer risk. A study was conducted to assess the associations between residential exposure to wildfires and the incidence of several cancer outcomes (lung cancer, brain cancer, non-Hodgkin lymphoma, multiple myeloma, and leukaemia) in Canada. The study used the 1996 Canadian Census Health and Environment Cohort of participants who were followed up for cancer incidence and mortality from 1996 to 2015.

  Results: Among 20 million participants, wildfire exposure was found to be associated with slightly increased incidence of lung cancer and brain tumours. For instance, cohort members exposed to wildfire within 50 km of residential locations in the past 10 years had a 4.9% relatively higher incidence of lung cancer than unexposed populations, and a 10% relatively higher incidence of brain tumours. Since wildfires are becoming a common seasonal threat to human health, further studies are needed to improve long-term estimates of wildfire exposures that capture the complex mixture of environmental pollutants released during these events.

  Publication: Korsiak, J., Pinault, L., Christidis, T., Burnett, RT., Abrahamowicz, M., Weichenthal, S. 2022. *Long-term exposure to wildfires and cancer incidence in Canada: a population-based observational cohort study.* Lancet Planet Health. Vol. 6, Issue 5, DOI: 10.1016/S2542-5196(22)00067-5

7.2.2.6 Air pollution and climate change

- **Health impacts of air pollution exposure and climate change**

  Focus of Research: Ambient extreme temperatures have been associated with mental and behavior disorders (MBDs). However, few studies have assessed the links between ambient air pollution, temperature, and the risk of death from suicide, or whether vulnerability factors such as ambient air pollution, pre-existing mental health conditions and residential environmental factors increase susceptibility. HC investigated the influence of short-term increases in air pollutants (NO_2, O_3, and $PM_{2.5}$) and temperature on suicide mortality in Canada. In addition, HC evaluated the associations between short-term variations in outdoor ambient extreme temperatures and MBD-related emergency department (ED) visits and how these associations are modified by vulnerability factors.

  Results: Daily increases in air pollution and temperature were found to increase the risk of death from suicide. Females, particularly during warmer season, were most vulnerable to these exposures. Cumulative exposure to extreme heat over 0-5 days was associated with ED visits for any MBD. HC also found heat to be associated with ED visits for specific MBDs such as substance use disorders, dementia, neurotic disorders, schizophrenia and personality behavior disorder. Individuals with pre-existing mental health conditions, those exposed to higher daily concentrations of NO_2 and O_3 and those residing in neighborhoods with greater material and social deprivation were at higher risk of heat-related MBD ED visits. Increasing tree canopy coverage appeared to mitigate risks of the effect of heat on MBD ED visits. Findings provide evidence that the impacts of heat on MBD ED visits may vary across different vulnerability factors. Policy decisions related to air pollution and climate change should consider effects on mental health.

  Publications: Lavigne, E., Maltby, A., Côté, JN., Weinberger, KR., Hebbern, C., Vicedo-Cabrera, AM., Wilk, P. 2023. *The effect modification of extreme temperatures on mental and behavior disorders by environmental factors and individual-level characteristics in Canada*. Environmental Research, Vol 219: 114999, DOI: 10.1016/j.envres.2022.114999

  Villeneuve, PJ., Huynh, D., Lavigne, É., Colman, I., Anisman, H., Peters, C., Rodríguez-Villamizar, LA. 2023. *Daily changes in ambient air pollution concentrations and temperature and suicide mortality in Canada: Findings from a national time-stratified case-crossover study.* Environmental Research. Volume 223:115477, DOI: 10.1016/j.envres.2023.115477

8. Appendix – Tables

Table 1. CESI updates and new releases from April 2022 to March 2023

Date	Indicators
April 2022	• Water quantity in Canadian rivers • Harvest levels of key fish stocks • Status of key fish stocks
May 2022	• Canada's conserved areas
June 2022	• Air pollutant emissions • Boil water advisories • Pulp and paper effluent quality
August 2022	• Emissions of harmful substances to air • Releases of harmful substances to water • Sustainability of timber harvest • Global greenhouse gas emissions
September 2022	• Land-based greenhouse gas emissions and removals
November 2022	• Ecological integrity of national parks
December 2022	• Air health trends • Changes in the status of species at risk
January 2023	• Greenhouse gas emissions projections • Air quality • General status of wild species • Species at risk population trends
February 2023	• Management of Canadian aquaculture • Shellfish harvest area water quality • Reductions in phosphorous loads to Lake Winnipeg • Water quality in Canadian rivers
March 2023	• Sea ice in Canada • Population exposure to outdoor air pollutants

Table 6. Summary of existing substance assessment decisions published from April 2022 to March 2023

Shaded cells indicate action taken during reporting period

Name of Substance (number of substances)	Draft screening assessment[1]	Conclusion on s. 64 toxicity[2] criteria? (number of substances)	Final screening assessment[3]	Risk Management Scope Document	Risk Management Approach Document	Action taken (number of substances)
Aldehydes Group (5)	October 8, 2022	Not met		NA[4]		
Anthraquinones Group (7)	November 3, 2018	• TOXIC (1) • Solvent Violet 13 Not met (6)	July 17, 2021	November 3, 2018	July 17, 2021	Notice proposing addition (1) to Schedule 1 October 1, 2022
Benzophenone (1)	August 4, 2018	TOXIC	January 30, 2021	August 4, 2018	January 30, 2021	Notice proposing addition (1) to Schedule 1 April 2, 2022
Caprolactam (1)	August 14, 2021	Not met	February 18, 2023	NA	NA	NFA[5]
Cyanides (10)	February 10, 2018	TOXIC (10)	February 25, 2023	February 10, 2018	February 25, 2023	Notice proposing addition (10) to Schedule 1 March 18, 2023
Dicyclopentadiene (DCPD) (1)	December 7, 2019	Not met	April 23, 2022	NA	NA	NFA
Dinoseb (1)	June 2, 2018	TOXIC	February 6, 2021	June 2, 2018	February 6, 2021	Notice proposing addition (1) to Schedule 1 October 1, 2022
Ethers Group (4)	March 13, 2021	Not met	February 4, 2023	NA	NA	NFA
Ethylene thiourea (ETU) (1)	November 11, 2017 (under the Heterocycles Group)	Not met	January 14, 2023	NA	NA	NFA

