CANADIAN ENVIRONMENTAL PROTECTION ACT, 1999

Annual Report to Parliament for April 2020 to March 2021

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

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Environment and Climate Change Canada
Public Inquiries Centre
12th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 819-938-3860
Toll Free: 1-800-668-6767 (in Canada only)
Email: enviroinfo@ec.gc.ca

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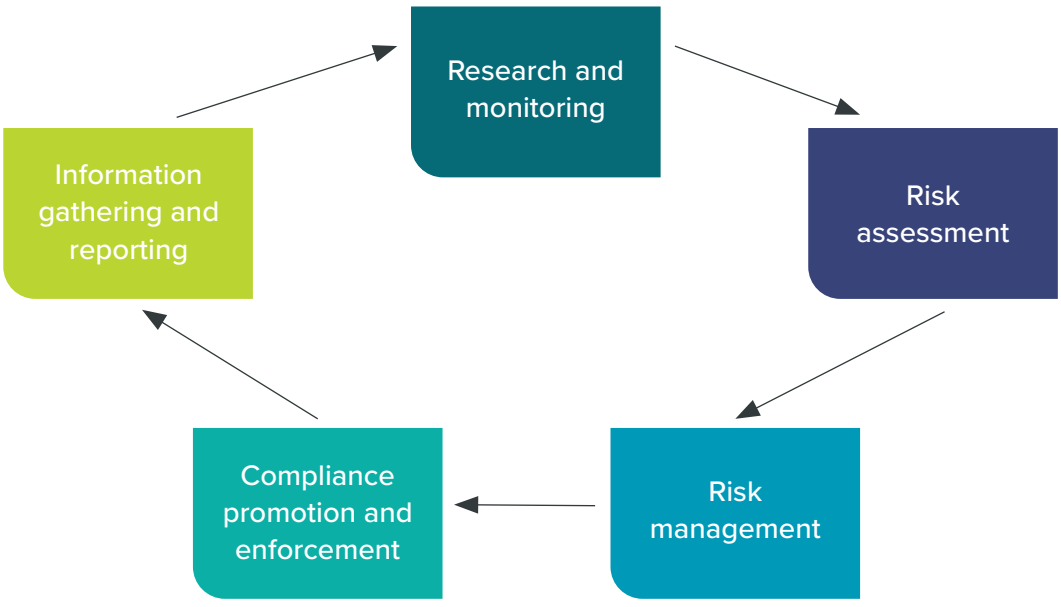
1. Introduction

This annual report provides an overview of the activities conducted and results achieved under the *Canadian Environmental Protection Act, 1999* (CEPA) from April 1, 2020, to March 31, 2021 by both Environment and Climate Change Canada (ECCC) and Health Canada (HC). It responds to the statutory requirement in section 342 of the Act to provide annual reports to Parliament on the administration and enforcement of the Act.

CEPA provides 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. For the most part, it functions as an enabling statute, providing a suite of instruments and measures for identifying, assessing and addressing risks.

The general steps followed to address each risk constitute a management cycle (see Figure 1). At each stage of the cycle, stakeholders are engaged, the public has an opportunity to be involved and exercise their procedural rights, and the government works closely with domestic and international jurisdictions and agencies.

Figure 1. CEPA management cycle



This report provides information on all stages of the management cycle. Section 2, “Monitoring the environment and human health”, covers 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. Section 3, “Addressing key risks”, covers information gathering, risk assessment, and risk management for substances, air pollution and greenhouse gases, water quality, and waste. Section 4, “Reporting programs and emission inventories”, covers information on releases of pollutants and greenhouse gases. Section 5, “Administration and public participation”, covers stakeholder engagement and inter-jurisdictional relationships. The report also includes Section 6, “Compliance promotion and enforcement” and Section 7, “Report of research”.

This report includes the following mandatory information:

- enforcement activities (section 6)
- research (section 7)
- activities of the National Advisory Committee (section 5.1)
- activities under administrative and equivalency agreements (section 5.1)

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.

The online CEPA Registry is a comprehensive source of information about activities taking place under the Act, including proposed and existing policies, guidelines, codes of practice, government notices and orders, agreements, permits, and regulations.

1.1 Review of the Act

In 2020-2021, work continued in both ECCC and HC to implement the commitment made in the September 2020 Speech from the Throne to strengthen CEPA. As part of this work, ECCC and HC continued to move forward on commitments made in the government’s June 2018 follow-up report to the House of Commons Standing Committee on Environment and Sustainable Development in response to that Committee’s 2017 report on CEPA entitled *Healthy Environment, Healthy Canadians, Healthy Economy: Strengthening the Canadian Environmental Protection Act, 1999*. They also continued engagement on key issues, such as renewal of the Chemicals Management Plan (CMP) Post-2020 and the environmental protection gap on First Nations reserve lands.

2. Monitoring the environment and human health

Monitoring and surveillance activities allow experts to determine levels and trends of chemicals, air pollutants and wastes that may affect the environment and/or human health.

2.1 Chemicals in our environment

A broad range of monitoring activities for chemicals were conducted under the following programs:

- 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: monitoring and research on contaminants

Monitoring activities also support Canada's contribution to international efforts, including the:

- Canada-United States Great Lakes Water Quality Agreement
- Great Lakes Herring Gull Contaminants Monitoring Program
- Arctic Council's Arctic Monitoring and Assessment Programme and the Arctic Contaminants Action Program
- United Nations Economic Commission for Europe's Convention on Long-range Transboundary Air Pollution
- 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 (see Table 1). 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.

Table 1. Substances monitored in indicated media under the CMP Environmental Monitoring and Surveillance Program in 2020-2021

Air	Surface Water	Fish (whole body tissue)
Per- and polyfluoroalkyl substances (PFASs)	Per- and polyfluoroalkyl substances (PFASs)	Per- and polyfluoroalkyl substances (PFASs)
Polychlorinated biphenyls (PCBs)	Polychlorinated biphenyls (PCBs)	Polychlorinated biphenyls (PCBs)*
Polybrominated diphenyl ethers (PBDEs)	Polybrominated diphenyl ethers (PBDEs)	Polybrominated diphenyl ethers (PBDEs)
Other flame retardants	Other flame retardants	Other flame retardants
Organochlorine pesticides	Organochlorine pesticides	Organochlorine pesticides*
Dichlorodiphenyltrichloroethane (DDT) and metabolites	Dichlorodiphenyltrichloroethane (DDT) and metabolites	Dichlorodiphenyltrichloroethane (DDT) and metabolites*
Polycyclic aromatic hydrocarbons (PAHs)	Polycyclic aromatic hydrocarbons (PAHs)	Chlorinated alkanes
Chlorinated alkanes	Metals*	Metals (including mercury)
Metals*	BPA + alternatives	Organosiloxanes
N/A	Alkylphenols	N/A

* Sampled in Great Lakes Basin only

In 2020-2021, Environment and Climate Change Canada (ECCC) conducted limited monitoring and surveillance activities due to the pandemic and related suspension of some of the laboratory and fieldwork. For some environmental media like air, wildlife and aquatic biota, external collaborators did a portion of the sampling and sample analysis. For other media (such as, sediments) and for wastewater and biosolids, there was no sampling done due to restrictions on fieldwork. However, there was significant progress made on data analysis and reporting, through publication of manuscripts, for many CMP priority substances and/or groups of substances monitored in all environmental media as well as in wastewater and biosolids.