Name of Substance (number of substances)	Draft screening assessment[1]	Conclusion on s. 64 toxicity[2] criteria? (number of substances)	Final screening assessment[3]	Risk Management Scope Document	Risk Management Approach Document	Action taken (number of substances)
Nitrilotriacetic acid trisodium salt (Na3NTA) (1)	December 19, 2020	Not met	November 26, 2022	NA	NA	NFA
Poly (alkoxylates/ ethers) Group (21)	December 14, 2019	Not met	November 5, 2022	NA	NA	NFA
Protein Derivatives and Yeast Extract Group (4)	February 6, 2021	Not met	October 1, 2022	NA	NA	NFA
p-Toluenesulfonic acid (PTSA) (1)	October 17, 2020	Not met	June 18, 2022	NA	NA	NFA
Resins and Rosins Group (12)	June 22, 2019	TOXIC (1) • Crude tall oil (CTO) Not met (11)	July 23, 2022	June 22, 2019	July 23, 2022	Notice proposing addition (1) to Schedule 1 February 18, 2023
Silver and its compounds (7)	August 15, 2020	Not met	August 27, 2022	NA	NA	NFA
Sodium cyclamate and Cyclohexylamine (2)	December 14, 2019	Not met	April 9, 2022	NA	NA	NFA
Sodium ortho-phenylphenate (SOPP) (1)	February 29, 2020	Not met	November 19, 2022	NA	NA	NFA
Sucrose acetate isobutyrate (SAIB) (1)	November 14, 2020	Not met	June 18, 2022	NA	NA	NFA
Sulfurized isobutylene (1)	July 4, 2020	Not met	May 14, 2022	NA	NA	NFA
Thiocarbamates Group (2)	February 3, 2018	TOXIC (1) • TMTD Not met (1)	January 9, 2021	February 3, 2018	January 9, 2021	Notice proposing addition (1) to Schedule 1, October 8, 2022

Name of Substance (number of substances)	Draft screening assessment[1]	Conclusion on s. 64 toxicity[2] criteria? (number of substances)	Final screening assessment[3]	Risk Management Scope Document	Risk Management Approach Document	Action taken (number of substances)
TMSS (Silanamine, 1,1,1-trimethyl-N-(trimethylsilyl)-, hydrolysis products with silica) (1)	September 19, 2020	Not met	May 14, 2022	NA	NA	NFA
Triarylmethanes Group (6)	December 8, 2018	TOXIC (4) • Basic Violet 3 • Malachite Green • Basic Violet 4 • Basic Blue 7 Not met (2)	October 17, 2020	December 8, 2018	October 17, 2020	Notice proposing addition (4) to Schedule 1, April 2, 2022
Triclocarban (1)	October 10, 2020	Not met	March 25, 2023	NA	NA	NFA

[1] Date that the screening assessment was published in the *Canada Gazette*

A screening assessment looks to determine the potential harm that a substance or a group of substances can cause to human health and the environment. Screening assessments vary in complexity and may result in either a toxic conclusion (i.e. meets section 64 criteria) or a non-toxic conclusion

[2] Section 64 of CEPA defines a substance as toxic "if it is entering or may enter the environment in a quantity or concentration or under conditions that: (a) have or may have an immediate or long-term effect on the environment or its biological diversity; (b) constitute or may constitute a danger to the environment on which life depends; or (c) constitute or may constitute a danger in Canada to human life or health"

[3] Date that the final screening assessment was published in the *Canada Gazette*

[4] NA – not applicable

[5] NFA – no further action

Table 7. Canadian Environmental Quality Guidelines published or under development from April 2022 to March 2023

Environmental compartment	Published	Under development
Water		• Nickel (ECCC provides technical expertise based on experience with similar guidelines, conducts reviews) • Neonicotinoid Pesticides (4) (ECCC conducts reviews) • Polycyclic aromatic hydrocarbons(PAHs) and alkyl substituted PAHs (ECCC leading development of guidelines) • Perfluorooctanoic acid (PFOA) (ECCC developing the guidelines)
Soils		• Perfluorooctanoic acid (PFOA) (ECCC developing the guidelines)
Groundwater		• Guidelines for n = 99 substances • Perfluorooctanoic acid (PFOA) (ECCC developing the guidelines)
Soil vapour		• Guidelines for n = 41 substances (being developed by Ontario; ECCC and HC provide scientific support on guideline development approach and input values)

Table 8. Federal Environmental Quality Guidelines published or under development from April 2022 to March 2023

Environmental compartment	Published	Under development
Water	Aluminum D4 Siloxane	• BTEX (benzene, toluene, ethylbenzene, xylene) • Iron* • Triclocarban* • Rare Earth Elements (REEs) (4)
Sediment	D4 Siloxane	• Triclocarban* • Rare Earth Elements (REEs) (4) • Tributyltin
Fish tissue	D4 Siloxane Selenium	
Wildlife diet	D4 Siloxane	
Bird egg	Selenium	

*Draft guidelines published for comments

Table 9. Significant new activity notices of intent for existing substances from April 2022 to March 2023

Substance	Publication date in the Canada *Gazette, Part I.*
Cyclohexanamine (CAS RN 108-91-8)	April 9, 2022
• Rosin (CAS RN 8050-09-7) • Tall-oil rosin (CAS RN 8052-10-6) • Resin acids and rosin acids (CAS RN 73138-82-6) • Resin acids and rosin acids, calcium salts (CAS RN 9007-13-0) • Resin acids and rosin acids, sodium salts (CAS RN 61790-51-0)	July 23, 2022
Thioperoxydicarbonic diamide ([(H2N)C(S)]2S2), tetramethyl- (CAS RN 137-26-8)	July 23, 2022
[1,1′-biphenyl]-2-ol, sodium salt (CAS RN 132-27-4)	November 19, 2022
Glycine, N,N-bis(carboxymethyl)-, trisodium salt (CAS RN 5064-31-3)	November 26, 2022