2.2 Chemicals in humans

Health Canada's (HC) human biomonitoring efforts continued in 2020-2021 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. Although ongoing collection of the CHMS was halted due to modernization efforts at Statistics Canada and subsequently due to the COVID-19 outbreak, the national biomonitoring program used samples collected in previous years to measure priority substances.

Other activities of the CHMS in 2020-2021 included the following.

- A trend analysis was conducted to examine the changes in chemical concentrations in Canadians over a 10-year period (2007 to 2017). Significant reductions in chemical concentrations included the plasticizer di-2-ethylhexyl phthalate (DEHP; 75% decrease), perfluorooctane sulfate (PFOS; 61% decrease), perfluorooctanoic acid (PFOA; 58% decrease), dimethylphosphate (DMP; 40% decrease), lead (33% decrease), and bisphenol A (BPA; 32% decrease).
- Laboratory analyses of samples from the CHMS biobank was ongoing, and will provide the first data for some chemicals, such as glyphosate, BPA replacements and time trends for other priority chemicals, such as fluoride.
- Eight biomonitoring fact sheets on priority chemicals were developed and will be released alongside the sixth biomonitoring report featuring results from CHMS cycle 6 in 2021-2022.
- The International Human Biomonitoring Guidance Values (i-HBM) Working Group was launched under the International Society of Exposure Science (ISES). The first virtual meeting was held and input was sought to develop a work plan and form a steering committee.

In addition, 82 journal articles that used the CHMS data were published during 2020-2021 with 23 articles authored by Health Canada researchers and the remainder authored by external researchers.

In December 2020, the first Report on Human Biomonitoring of Environmental Chemicals in Pooled Samples – Results of the Canadian Health Measures Survey Cycle 1 (2007 to 2009), Cycle 3 (2012 to 2013), Cycle 4 (2014 to 2015) and Cycle 5 (2016 to 2017) was released. This report presents the first set of pooled serum data from the national biomonitoring program collected as part of the CHMS and is the first nationally representative dataset in blood for these specific 90 persistent environmental chemicals.

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. The assessment of prenatal exposure to chemicals and establishment of national estimates of maternal and fetal exposures continued under MIREC (see section 7.1.2.3 for publications).

In 2020-2021, progress was made on the follow-up study MIREC-ENDO initiated in 2018 to study the effects of prenatal exposure to environmental chemicals on puberty and metabolic function in the child, as well as maternal health. In 2020-2021, participant recruitment, data collection and laboratory analysis of collected biospecimens were completed for Phase 1. The participant recruitment plan was revised to a questionnaire-based model due to COVID-19 restrictions, and was completed at home without in-person visits. Through the questionnaire, 437 families were recruited in Phase 1 and another 307 families have indicated interest. Phase 2 will be launched in the spring of 2022.

Monitoring in the North

Both ECCC and HC contribute 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 2020-2021, HC supported 5 human biomonitoring and health projects under the NCP. These projects addressed exposure to contaminants and links to country foods, nutritional status in multiple northern regions (Yukon, Northwest Territories, and Nunavik), and the development and evaluation of health communication tools.

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.

Air pollution

Ambient (outdoor) air quality monitoring informs air quality management in Canada, including tracking progress relative to the Canadian Ambient Air Quality Standards. The data is used for validation of numerical air quality prediction models, for evaluating the benefits and effectiveness of control measures, as well as for assessments of the impact of air pollution on Canadians and the environment.

ECCC monitors ambient air quality across the country through 2 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.

Data collected through NAPS, CAPMoN and other provincial, territorial and municipal monitoring stations are used to calculate air quality indicators. The air quality 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 air pollutant 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 in order 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.

The Air Quality Health Index (AQHI)

Data collected through these programs are used to determine the AQHI. It is a scale 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 common air pollutants that are known to harm human health. These pollutants are:

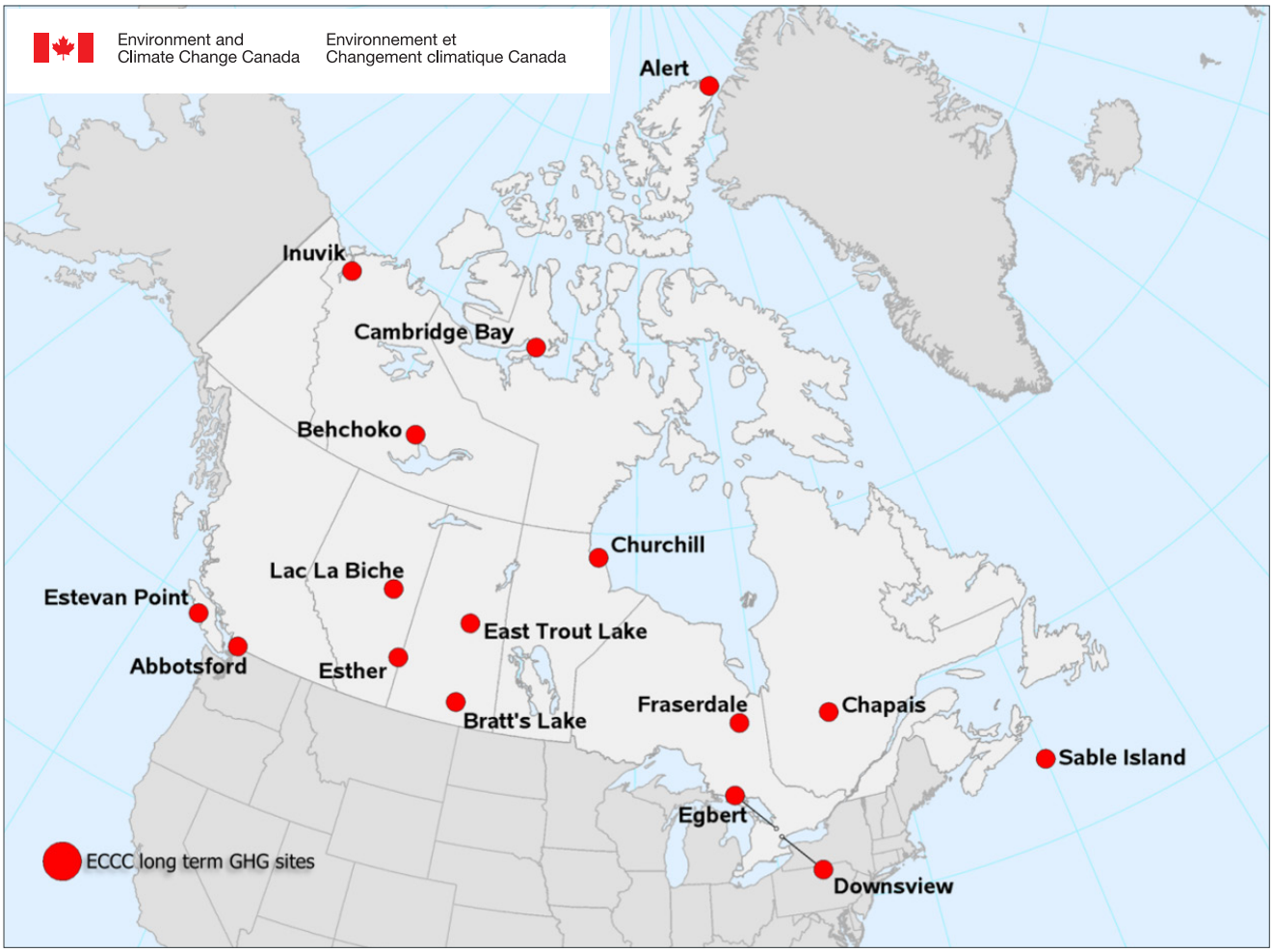
- Ozone (O_3) at ground level
- Particulate matter ($PM_{2.5}$/PM_{10})
- Nitrogen dioxide (NO_2)

The AQHI is a health protection tool designed to help people make decisions to protect their health by limiting short-term exposure to air pollution and adjusting their activity levels during increased levels of air pollution. It also provides advice on how people can improve the quality of the air they breathe.

Greenhouse gases

The Canadian Greenhouse Gas Monitoring Program includes observations of carbon dioxide and other GHGs from 16 long-term measurement sites across Canada (Figure 2). Among the sites is the Alert Global Atmosphere Watch Observatory. Alert serves as one of 3 global GHG inter-comparison sites to ensure consistent measurement of carbon dioxide (CO_2) and other greenhouse gas concentrations across the world.

Figure 2. 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; World Meteorological Organization (WMO); World Data Centres for GHGs; 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 March 1975 at Alert, Nunavut (Figure 3). The annual average CO_2 value at Alert in 2020 was 414.9 parts per million (ppm), which is slightly higher than the annual average CO_2 values at Alert in 2019 and 2018 which were 412.0 ppm and 409.5 ppm, respectively.

ECCC began measuring atmospheric methane (CH_4) in August 1985 at Alert, Nunavut (Figure 4). The annual average CH_4 value at Alert in 2020 was 1967.7 parts per billion (ppb). The rate of annual increase in CH_4 concentrations showed a steady decline in the late 1980s and hovered around zero from 1999 to 2006, reflecting a near global balance between emissions and removal by atmospheric chemical processes. Since 2007, CH_4 has increased every year on average by 6 ppb per year until very recently. In 2019 and 2020, the annual change in CH_4 at Alert has significantly jumped by 10.4 and 16.7 ppb respectively.

Figure 3. Atmospheric carbon dioxide measured at Alert, Nunavut

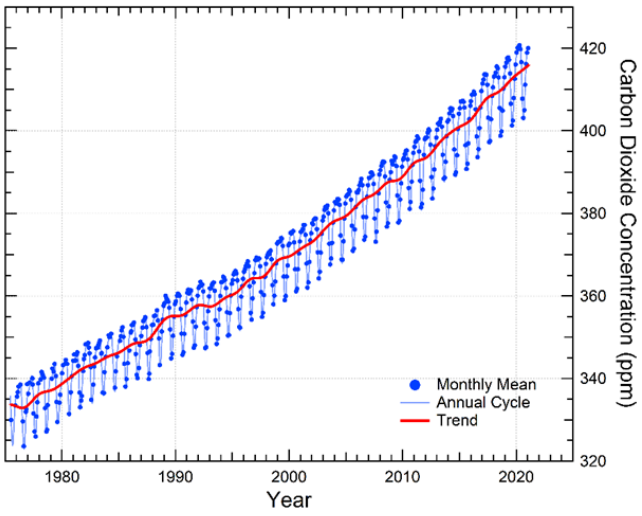
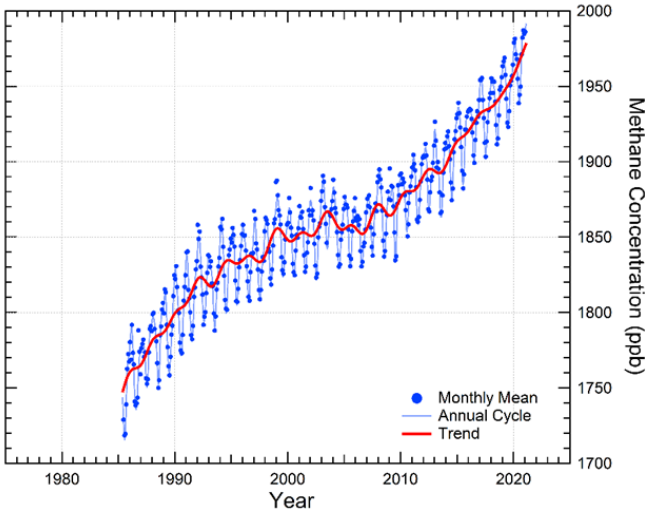


Figure 4. Atmospheric methane measured at Alert, Nunavut



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 can have continued access to suitable sites. Where monitoring indicates a problem or where the site has reached its capacity over time, management action in the form of closing, moving or altering the site use can occur.

In 2020-2021, monitoring projects were completed at 9 ocean disposal sites nationally, which amounts to monitoring 13% of the 71 actively used sites. Due to the restrictions on fieldwork resulting from the COVID-19 pandemic, many field-monitoring projects were cancelled or postponed.

Pacific region

Field work was largely cancelled in Pacific Region in 2020-2021 due to COVID-19 restrictions for staff working on ships. However, partnerships with other agencies did allow for some sediment sampling in and around the Sandheads and Point Grey disposal sites, in Southern Resident Killer Whale habitat. These samples were analyzed for an extensive suite of chemicals, including polybrominated diphenyl ethers (PBDEs) and microplastics, to generate new data 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.

Highlight – Use of Acoustic Doppler Current Profiler

In 2019-2020, Natural Resources Canada and ECCC embarked on a research project to deploy an Acoustic Doppler Current Profiler (ADCP) on the seafloor at the Point Grey disposal site to collect seasonal current velocity and directional information 1 m above the seafloor over a 1-year period. The objective of this monitoring was to characterize the movement of sediment over time at and around the disposal footprint. Results of this seafloor monitoring show that the Point Grey site is non-dispersive, meaning the material is likely to remain within the disposal footprint following disposal. The use of the ADCP was proven to be very useful and is now deployed for a 1-year period at the Sandheads disposal site to gain a more nuanced understanding of the movement of sediment at that site.

Quebec region

In 2020-2021, a total of 6 disposal sites were monitored in the Gulf of the St. Lawrence off the coast of the province of Quebec; 2 in the Gaspé region and 4 near the Magdalen Islands (see Table 2). 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.

The 2 sites monitored in the Gaspé region, PD-6 and SG-2, had a previously identified pattern of not being able to find the material that was disposed of in that location. This raised concerns that the material was in fact being disposed of outside the disposal sites’ boundaries. Investigations and preliminary conversations with the permit holder have suggested that incorrect coordinates may have been entered in the GPS of an inexperienced contractor. As a result, new measures, such as requiring contractors to register the coordinates of each disposal, have been put in place. The investigation continued in 2020-2021 in order to resolve the issue for future permits.

Table 2. Results of monitoring disposal at sea sites off the coast of Quebec in 2020-2021

Disposal site	Results of hydrographic surveys	Comments
Port-Daniel-Est (PD-6)	No material detected at disposal site even though permittee reported that 2927 m^3 of material had been disposed of at this site	Unexpected result. Continued annual hydrographic surveys recommended.
Saint-Godefroi (SG-2)	No material detected at disposal site even though permittee reported that 1777 m^3 of material had been disposed of at this site	Unexpected result. Since 2013, more than 16 500m^3 has been disposed of at this site but not detected. New coordinate registration requirements and a new contractor in 2019 have not resolved this issue. Continued annual hydrographic surveys recommended.
IE-6	3134 m^3 of material was detected, more than 1000 m^3 greater than the 2115 m^3 expected	Unexpected result. This may be due to the creation of a “sand trap” at site, or sediment dynamic being slightly different over the past year. The depth of the site is still safe for navigation. Annual hydrographic surveys recommended.
GI-2	No material detected at disposal site	Expected result as it is a highly dispersive site. The depth is still safe for navigation and another hydrographic survey in 5 years is recommended.
PBCM-1	43 087 m^3 was detected, almost exactly equal to the expected amount of 42 888 m^3	Expected result. Site is very stable. The portion of the site currently in use is approaching its capacity for safe navigation; therefore consideration is being given to opening an unused section of the site. Annual hydrographic surveys recommended.
Dépôt E	Nearly 93% of the 207 300m^3 disposed of the site was detected	Expected result. A dispersion pattern for disposal of material was used at this site in 2020 to fill in sections of the site, rather than creating a single mound. The site is stable and still safe for navigation. A follow up hydrographic survey is recommended in 2 years.

Atlantic region

In 2020-2021, a single hydrographic monitoring survey was conducted in August 2020 at the Black Point disposal site off the coast of New Brunswick. The survey results were used to assess changes to the footprint and the height of accumulated disposed material at the disposal site. The elevation of accumulated material was assessed to determine whether it is less than 7 m above the 1959 baseline elevation. The 7 m threshold was selected as a conservative navigational criterion.

Repetitive hydrographic surveys at the Black Point disposal site have shown significant sediment build-up. It appears that sediment has travelled and settled in a south-southwest direction surpassing the disposal site boundary. It also appears that disposed material accumulation is nearing or exceeding 7 m in height throughout most of the seabed under the 2017-2020 release zone. Based on these observations, it was decided to move disposal activities to a new release zone commencing in January 2021. In order to better understand the changes to the disposed material footprint, the area to be surveyed in 2021 will be increased beyond that of the 2020 survey. Analysis of the results of the 2019 physico-chemical and biological studies at the Black Point disposal site are still underway.

2.5 Water quality monitoring

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.

In 2020, ECCC's Freshwater Quality Monitoring and Surveillance (FWQMS) program completed an analysis of cadmium concentrations and trends in sediments, water, and fish. This analysis supports performance measurement and reporting for the CMP across Canada.

FWQMS also supports CMP priorities through the Monitoring and Surveillance Working Group. In February 2021, members of the working group published a multimedia analysis of Bisphenol A (BPA) in the Canadian environment[1], which recommended monitoring of surface water for future trends of BPA in the environment, identified wastewater discharge impacts, and evaluated the efficacy of Canadian actions in reducing environmental concentrations.

Please see the *Canada Water Act* Annual Report for an update on freshwater quality monitoring in Canada.

1. Gewurtz, S.B. et al. 2021. *Bisphenol A in the Canadian environment: A multimedia analysis*. Science of the Total Environment Vol. 755 Part 2. 10 February 2021, 142472 DOI: 10.1016/j.scitotenv.2020.142472.

2.6 Canadian Environmental Sustainability Indicators

The Canadian Environmental Sustainability Indicators (CESI) program reports on key environmental sustainability issues including climate change, air quality, water quality and availability, wildlife, biodiversity, habitat, pollution, waste and toxic substances. It is designed to convey the state of Canada's environment, including historical trends, in a straightforward and transparent manner. CESI is used to provide citizens, Parliamentarians, policy makers and researchers with comprehensive, unbiased and authoritative environmental information. The CESI program responds to ECCC's commitments under CEPA and the *Department of the Environment Act* to report to Canadians on the state of the environment and is the prime instrument to measure progress on the Federal Sustainable Development Strategy.

ECCC prepares the indicators through close collaboration with science and data experts across the federal government, including in Health Canada, Statistics Canada, Natural Resources Canada, Agriculture and Agri-Food Canada, and Fisheries and Oceans Canada, as well as relevant provincial and territorial counterparts. The data used to calculate indicators originate from a variety of sources, including surveys, measurement networks and other research initiatives that are expected to be maintained and updated for the foreseeable future.