Table 10. Significant new activity orders for existing substances from April 2022 to March 2023

Order No.	Substance	Publication date in the *Canada Gazette, Part II.*
• 2022-87-24-01 • 2022-87-24-01 • 2022-87-24-01	Ethane, 1,2-dimethoxy- (CAS RN 110-71-4) Ethane, 1,1′-oxybis[2-methoxy- (CAS RN 111-96-6) 2,5,8,11-tetraoxadodecane (CAS RN 112-49-2)	August 3, 2022 August 3, 2022 August 3, 2022
• 2022-87-23-01	Hexanoic acid, 2-ethyl-, calcium salt (CAS RN 136-51-6)	August 17, 2022

Table 11. Notices of Ministerial conditions for new substances from April 2022 to March 2023

Ministerial Conditions No.	Substance	Publication date[1]
19916a[2]	Amines, C36-alkylenedi-	May 28, 2022
21069	2-Pyrrolidinone, 1-butyl-	May 28, 2022
21114	1,2-Ethanediol, 1,2-dibenzoate	July 16, 2022
21127	α-D-Glucopyranoside, 4-hydroxyphenyl	July 9, 2022
21184	Iron(1+), chloro[dimethyl 9,9-dihydroxy-3-methyl-2,4-di(2-pyridinyl-κN)-7-[(2-pyridinyl-κN)methyl]-3,7-diazabicyclo[3.3.1]nonane-1,5-dicarboxylate-κN3,κN7]-, chloride (1:1)	November 5, 2022
21193	Carbopolycycle, acid-treated, oxidized, silver-doped	August 13, 2022
21194	Carbopolycycle, acid-treated, oxidized	August 27, 2022
21235	1,2-Ethanediamine, N-(2-aminoethyl)-, reaction products with glycidyl p-tolyl ether	February 18, 2023
21256	1-Propanaminium, 3-amino-N-(carboxymethyl)-N,N-dimethyl-, N-C8-18 acyl derivs., inner salts	December 10, 2022
21280	1-Propanaminium, N-(3-aminopropyl)-2-hydroxy-N,N-dimethyl-3-sulfo-, N-(C12-18 and C18-unsatd. acyl) derivs., inner salts	March 11, 2023
21338	Sulfonic acids, branched alkane hydroxy and branched alkene, sodium salts	January 21, 2023

[1] Date on which the Final Notice published in the *Canada Gazette, Part I*.

[2] Variation to a Notice of Ministerial Conditions.

Table 12. Significant new activity notices and order for new substances issued from April 2022 to March 2023

SNAc Notice No.	Substance	Publication date[1]
20948	1-Hexanamine, 2-ethyl-N,N-bis(2-ethylhexyl)-	April 2, 2022
21033	Fatty acids, coco, hydrogenated, reaction products with 2-[(2-aminoethyl)amino] ethanol and sodium 2-chloroacetate (1:1), sodium salts	April 16, 2022
20996	2-Furancarboxylic acid	June 18, 2022
21064	Alkanoic acid, trialkyl-, mixed polyesters with alkylalkanoic acid and poly(substituted alkyl)alkanepolyol	July 9, 2022

[1] Date on which the Final Notice or Order published in the *Canada Gazette, Part I*.

Table 13. Living organisms deleted from the Domestic Substances List

Confidential substance identity number	Inanimate biotechnology product and living organism
13637-2	**Name:** Complex microbial culture **Source:** Coastal marine waters of the Gulf of Mexico **History:** Grown in a specialized medium **Characteristics:** Spiral and rod-shaped microorganisms that are, in the fresh product, found in a proportion of 1:10 **Use:** Bioremediation of oil field production systems, waste streams, grease traps and various hazardous waste sites in Canada

Table 14. Significant new activity orders for existing living organisms from April 2022 to March 2023

Order No.	Substance	Date Published in the Canada *Gazette, Part II.*
2021-112-21-01	*Aspergillus awamori* (ATCC 22342)	June 22, 2022
2021-112-21-01	*Aspergillus brasiliensis* (ATCC 9642)	June 22, 2022

Table 15. Guideline documents for Canadian drinking water quality from April 2022 to March 2023

Published final guidelines	In progress*
• Guidelines for Canadian Recreational Water Quality: Physical, Aesthetic and Chemical Characteristics (June 2022) • Guidance on Waterborne Pathogens in Drinking Water (September 2022) • Guidelines for Canadian Drinking Water Quality: Dimethoate and Omethoate (September 2022) • Guidelines for Canadian Drinking Water Quality: Malathion (January 2023) • Canadian Recreational Water Quality Guidelines: Indicators of Fecal Contamination (February 2023) • Canadian Recreational Water Quality Guidelines: Guidelines for Understanding and Managing Risks in Recreational Waters (March 2023) • Guidelines for Canadian Drinking Water Quality: Boron (March 2023)	• Draft Guidelines for Canadian Recreational Water Quality: Microbiological Pathogens and Biological Hazards (November 2022) • Draft Guidance on Sampling and Mitigation Measures for Controlling Corrosion (February 2023) • Draft Objective for Per- and Polyfluoroalkyl Substances in Canadian Drinking Water (February 2023) • Draft Guidelines for Canadian Drinking Water Quality – Antimony (March 2023)

*In progress refers to guidelines published for consultation

Table 16. Disposal at sea quantities permitted (in tonnes) and permits issued from April 2022 to March 2023

Material	Quantity by region			Total quantity permitted	Permits by region			Total permits issued
	Atlantic	Quebec and Prairie and Northern	Pacific and Yukon		Atlantic	Quebec and Prairie and Northern	Pacific and Yukon	
Dredge material	1 304 940	523 900	3 608 800	5 437 640	14	14	22	50
Fisheries waste	26 520	1 150		27 670	25	3		28
Geological matter			3 129 100	3 129 100			20	20
Vessels								
Organic matter	350			350	2			2
Total				**8 594 760**				**100**

Note: Dredged material and geological matter were converted to tonnes using an assumed density of 1.3 tonnes per cubic metre.