The indicators are published on the CESI website showing national and regional results along with the methodology explaining each indicator and links to related socio-economic issues and information. CESI also has an interactive map that enables the user to quickly explore Canada's local and regional environmental indicators. The indicators and their corresponding datasets are also published in the Government of Canada Open Data Portal.

Table 3. Canadian Environmental Sustainability Indicators (CESI) updates and new releases in 2020-2021

Date	Indicators
April 2020	Greenhouse gas emissions from large facilities
	Greenhouse gas emissions
	Global greenhouse gas emissions
July 2020*	Population exposure to outdoor air pollutants
	Bisphenol A in water and sediment
	Snow cover in Canada
	Drinking water advisories
	Pulp and paper effluent quality
	Canada's conserved areas
	Temperature change in Canada
	Sustainability of timber harvest
	Carbon dioxide emissions from a consumption perspective

Date	Indicators
August 2020	Restoring the Great Lakes Areas of Concern
September 2020	Phosphorous levels in the offshore waters of the Great Lakes
	Human exposure to harmful substances
October 2020	Phosphorus loading to Lake Erie
	Land-based greenhouse gas emissions and removals
November 2020	Air pollutant emissions
	Reductions in phosphorus loads to Lake Winnipeg
	Monitoring disposal at sea
	Metal and diamond mining effluent quality
	Ecological integrity of national parks
	Shellfish harvest area quality
December 2020	Emissions of harmful substances to air
	Changes in the status of species at risk
	Species at risk population trends
	Eelgrass in Canada
	Municipal wastewater treatment
	Plastic particles in the Northern Fulmar
January 2021	Releases of harmful substances to water
	Nutrients in the St. Lawrence River
	Number of long-term drinking water advisories on public systems on reserve
February 2021	Sea ice in Canada
	Management of Canadian aquaculture
March 2021	Population exposure to outdoor pollutants
	Sustainable fish harvest
	Progress towards Canada's greenhouse gas emissions reduction target

* Due to COVID-19 restrictions including a publication blackout in the spring, the release of some indicators was delayed to July.

3. Addressing key risks

This section on addressing key risks covers information gathering, risk assessment, and risk management for chemicals, living organisms, air pollution and greenhouse gases, water quality, and waste.

3.1 Chemicals

Parts 4, 5 and 6 of CEPA include specific provisions for data collection, assessment and management of toxic substances. Substances include both chemicals and living organisms (specific information on living organisms begins in section 3.2).

There are two streams of risk assessment for substances in Canada based on when they enter into commerce. Substances on the Domestic Substances List (DSL) are referred to as **existing substances** and many have been in use in Canada for over 3 decades. Substances that are not on the DSL are considered **"new" substances.**

Chemicals management plan update

The CMP is a program developed to protect Canadians and the environment from exposure to toxic substances. This includes a commitment to finish addressing approximately 4300 substances of potential concern that were already in commerce in Canada between 1984 and 1986. Under the CMP, the government also conducts pre-market assessments of health and environmental effects of approximately 400 substances that are new to Canada each year.

Highlight – Progress under the Chemicals Management Plan

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, 2021, the Government of Canada has:

- **addressed 91% (3974) of the 4363 existing substances** identified as priorities in 2006
- **found 333 existing substances to be harmful to the environment and/or human health**, for a total of 582 when including toxic substances identified prior to 2006
- **implemented over 200 risk management actions for existing substances**
- **received and assessed approximately 6645 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

On October 10, 2020, the Minister of Environment and Climate Change issued an information gathering Notice under section 71 of the Act with respect to perfluorohexane sulfonic acid, its salts and its precursors for assessing whether to control or the manner in which to control the substance. Also in October 2020, summaries of data received were published via the Government of Canada Open Data Portal, for the following 3 notices that had been issued in 2018:

- *Notice to provide information for the risk management of 1,4-benzenediamine, N,N′-mixed phenyl and tolyl derivatives (BENPAT)* (issued under s.71)
- *Notice to provide information for the risk management of certain coal tars and their distillates* (issued under section 71)
- *Notice with respect to certain quaternary ammonium compounds in Canadian commerce — Phase 1* (issued under section 46)

Targeted voluntary data-gathering activities also contribute to risk assessments and risk management activities. In 2020-2021, Health Canada issued 1 targeted voluntary data request for Turpentine and turpentine oil (part of the terpenes and terpenoïds Group 1: Acyclic, monocyclic, and bicyclic monoterpenes) to inform risk assessment and risk management activities. Environment and Climate Change Canada also issued 1 voluntary request to industry stakeholders for information on barriers to supply chain transparency for chemicals, to help the Government gain a better understanding of the issues.

3.1.2 Existing substances risk assessment

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, which is followed by publication of the final screening assessments.

During 2020-2021 (see Table 4), the Minister of Environment and Climate Change and the Minister of Health:

- published 24 draft screening assessment reports covering 98 substances
- published 20 final screening assessment reports covering 167 substances
- published 1 science approach document
- published the bisphenols technical consultation
- proposed that 32 substances meet one or more of the toxicity criteria set out in section 64 of CEPA
- concluded that 8 substances meet one or more of the toxicity criteria set out in section 64 of CEPA

Table 4. Summary of existing substance assessment decisions published from April 2020 to March 2021 (NFA – no further action)

Substances (and number of substances)	Meet s. 64 criteria	Proposed measure	Publication date of draft notice	Publication date of final notice
Naphthalene Sulfonic Acids and Salts Group (6)	No	NFA	July 4, 2020	
Sulfurized Isobutylene (1)	No	NFA	July 4, 2020	
Antimony-containing Substances Group (11)	No	NFA	September 15, 2018	July 11, 2020
Base Oils (39)	No	NFA	October 6, 2018	July 11, 2020
Alkanolamines and Fatty Alkanolamides Group (11)	No	NFA	July 18, 2020	
Pigments and Dyes Group (6)	No	NFA	January 5, 2019	August 1, 2020
Nitro Musks Group (2)	No	NFA	September 15, 2018	August 1, 2020
Fatty Acids and Derivatives Group (9)	No	NFA	August 18, 2018	August 1, 2020
Epoxides and Glycidyl Ethers Group (5)	No	NFA	November 24, 2018	August 8, 2020
Poly(amines) Group (9)	No	NFA	November 10, 2018	August 15, 2020
Silver and its compounds (7)	No	NFA	August 15, 2020	
Aromatic Amines Group (8)	Yes – 1 substance*	Add to Schedule 1	August 15, 2020	
TMSS (1)	No	NFA	September 19, 2020	
Thallium and its compounds (5)	Yes*	Add to Schedule 1	September 19, 2020	
Petroleum Coke Group (2)	No	NFA	September 19, 2020	
Other polymers group (5)	Yes -2 substances*	Add to Schedule 1	October 3, 2020	

Substances (and number of substances)	Meet s. 64 criteria	Proposed measure	Publication date of draft notice	Publication date of final notice
Triclocarban (1)	No	NFA	October 10, 2020	
p-Toluenesulfonic acid (1)	No	NFA	October 17, 2020	
Melamine (1)	Yes*	Add to Schedule 1	October 17, 2020	
TCPP and TDCPP (2)	Yes*	Add to Schedule 1	October 17, 2020	
Triarylmethanes Group (6)	Yes – 4 substances**	Add to Schedule 1	December 8, 2018	October 17, 2020
Coumarin 1 (1)	Yes*	Add to Schedule 1	October 31, 2020	
Sucrose acetate isobutyrate (SAIB) (1)	No	NFA	November 14, 2020	
Inorganic substances identified as being of low concern (21)	No	NFA	April 13, 2019	November 14, 2020
Phthalate Substance Grouping (28)	Yes – 1 substance**	DEHP to remain on Schedule 1	October 7, 2017	December 5, 2020
Phenol-formaldehyde Resins Group (8)	No	NFA	April 6, 2019	December 12, 2020
Phosphoric Acid Derivatives Group (3)	No	NFA	July 13, 2019	December 19, 2020
Na_3NTA (1)	No	NFA	December 19, 2020	
Used and Re-refined Oils Group (9)	No	NFA	April 6, 2019	December 26, 2020
Substituted Alkyl Imidazolines Group (4)	No	NFA	June 22, 2019	December 26, 2020
Thiocarbamates Group (2)	Yes – 1 substance**	Add to Schedule 1	February 3, 2018	January 9, 2021
Decenes Group (2)	Yes*	Add to Schedule 1	January 9, 2021	
Diazenedicarboxamide (1)	No	NFA	April 20, 2019	January 16, 2021

Substances (and number of substances)	Meet s. 64 criteria	Proposed measure	Publication date of draft notice	Publication date of final notice
Acetic Acid (1)	No	NFA	July 20, 2019	January 16, 2021
Benzophenone (1)	Yes**	Add to Schedule 1	August 4, 2018	January 30, 2021
Protein Derivatives and Yeast Extract Group (4)	No	NFA	February 6, 2021	
Dimethoxymethane (1)	No	NFA	July 20, 2019	February 6, 2021
Dinoseb (1)	Yes**	Add to Schedule 1	June 2, 2018	February 6, 2021
Hexamethylenetetramines Group (3)	Yes – 2 substances*	Add to Schedule 1	March 6, 2021	
Benzotriazoles and Benzothiazoles Group (15)	Yes – 6 substances*	Add to Schedule 1	March 6, 2021	
Aliphatic Amines Group (13)	Yes – 9 substances*	Add to Schedule 1	March 6, 2021	
Thiophosphate Alkyl Esters Group (2)	Yes – 1 substance*	Add to Schedule 1	March 13, 2021	
Piperazine (1)	No	NFA	March 13, 2021	
Ethers Group (4)	No	NFA	March 13, 2021	

* Risk Management Scope document published (see section 3.1.3)

** Risk Management Approach document published (see section 3.1.3)

Final decision by Ministers

Ministers may recommend the addition of a substance to Schedule 1 of CEPA if a screening assessment shows that a substance meets one or more of the toxicity criteria set out in section 64 of CEPA. The Governor in Council may then approve an Order specifying its addition to Schedule 1. The decision to recommend adding a substance to Schedule 1 obliges the Ministers to develop a "regulation or instrument respecting preventive or control actions" within specific time periods (see section 3.1.3).

In 2020-2021, the Ministers proposed that 1 substance be added to Schedule 1 of CEPA as listed in Table 5. For the Order proposing the addition of plastic manufactured items to Schedule 1 see section 3.5.1 on Plastic pollution.

Table 5. Order proposing addition of a substance to Schedule 1 of CEPA from April 2020 to March 2021

Substance	Proposed Order *
Chlorhexidine and its salts	March 6, 2021

* Date of Publication in *Canada Gazette Part I*

In 2020-2021, 1 substance was added to Schedule 1 and 1 substance was removed as listed in Table 6. New information about the substance benzenamine, *N*-phenyl- (BNST) indicates that it has a lower potential to cause ecological harm in Canada than previously available information had indicated. Therefore, an order to remove BNST from Schedule 1 of the Act was published in October 2020.

Table 6. Orders adding or removing substances to Schedule 1 of CEPA from April 2020 to March 2021

Substance	Final Order *
Added – Benzene, 1-chloro-2-[2,2-dichloro-1-(4- chlorophenyl)ethyl]-, which has the molecular formula $C_{14}H_{10}Cl_4$	October 28, 2020
Removed – benzenamine, *N*-phenyl-, reaction product with styrene and 2,4,4-trimethylpentene (CAS RN 68921-45-9 (BNST)	October 28, 2020

* Date of publication in *Canada Gazette Part II*

Identifying Risk Assessment Priorities

Since 2014, ECCC and HC formalized their approach to the identification of risk assessment priorities (IRAP) for chemicals and polymers under CEPA. As a result of the IRAP process, substances may be considered for future risk assessment. In December 2020, ECCC and HC published the results of their 2019 IRAP review, recommending 85 substances for further scoping. The 2019 IRAP review took into consideration quantity and use information obtained through the 2017 DSL inventory update. Results of this IRAP review, along with results of the 2017-2018 IRAP review, will inform post-2020 assessment activities, including data gathering.

In March 2021, HC published a *Science Approach Document – Bioactivity exposure ratio: Application in priority setting and risk assessment* which presents the application of computational tools and new approach methods (NAM) in a quantitative risk-based approach to identify substances of a greater potential concern or substances of low concern for human health.

3.1.3 Existing substances risk management

Risk management instruments are put in place to reduce or eliminate risks to the environment and/or human health. They range from regulations, notices to require the preparation of pollution prevention plans, codes of practice, environmental performance agreements, and release guidelines, to environmental quality guidelines.