Table 19. Number of inspections, investigations and enforcement measures taken under CEPA from April 2022 to March 2023

Regulation	Inspections			Investigations[1]			Enforcement measures[2]					
	On-site	**Off-site**	**Total**	Started **prior** to fiscal year and ongoing	**Started** during fiscal year	**Ended** in fiscal year	**Written warnings[3]**	**EPCOs[3]**	**AMPs[3]**	**Other Enforcement measures[4]**	**Total**	Number of **subjects** involved in EPCOs[5]
Total	**835**	**271**	**1 106**	**19**	**9**	**12**	**163**	**50**	**196**	**4**	**413**	**54**
2-Butoxyethanol Regulations	9	2	**11**		2	1		3			**3**	4
Benzene in Gasoline Regulations	21	2	**23**									
CEPA – various section(s)	59	5	**64**	5	2	2	10	9	47	1	**67**	9
Chromium Electroplating, Chromium Anodizing and Reverse Etching Regulations	24	4	**28**				8				**8**	
Concentration of Phosphorus in Certain Cleaning Products Regulations	2	1	**3**				1	3			**4**	3
Cross Border Movement of Hazardous Waste and Hazardous Recyclable Material Regulations	62	26	**88**				4	2	11		**17**	3
Disposal at Sea Regulations	17	43	**60**				6				**6**	
Environmental Emergency Regulations	119	28	**147**	1	1		12	4			**16**	3

Regulation	Inspections			Investigations[1]			Enforcement measures[2]					
	On-site	**Off-site**	**Total**	Started **prior** to fiscal year and ongoing	**Started** during fiscal year	**Ended** in fiscal year	**Written warnings**[3]	**EPCOs**[3]	**AMPs**[3]	**Other Enforcement measures**[4]	**Total**	Number of **subjects** involved in EPCOs[5]
Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations	8	3	**11**			1	3		5		**8**	
Export of Substances on the Export Control List Regulations	2	2	**4**				1				**1**	
Federal Halocarbon Regulations, 2022	40	14	**54**				2		2		**4**	
Federal Halocarbon Regulations, 2003	10	4	**14**			1	6		1		**7**	
Fuels Information Regulations, No. 1	5	1	**6**									
Gasoline and Gasoline Blend Dispensing Flow Rate Regulations	1		**1**									
Gasoline Regulations	11		**11**				7				**7**	
Interprovincial Movement of Hazardous Waste Regulations	3		**3**									

Regulation	Inspections			Investigations[1]			Enforcement measures[2]					
	On-site	Off-site	Total	Started **prior** to fiscal year and ongoing	**Started** during fiscal year	**Ended** in fiscal year	Written warnings[3]	EPCOs[3]	AMPs[3]	Other Enforcement measures[4]	Total	Number of **subjects** involved in EPCOs[5]
Marine Spark-Ignition Engine, Vessel and Off-Road Recreational Vehicle Emission Regulations	1		**1**									
Microbeads in Toiletries Regulations	44		**44**				8	9			**17**	10
Multi-Sector Air Pollutants Regulations		1	**1**									
National Pollutant Release Inventory	13	4	**17**				1				**1**	
New Substances Notification Regulations (Chemicals and Polymers)	2	1	**3**				1				**1**	
Notice s.56 for a Pollution prevention plan	8	7	**15**									
Off-Road Compression-Ignition Engine Emission Regulations	13	3	**16**	2			3		7		**10**	
Off-Road Compression-Ignition (Mobile and Stationary) and Large Spark-Ignition Engine Emission Regulations	38	4	**42**				3		108		**111**	

Regulation	Inspections			Investigations[1]			Enforcement measures[2]					
	On-site	**Off-site**	**Total**	Started **prior** to fiscal year and ongoing	**Started** during fiscal year	**Ended** in fiscal year	**Written warnings**[3]	**EPCOs**[3]	**AMPs**[3]	**Other Enforcement measures**[4]	**Total**	Number of **subjects** involved in EPCOs[5]
Off-Road Small Spark-Ignition Engine Emission Regulations	8	3	**11**	1	1		2		1		**3**	
On-Road Vehicle and Engine Emission Regulations	2	1	**3**	1								
Ozone-depleting Substances and Halocarbon Alternatives Regulations	34	9	**43**				20			2	**22**	
PCB Regulations	30	19	**49**	4	1		3	2		1	**6**	4
PCB Waste Export Regulations, 1996												
Products Containing Mercury Regulations	3	3	**6**				1				**1**	
Prohibition of Asbestos and Products Containing Asbestos Regulations	11	1	**12**					1			**1**	1
Prohibition of Certain Toxic Substances Regulations, 2012	6		**6**	1			1	4			**5**	4
Pulp and Paper Mill Defoamer and Wood Chip Regulations		4	**4**									

Regulation	Inspections			Investigations[1]			Enforcement measures[2]					
	On-site	Off-site	Total	Started **prior** to fiscal year and ongoing	**Started** during fiscal year	**Ended** in fiscal year	Written warnings[3]	EPCOs[3]	AMPs[3]	Other Enforcement measures[4]	Total	Number of **subjects** involved in EPCOs[5]
Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations		8	**8**									
Renewable Fuels Regulations	20		**20**	1			2				**2**	
Solvent Degreasing Regulations	5	1	**6**				1				**1**	
Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations	75	37	**112**	3		2	20	5	14		**39**	5
Sulphur in Diesel Fuel Regulations	30	4	**34**				2				**2**	
Sulphur in Gasoline Regulations	21	2	**23**				1				**1**	
Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations	70	24	**94**			1	30	1			**31**	1
Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations	5		**5**		1	2	1	5			**6**	5

Regulation	Inspections			Investigations[1]			Enforcement measures[2]					
	On-site	**Off-site**	**Total**	Started **prior** to fiscal year and ongoing	**Started** during fiscal year	**Ended** in fiscal year	**Written warnings**[3]	**EPCOs**[3]	**AMPs**[3]	**Other Enforcement measures**[4]	**Total**	Number of **subjects** involved in EPCOs[5]
Volatile Organic Compound (VOC) Concentration Limits for Automotive Refinishing Products Regulations	3		**3**		1	2	3	2			**5**	**2**

[1] Investigations are tabulated by the number of investigation files at the regulation level, based on the start or end date of the investigation. An investigation may be counted under 1 or more regulations.