Risk management scope and approach documents

In general, 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. Risk management scopes are used as discussion documents to engage stakeholders on potential risk management actions. In 2020-2021, 11 risk management scope documents were published for the following substances or groups of substances that were proposed to have met one or more of the toxicity criteria set out in section 64 of CEPA (see Table 4):

- TPAE-1 of the thiophosphate alkyl ester group
- long-chain aliphatic amines
- 2-mercaptobenzothiazole (MBT) and its precursors (from the Benzotriazoles and Benzothiazoles Group)
- certain substances in the Hexamethylenetetramines Group
- 1-decene, dimer, hydrogenated and 1-Decene, tetramer, mixed with 1-decene trimer, hydrogenated (The Decenes Group)
- 2H-1-benzopyran-2-one, 7-(diethylamino)-4-methyl- (coumarin 1)
- 1,3,5-triazine-2,4,6-triamine (melamine)
- TCPP and TDCPP (updated)
- poly (iminocarbonimidoyliminocarbonimidoylimino-1,6-hexanediyl), hydrochloride and poly (hexamethylenebiguanine) (PHMB)
- thallium and its compounds
- Aromatic Amines Group, specifically: benzenamine, N,N-dimethyl- (dimethylaniline)

When the final screening assessment report concludes that a substance is "toxic" under CEPA and is proposed for addition to Schedule 1 of the Act, a risk management approach document is developed and published at the same time as the final risk assessment report. The risk management approach document provides a more detailed description of the risk management being considered.

In 2020-2021, 5 risk management approach documents were published for the following substances, or substance groups that met one or more of the toxicity criteria set out in section 64 of CEPA (see Table 4):

- Phenol, 2-(1-methylpropyl)-4,6-dinitro- (Dinoseb)
- Benzophenone
- Thioperoxydicarbonic diamide ([(H2N)C(S)]2S2), tetramethyl- (TMTD) in the Thiocarbamates Group
- 1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester (DEHP)
- Certain triarylmethanes

Final Regulations

On April 1, 2020, final *Regulations Amending the Chromium Electroplating, Chromium Anodizing and Reverse Etching Regulations* were published in the *Canada Gazette*, *Part II*. These regulations aim to limit emissions of hexavalent chromium compounds during chromium electroplating, chromium anodizing and reverse etching processes at facilities that use more than 50 kg of chromium trioxide per calendar year. The amendments address the concerns raised by the Standing Joint Committee for the Scrutiny of Regulations (SJCSR) by improving consistency between the French and English versions of the Regulations, improving the clarity of the regulatory text related to laboratory accreditation, and removing a reference to an outdated technical standard.

On September 02, 2020, the final *Regulations Amending the Ozone-depleting Substances and Halocarbon Alternatives Regulations* were published in the *Canada Gazette*, *Part II*. The amendments revise the Canadian hydrofluorocarbon (HFC) baseline value in accordance with the October 2018 Interim Order. In addition, the amendments allow the consumption of HCFC-123 (hydrochlorofluorocarbon) for the servicing of existing fire protection equipment until 2029, in accordance with recent adjustments to the Montreal Protocol on Substances that Deplete the Ozone Layer.

On November 11, 2020, the final *Reduction in the Release of Volatile Organic Compounds Regulations (Petroleum Sector)* were published in the *Canada Gazette*, *Part II*. These regulations require the implementation of comprehensive leak detection and repair programs at Canadian petroleum refineries, upgraders and certain petrochemical facilities. The operators of these facilities are also required to ensure that certain equipment components are designed and operated in a manner that prevents leaks, and to monitor the level of certain volatile organic compounds at facility fencelines.

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 them.

- In 2020-2021, approximately 135 permits were issued under these Regulations. Additionally, consumption allowances for HFCs and HCFCs were issued to eligible companies. The lists of HCFC and HFC allowance holders are available online.

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. The Export Control List includes substances whose export from Canada is controlled because their use in Canada is prohibited or restricted, or because they are subject to an international agreement that requires notification or consent of the country of destination before the substance is exported from Canada.

- In 2020-2021, 16 notices of proposed export were submitted to the Minister of the Environment; however, only 1 export permit was requested and issued by the Minister.

Cosmetic Ingredient Hotlist

The Cosmetic Ingredient Hotlist is an administrative tool that HC uses to communicate to manufacturers and others that certain substances may be prohibited or restricted for use in cosmetics.

- On October 15, 2020, 2-Ethylhexyl-2-ethylhexanoate (2-EH-2-EHA) (CAS RN 7425-14-1) was proposed for addition to the list of restricted substances due to health concerns.

Codes of Practice

In August 29, 2020, a final *Code of Practice for Certain Methylenediphenyl Diisocyanates in Low-Pressure Two-Component Spray Polyurethane Foam Products* was published in the *Canada Gazette*, *Part I*. Methylenediphenyl Diisocyanates (MDIs) are widely used in the production of a wide range of products including polyurethanes, adhesives, sealants, paints and coatings. The code of practice aims to reduce exposure of the general population to MDIs resulting from the use by consumers of low-pressure two-component spray polyurethane foam (SPF) products containing MDIs. The Code of Practice sets elements of best practices and recommendations for any person who manufactures, imports, or sells low-pressure two-component SPF products containing MDIs to consumers.

The complete list with status updates for all active Codes of Practice is available online.

Pollution Prevention Planning Notices

On October 10, 2020, the final Notice requiring the preparation and implementation of pollution prevention plans with respect to triclosan in certain products was published in the *Canada Gazette*, *Part I*. The Notice applies to any person or class of persons who, on the date of publication and anytime thereafter uses 100 kg or more of triclosan in a calendar year in the manufacture of cosmetics, natural health products or drugs, or imports 100 kg or more of triclosan in a calendar year contained in cosmetics, natural health products or drugs.

On July 17, 2020, the Government published the Final Performance Report for the Pollution prevention (P2) planning notice for the synthetic rubber manufacturing sector (isoprene). This notice was published in 2012 with the risk management objective of reducing human exposure to isoprene through the

reduction of industrial emissions of isoprene to the environment by 80% relative to the baseline year, using best available techniques economically achievable. In 2018, the one facility subject to the P2 notice reduced its emissions of isoprene by 78% as compared to their 2009 baseline year, an achievement within 2% of the objective.

Progress under Pollution Prevention Planning notices is available online.

Environmental Performance Agreements

The *2020-2025 Environmental Performance Agreement Respecting the Use of Tin Stabilizers in the Vinyl Industry* was published on June 4, 2020. This was the second renewal of this agreement between ECCC, the Vinyl Institute of Canada (VIC) and participating companies with vinyl compounding facilities. The purpose of this agreement is to prevent the release of tin stabilizers into the environment through the continued implementation of effective stewardship practices by Canadian vinyl compounding facilities.

The final progress report for the previous 2015-2020 Environmental Performance Agreement Respecting the Use of Tin Stabilizers in the Vinyl Industry was published on the Government of Canada website on March 9, 2021. This final progress report indicates that all participating facilities have met the objective of the agreement.