[2] Enforcement measures issued between April 1, 2022 and March 31, 2023. Note that the initial inspection may have been conducted in a different fiscal year than when the measure was issued.

[3] Written warnings, Environmental Protection Compliance Orders (EPCOs) and Administrative Monetary Penalties (AMPs) are tabulated by number of measures issued at the regulation level. For example, if 1 warning is issued for 2 different regulations, the number of warnings is 2.

[4] This category includes enforcement measures that were rarely issued during 2022-23. It includes 2 Prosecutions (one issued under the *CEPA Sections Regulations* and the other under PCB Regulations) and 2 Tickets issued under the *Ozone-depleting Substances and Halocarbon Alternatives Regulations*.

[5] The number of subjects involved in EPCOs is represented by the number of regulatees issued EPCOs, regardless of the number of sections. For example, if 1 regulatee was issued an EPCO for 3 sections of the PCB Regulations, the number of subjects involved is 1.

Table 20. Prosecutions, number of tickets and Administrative Monetary Penalties (AMPs) with associated penalty amounts issued between April 2022 and March 2023

Instrument	Prosecutions		Number of Tickets	Number of Administrative Monetary Penalty (AMPs)	Penalty Amounts ($)		
	Number of Convicted Subjects[1]	Number of Guilty Counts[2]			Fines (Convictions and Tickets)	Administrative Monetary Penalty (AMPs)	Total Penalty Amount[3]
Total	**3**	**3**	**2**	**196**	**$466,515**	**$199,600**	**$666,115**
CEPA – various section(s)				47		$61,600	$61,600
Cross Border Movement of Hazardous Waste and Hazardous Recyclable Material Regulations				11		$44,800	$44,800
Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations				5		$10,000	$10,000
Federal Halocarbons Regulations, 2003				1		$5,000	$5,000
Federal Halocarbons Regulations, 2022				2		$6,000	$6,000
Off-road Compression-Ignition (Mobile and Stationary) and Large Spark-Ignition Engine Emission Regulations				108		$47,200	$47,200
Off-Road Compression-Ignition Engine Emission Regulations				7		$10,000	$10,000

Instrument	Prosecutions		Number of Tickets	Number of Administrative Monetary Penalty (AMPs)	Penalty Amounts ($)		
	Number of Convicted Subjects[1]	Number of Guilty Counts[2]			Fines (Convictions and Tickets)	Administrative Monetary Penalty (AMPs)	Total Penalty Amount[3]
Off-Road Small Spark-Ignition Engine Emission Regulations				1		$1,000	$1,000
Ozone-depleting Substances and Halocarbon Alternatives Regulations			2		$1,515		$1,515
PCB Regulations	2	1			$15,000		$15,000
Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations	2	2		14	$450,000	$14,000	$464,000

[1] The number of subjects convicted during the reporting period, based on date sentenced.

[2] The number of sections of legislation or regulations, for which there was a charge or conviction during the reporting period. For example, if 1 person is charged with 2 counts under CEPA, this is considered 1 charge laid against the subject and 2 counts.

[3] A total of $664,600 of the CEPA penalty amounts have been directed to the Environmental Damages Fund in 2022-23.

Table 21. Percentage of reductions of air pollutants from 1990-2021 from major sources

Source	Pollutant	Percentage decrease 1990-2021
Non-ferrous refining and smelting • closures of outdated smelters and effective risk management (including implementation of pollution prevention measures)	Hg	99%
	Cd	97%
	SO_x	95%
	Pb	93%
Home firewood burning • reduction in wood consumption and adoption of more efficient wood combustion equipment	$PM_{2.5}$	46%
	VOC	42%
	CO (carbon monoxide)	37%
	PAH (polycyclic aromatic hydrocarbons)	32%

Coal-fired electric power generation • phasing out of coal-fired plants that are replaced by lower-emission sources	HCB (hexachlorobenzene)	98%
	Hg	76%
	SO_x	69%
Light-duty gasoline trucks and vehicles • effective fuel and engine regulations	NO_x	89%
	PAH	82%
Transportation associated with combustion of gasoline • effective fuel and engine regulations	CO	72%
	VOCs	68%
Waste incineration • improvements in incineration technologies	Dioxins and Furans	70%
	HCB	36%

Annex – Research Publications

A comprehensive list of all of the research published in the 2022-2023 reporting year by ECCC and HC, including the work already highlighted in section 7 of this report, appears below. Publications in the bibliography contain either the Digital Object Identifier (DOI) or International Standard Book Number (ISBN). Copy and paste the DOI or ISBN into your search browser to be directed to an online publication of the research.

Chemical substances and living organisms

Environment and Climate Change Canada

Chemical substances in the environment

Barton-Maclaren, T.S., Wade, M., Basu, N., Bayen, S., Grundy, J., Marlatt V., Moore, R., Parent L., Parrott, J., Grigorova, P., Pinsonnault-Cooper, J., Langlois, V.S. 2022. *Innovation in regulatory approaches for endocrine disrupting chemicals: The journey to risk assessment modernization in Canada*. Environmental Research, Vol. 204, Part C, DOI: 10.1016/j.envres.2021.112225

Belontz, S.L., Corcoran, P.L., de Haan-Ward, J., Helm, P.A., Marvin, C. 2022. *Factors driving the spatial distribution of microplastics in nearshore and offshore sediment of Lake Huron, North America*. Marine Pollution Bulletin, Vol. 179, DOI: 10.1016/j.marpolbul.2022.113709

Castilloux, A.D., Houde, M., Gendron, A., De Silva, A., Soubaneh, Y.D., Lu, Z. 2022. *Distribution and Fate of Ultraviolet Absorbents and Industrial Antioxidants in the St. Lawrence River, Quebec, Canada*. Environmental Science & Technology Vol. 56, Issue 8, pp 5009-5019, DOI: 10.1021/acs.est.1c07932

Chételat, J., McKinney, M.A., Amyot, M., Dastoor, A., Douglas, T.A., Heimbürger-Boavida, L-E., Kirk, J., Kahilainen, K.K., Outridge, P.M., Pelletier, N., Skov, H., St. Pierre, K., Vuorenmaa, J., Wang, F. 2022. *Climate change and mercury in the Arctic: Abiotic interactions*. Science of The Total Environment, Volume 824, DOI: 10.1016/j.scitotenv.2022.153715

Chibwe, L., De Silva, A.O., Spencer, C., Teixera, C.F., Williamson, M., Wang, X., Muir, D.C.G. 2023. *Target and nontarget screening of organic chemicals and metals in recycled plastic materials.* Environmental Science & Technology Vol. 57, Issue 8, pp 3380-3390, DOI: 10.1021/acs.est.2c07254

Gagné, F. 2022. *Isolation and Quantification of Polystyrene Nanoplastics in Tissues by Low Pressure Size Exclusion Chromatography*. Journal of Xenobiotics Vol. 12, Issue 2, pp 109-121 DOI:10.3390/jox12020010

Houde, M., Krümmel, E.M., Mustonen, T., Brammer, J., Brown, T.M., Chételat, J., Dahl, P.E., Dietz, R., Evans, M., Gamberg, M., Gauthier, M-J., Gérin-Lajoie, J., Hauptmann, A.L., Heath, J.P., Henri, D.A., Kirk, J., Laird, B., Lemire, M., Lennert, A.E., Letcher, R.J., Lord, S., Loseto, L., MacMillan, G.A., Mikaelsson, S., Mutter, E.A., O'Hara, T., Ostertag, S., Robards, M., Shadrin, V., Smith, M., Stimmelmayr, R., Sudlovenick, E., Swanson, H., Thomas, P.J., Walker, V.K., Whiting, A. 2022. *Contributions and perspectives of Indigenous Peoples to the study of mercury in the Arctic.* Science of The Total Environment, Vol. 841, DOI: 10.1016/j.scitotenv.2022.156566

Hung, H., Halsall, C., Ball, H., Bidleman, T., Dachs, J., De Silva, A., Hermanson, M., Kallenborn, R., Muir, D., Sühring, R., Wang, X., Wilson, S. 2022. *Climate change influence on the levels and trends of persistent organic pollutants (POPs) and chemicals of emerging Arctic concern (CEACs) in the Arctic physical environment – a review*. Environmental Science: Processes & Impacts, Vol. 24, Issue 10, pp 1577-1615, DOI:10.1039/D1EM00485A

Lohmann, R., Letcher, R.J. 2023. *The universe of fluorinated polymers and polymeric substances and potential environmental impacts and concerns*. Current Opinion in Green and Sustainable Chemistry, Vol. 41, Article #: 100795, DOI: /10.1016/j.cogsc.2023.100795

MacInnis, J., De Silva, A.O., Lehnherr, I., Muir, D.C.G., St. Pierre, K.A., St. Louis, V.L., Spencer, C. 2022. *Investigation of perfluoroalkyl substances in proglacial rivers and permafrost seep in a high Arctic watershed*. Environmental Science: Processes and Impacts, Vol. 24, Issue 1, pp 42-51, DOI:10.1039/D1EM00349F

Turcotte, P., Smyth, S.A., Gagné, F., Gagnon, C. 2022. *Lanthanides Release and Partitioning in Municipal Wastewater Effluents.* Toxics Vol. 10, Issue 5, pp 254-267, DOI: 10.3390/toxics10050254

Vorkamp, K., Carlsson, P., Corsolini, S., de Wit, C.A., Dietz, R., Gribble, M.O., Houde, M., Kalia, V., Letcher, R.J., Morris, A., Rigét, F.F., Routti, H., Muir, D.C.G. 2022. *Influences of climate change on long-term time series of persistent organic pollutants (POPs) in Arctic and Antarctic biota*. Environmental Science: Processes & Impacts, Vol. 24, Issue 10, DOI: 10.1039/D2EM00134A

Zhou, P., Li, Z., El-Dakhakhni, W., Smyth, S.A., 2022. Prediction of bisphenol A contamination in Canadian municipal wastewater. Journal of Water Process Engineering 50, 103304. DOI:10.1016/j.jwpe.2022.103304

Chemical substances in the water

Castilloux, A.D., Houde, M., Gendron, A., De Silva, A., Soubaneh, Y.D., Lu, Z. 2022. *Distribution and Fate of Ultraviolet Absorbents and Industrial Antioxidants in the St. Lawrence River, Quebec, Canada*. Environmental Science & Technology Vol. 56, Issue 8, pp 5009-5019, DOI:10.1021/acs.est.1c07932

Chibwe, L., De Silva, A.O., Spencer, C., Teixera, C.F., Williamson, M., Wang, X., Muir, D.C.G. 2023. *Target and nontarget screening of organic chemicals and metals in recycled plastic materials.* Environmental Science & Technology Vol. 57, Issue 8, pp 3380-3390, DOI: 10.1021/acs.est.2c07254

Turcotte, P., Smyth, S.A., Gagné, F., Gagnon, C. 2022. *Lanthanides Release and Partitioning in Municipal Wastewater Effluents.* Toxics Vol. 10, Issue 5, pp 254-267, DOI: 10.3390/toxics10050254

Zhou, P., Li, Z., El-Dakhakhni, W., Smyth, S.A.. 2022. *Prediction of bisphenol A contamination in Canadian municipal wastewater*. Journal of Water Process Engineering, Vol. 50, 103304. DOI: 10.1016/j.jwpe.2022.103304

Chemicals and effects in wildlife, fish and associated food webs and ecosystems

Bouffard, J., Careau, V., Robinson, S.A., Bergeron, P. 2022. *Effects of a neonicotinoid insecticide and population density on behavior and development of wood frogs (Rana sylvatica)*. Environmental Toxicology and Chemistry, Vol. 41, Issue 12, pp. 2968-2980, DOI: 10.1002/etc.5477

Baak, JE, RM Lacombe, ES Choy, KH Elliott, JE Elliott (2023*) Interactions between Climate Change and Contaminants,* Climate Change and Animal Health, pp. 157-180, ISBN:9781003149774

Bean T.G., V.R. Beasley, P. Berny, K.M. Eisenreich, J.E. Elliott, M.L .Eng, ... (2023) *Toxicological Effects Assessment for Wildlife in the 21st Century: Review of Current Methods and Recommendations for a Path Forward*. Integrated Environmental Assessment and Management. DOI: 10.1002/ieam.4795

Bishop Christine A., Simon G. English, France Maisonneuve, Alison J. Moran, Heather A. Higo, Julia Common, Kristina G. Hick, John E. Elliott. (2022). (2018, 2019). Environmental Advances. 8 DOI: 10. *Temporal and spatial patterns of systemic insecticides in avian and insect pollinators and flowers in western Canada* DOI: 1016/j. envadv.2022.100211

Chibwe, L., Parrott, J.L., Shires, K., Khan, H., Clarence, S., Lavalle, C., Sullivan, C., O'Brien, A.M., De Silva, A.O., Muir, D.C.G., Rochman, C.M. 2022. *A Deep Dive into the Complex Chemical Mixture and Toxicity of Tire Wear Particle Leachate in Fathead Minnow.* Environmental Toxicology, Vol. 41, Issue 5, pp 1144-1153, DOI: 10.1002/etc.5140

Choy, E.S., Blight, L.K., Elliott, J.E., Hobson, K.A., Zanuttig, M. and Elliott, K.H. (2022). *Stable Mercury Trends Support a Long-Term Diet Shift Away from Marine Foraging in Salish Sea Glaucous-Winged Gulls over the Last Century*. Environmental Science & Technology. 56(17). DOI: 10.1021/acs.est.1c03760

Ciesielski, T.M., Sonne, C., Smette, E.I., Villanger, G.D., Styrishave, B., Letcher, R.J., Hitchcock, D.J., Dietz, R., Jenssen, B.M. 2023. *Testosterone and persistent organic pollutants in East Greenland male polar bears (Ursus maritimus*). Helyion, Vol. 9, Article #e13263. DOI: 10.1016/j.heliyon.2023.e13263

Elliott, John E., Kesic, Robert., Lee, Sandi. L, Elliott, Kyle H. (2023). *Temporal trends of legacy persistent organic pollutants (POPs) in seabird eggs from the northeast Pacific: is it finally twilight for old POPs*? Science of the Total Environment. DOI: 10.1016/j.scitotenv.2022.160084

English, S.G., Hess, H., Bishop, C.A., Porter, E., Cheng, K.M. and Elliott, J.E. (2022). *Bioaccumulation and effects of selenium from surface coal mining in an aquatic songbird*. Environmental Research. 208 DOI: 10.1016/j.envres.2022.112702

Ewald, J.D., Basu, N., Crump, D., Boulanger, E., Head, J. 2022. *Characterizing variability and uncertainty associated with transcriptomic dose-response modeling.* Environmental Science and Technology. Vol. 56, Issue 22, pp 15960-15968, DOI: 10.1021/acs.est.2c04665

Goodchild, C.G., Karouna-Renier, N.K., Braham, R.P., Henry, P.F.P., Letcher, R.J. Fernie, K.J. 2022. *Hepatic gene expression profiling of American kestrels (Falco sparverius) exposed in ovo to three alternative brominated flame retardants (BTBPE, EHTBB, and TBPH).* Biology, Vol, 11, 1341, DOI:10.3390/biology11091341

Hanana, H., Gagné, F., Trottier, S., Bouchard, P., Farley, G., Auclair, J., Gagnon, C. 2022. *Assessment of the toxicity of a mixture of five rare earth elements found in aquatic ecosystems in Hydra vulgaris*. Ecotoxicology and Environmental Safety, Vol. 241, DOI: 10.1016/j.ecoenv.2022.113793

Hebert, C.E., Letcher, R.J., Cyr, F., Drake, C. 2022. *Fatty acid ecological tracers highlight the role of diet in perfluoroalkyl acid contaminant exposure in eggs of an omnivorous bird*. Journal of Great Lakes Research, Vol. 48, pp 1270-1277. DOI: /10.1016/j.jglr.2022.08.010

Hebert C.E., Burgess N.M., Elliott J.E. (2022). *Temporal trends in levels of essential omega-3 fatty acids in Atlantic and Pacific food webs as measured in Leach's storm-petrel (oceanodroma leucorhoa) eggs*. Marine Ecology Progress Series. 684: 199-210. DOI: 10.3354/meps13955

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Hopkins, K., McKinney, M.A., Letcher, R.J., Fernie, K.J. 2023. *The influence of environmental and ecological factors on the accumulation and distribution of short- and long-chain perfluoroalkyl acids in a mid-trophic avian insectivore*. Environmental Pollution, Vol, 321, 121133, DOI: 10.1016/j.envpol.2023.121133

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Jeon, Y.S., Crump, D., Boulanger, E., Soufan, O., Park, B., Basu, N., Hecker, M., Xia, J., Head, J. 2022. *Hepatic transcriptomic responses to ethinylestradiol in two life stages of japanese quail*. Environmental Toxicology and Chemistry. Vol. 41, Issue 11, pp 2769-2781, DOI: 10.1002/etc.5464

Johnson, K.J., Auerbach, S.S., Stevens, T., Barton-Maclaren, T.S., Costa, E., Currie, R.A., Dalmas Wilk, D., Haq, S., Rager, J.E., Reardon, A.J.F., Wehmas, L., Williams, A., O'Brien, J., Yauk, C., LaRocca, J.L., Pettit, S. 2022. *A*

transformative vision for an omics-based regulatory chemical testing paradigm. Toxicological Sciences. Vol. 190, Issue 2, pp 127-132, DOI: 10.1093/toxsci/kfac097

King M.D., J.E. Elliott, I. Idowu, G.T. Tomy, T.D. Williams (2023) *Polycyclic aromatic compound and trace metal element residues in Mytilus mussels at marine wildlife hotspots on the Pacific coast of Canada.* Environmental Pollution 316, 120624. DOI: 10.1016/j.envpol.2022.120624

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Mancuso, K., Hodges, K. E., Grosselet, M., Elliott, J. E., Alexander, J. D., Zanuttig, M., & Bishop, C. A. (2022). *Mercury toxicity risk and corticosterone levels across the breeding range of the Yellow-breasted Chat.* Ecotoxicology. 31: 234-250. DOI: 10.1007/s10646-021-02510-6

McKinney, M.A., Chételat, J., Burke, S.M., Elliott, K.H., Fernie, K.J., Houde. M., Kahilainen, K.K., Letcher, R.J., Morris, A.D., Muir, D.C.G., Routti, H., Yurkowski, D.J. 2022. *Climate change and mercury in the Arctic: Biotic interactions.* Science of The Total Environment, Vol. 834, DOI: 10.1016/j.scitotenv.2022.155221

Munoz, G., Mercier, L., Duy, S.V., Liu, J., Sauvé, S., Houde, M. 2022. *Bioaccumulation and trophic magnification of emerging and legacy per- and polyfluoroalkyl substances (PFAS) in a St. Lawrence River food web*. Environmental Pollution, Vol. 309, DOI: 10.1016/j.envpol.2022.119739

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Parrott, J.L, Restivo, V.E., Kidd, K.A., Zhu, J., Shires, K., Clarence, S., Khan, H., Sullivan, C., Pacepavicius, G., Alaee, M. 2022. *Chronic Embryo-Larval Exposure of Fathead Minnows to the Pharmaceutical Drug Metformin: Survival, Growth, and Microbiome Responses*. Environmental Toxicology Vol. 41, Issue 3, pp 635-647, DOI: 10.1002/etc.5054

Rattner, B. A., Bean, T. G., Beasley, V. R., Berny, P., Eisenreich, K. M., Elliott, J. E., ... & Salice, C. J. (2023). Wildlife ecological risk assessment in the 21st century: Promising technologies to assess toxicological effects. *Integrated Environmental Assessment and Management*. DOI: 10.1002/ieam.4806

Ruberg, E.J., King, M.D., Elliott, J.E., Tomy, G.T., Idowu, I., Vermette, M.L. and Williams, T.D. (2022). *Effects of diluted bitumen exposure on the survival, physiology, and behaviour of zebra finches (Taeniopygia guttata)*. Ecotoxicology & Environmental Safety. DOI: 10.1016/j.ecoenv.2021.113071

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Schutten, K., Chandrashekar, A., Bourdages, M., Bowes, V., Elliott, J., Lee, S. (2023) *Assessing plastic ingestion in birds of prey from British Columbia, Canada,* Environmental Science and Pollution Research, 1-9. DOI: 10.1007/s11356-023-27830-4

van der Vegt, R., Maguire, S., Crump, D., Hecker, M., Basu, N., Hickey, G. 2022. *Chemical Risk Governance: Exploring Stakeholder Participation in Canada, the USA, and the EU*. Ambio. Vol 51, Issue 7, pp 1698-1710, DOI: 10.1007/s13280-021-01671-2

Vorkamp, K., Carlsson, P., Corsolini, S., de Wit, C., Dietz, R., Gribble, M.O., Houde, M., Kalia, V., Letcher, R.J., Morris, A.D., Rigét, F.F., Routti, H., Muir, D.C.G. 2022. *Influences of climate change on long-term time series of persistent*

organic pollutants (POPs) in Arctic and Antarctic biota Special Issue-Environmental Science, Processes and Impacts, Vol. 24, Article #1643. DOI: /10.1039/d2em00134a

Biological Assessment and Standardization Section. 2023. *Toxicity and Application of New Approach Methodologies (NAM) for Measurement of Effects from Exposure to Organic and Inorganic Complexes of Rare Earth Elements in Soil*. Technical research report. Environment and Climate Change Canada, Ottawa, Ontario

Multiple approaches including non-target analysis (NTA) to understand chemical biotransformation and protein adduction in biota

Herczegh, S.M., Chu, S.G., Letcher, R.J. 2023. *Biotransformation and metabolites of bisphenol-A bis(diphenyl phosphate): in vitro, in silico, and non-target screening in rat and bird liver microsomal models.* Chemosphere, Vol. 310, Article #136796**,** DOI: 10.1016/j.chemosphere.2022.136796

Letcher, R.J., Chu, S.G. 2023. *Bottom-up proteomics analysis for adduction of the broad spectrum herbicide atrazine to histone.* Analytical and Bioanalytical Chemistry, Vol. 415, pp. 1497–1504. DOI: 10.1007/s00216-023-04545-6

Nanomaterials

Auclair, J., Gagné, F. 2022. *Shape-Dependent Toxicity of Silver Nanoparticles on Freshwater Cnidarians.* Nanomaterials Vol. 12, Issue 18, pp 3107-3115, DOI: 10.3390/nano12183107

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Samarajeewa, A., Velicogna, J., Schwertfeger, D., Meier, M., Subasinghe, R., Princz, J., Scroggins, R., Beaudette, L. 2023. *Cerium oxide nanoparticles ($NCeO_2$) exert minimal adverse effects on microbial communities in soils with and without biosolids amendment.* Environmental Science and Pollution Research, Vol. 30, pp 72336-72353, DOI: 10.1007/j.espr.2023.s11356-023-27313-6

Chemical substances in the atmosphere

Araujo, B.F., Osterwalder, S., Szponar, N. et al. 2022. *Mercury isotope evidence for Arctic summertime re-emission of mercury from the cryosphere.* Nat Commun 13, 4956, DOI: 10.1038/s41467-022-32440-8

Bonnie M. Hamilton, Liisa Jantunen, Melanie Bergmann, Katrin Vorkamp, Julian Aherne, Kerstin Magnusson, Dorte Herzke, Maria Granberg, Ingeborg G. Hallanger, Alessio Gomiero, and Ilka Peeken. 2022. *Microplastics in the atmosphere and cryosphere in the circumpolar North: a case for multicompartment monitoring*. Arctic Science. 8(4): 1116-1126, DOI: 10.1139/as-2021-0054

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Health Canada

Chemical substances in Canadians

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