Results from 4 active EPAs and all completed EPAs are posted on the List of EPAs website.

Release guidelines

Release guidelines recommend limits for the release of substances into the environment from works, undertakings or activities. They may be issued by the Minister of the Environment under section 54, or by the Minister of Health under section 55 of the Act.

On September 5, 2020, the Government of Canada published the final Release Guidelines for Disperse Yellow 3 and 25 other azo disperse dyes in the textile sector in the *Canada Gazette*, *Part I*. The Guidelines recommend limits, expressed as concentrations or quantities, for the release of Disperse Yellow 3 (DY3) and the 25 other azo disperse dyes into the aquatic environment from textile dye formulation and textile dyeing activities.

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) or federally under section 54 of CEPA as Federal Environmental Quality Guidelines (FEQGs).

Table 7 lists the CEQGs that were being developed nationally through CCME in 2020-2021.

Table 7. Canadian Environmental Quality Guidelines under development in 2020-2021

Environmental compartment	Under development
Water	Nickel Neonicotinoid Pesticides (4) Polycyclic aromatic hydrocarbons (PAHs) and alkyl substituted PAH
Soils	Perfluorooctane sulfonate (PFOS)
Groundwater	Guidelines for n = 101 substances (including PFOS)
Soil vapour	Guidelines for n = 41 substances

Table 8 lists the FEQGs for various CMP substances that were published or under development by ECCC in 2020-2021.

Table 8. Federal Environmental Quality Guidelines in 2020-2021

Environmental compartment	Published	Under development
Water	Lead Quinoline Strontium	Aluminum BTEX (benzene, toluene, ethylbenzene, xylene) Copper D4 Siloxane Iron* Rare Earth Elements (REEs) (4) Triclocarban
Sediment		D4 Siloxane Rare Earth Elements (REEs) (4)
Fish tissue		D4 Siloxane Selenium
Wildlife diet		D4 Siloxane
Bird egg		Selenium
Soil	Quinoline	Perfluorooctanoic acid (PFOA)
Groundwater	Quinoline	

* Draft guidelines published for comments

In addition, an FEQG summary table is available online as of Feb 2021.

Significant New Activity requirements

A Significant New Activity (SNAc) requirement is applied when a 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 2020-2021, 4 SNAc Notices of Intent were issued for 6 existing substances (Table 9).

Table 9. Significant New Activity Notices of intent for existing substances from April 2020 to March 2021

Substance	Publication date
Oxirane, [(2-propenyloxy)methyl]- (CAS RN 106-92-3)	August 8, 2020
Oxirane, [(2-methylphenoxy)methyl]- (CAS RN 2210-79-9)	August 8, 2020
1,3,5-Triazine-2,4,6(1H,3H,5H)-trione, 1,3,5-tris(oxiranylmethyl)- (CAS RN 2451-62-9)	August 8, 2020
Ethanol, 2-[(2-aminoethyl)amino]- (CAS RN 111-41-1)	September 12, 2020
Hexanoic acid, 2-ethyl-, 2-ethylhexyl ester (CAS RN 7425-14-1)	September 12, 2020
Phenol, dimethyl-, phosphate (3:1) (CAS RN 25155-23-1)	December 19, 2020

In 2020-2021, 3 SNAc Orders were issued for 27 existing substances (Table 10).

Table 10. Significant New Activity Orders for existing substances from April 2020 to March 2021

Substance	Publication date
Acetamide, N-(4-ethoxyphenyl)- (CAS RN 62-44-2)	July 22, 2020
Benzenamine, 4,4′-[(1methylethylidene)bis(4,1-phenyleneoxy)]bis- (CAS RN 13080-86-9)	August 19, 2020
Benzene, 1,1′-(2,2,2-trichloroethylidene)bis[4-methoxy- (CAS RN 72-43-5)	March 17, 2021
Phenol, pentachloro- (CAS RN 87-86-5)	March 17, 2021
Benzenamine, 2,6-dinitro-N,N-dipropyl-4(trifluoromethyl)- (CAS RN 1582-09-8)	March 17, 2021

Substance	Publication date
1,3-Benzenedicarbonitrile, 2,4,5,6-tetrachloro- (CAS RN 1897-45-6)	March 17, 2021
1,3,5-Triazine-2,4-diamine, 6-chloro-N-ethyl-N′-(1-methylethyl)- (CAS RN 1912-24-9)	March 17, 2021
1H-Indene-1,3(2H)-dione, 2-[(4-chlorophenyl) phenylacetyl]- (CAS RN 3691-35-8)	March 17, 2021
1,3-Benzodioxole, 5-[[2-(2-butoxyethoxy)ethoxy]methyl]-6-propyl- (CAS RN 51-03-6)	March 17, 2021
Phosphoric acid, 2,2-dichloroethenyl dimethyl ester (CAS RN 62-73-7)	March 17, 2021
Methane, trichloronitro- (CAS RN 76-06-2)	March 17, 2021
1,3,5-Triazine-2,4,6(1H,3H,5H)-trione, 1,3,5-trichloro- (CAS RN 87-90-1)	March 17, 2021
Phenol, 4-nitro-3-(trifluoromethyl)- (CAS RN 88-30-2)	March 17, 2021
Acetic acid, (2,4-dichlorophenoxy)- (CAS RN 94-75-7)	March 17, 2021
1H-Isoindole-1,3(2H)-dione, 3a,4,7,7a-tetrahydro-2-[(trichloromethyl)thio]- (CAS RN 133-06-2)	March 17, 2021
1H-Isoindole-1,3(2H)-dione, 2-[(trichloromethyl)thio]- (CAS RN 133-07-3)	March 17, 2021
Phosphorothioic acid, O,Odiethyl O-[6-methyl-2-(1-methylethyl)-4-pyrimidinyl] ester (CAS RN 333-41-5)	March 17, 2021
Cyclopropanecarboxylic acid, 2,2-dimethyl-3-(2-methyl-1-propenyl)-, 2-methyl-4-oxo-3-(2-propenyl)-2-cyclopenten-1-yl ester (CAS RN 584-79-2)	March 17, 2021
Phosphorothioic acid, O,Odiethyl O-(3,5,6-trichloro-2-pyridinyl) ester (CAS RN 2921-88-2)	March 17, 2021
Creosote (CAS RN 8001-58-9)	March 17, 2021
Pyrethrins and pyrethroids (CAS RN 8003-34-7)	March 17, 2021
Cyclopropanecarboxylic acid, 2,2-dimethyl-3-(2-methyl-1-propenyl)-, [5-(phenylmethyl)-3-furanyl]methyl ester (CAS RN 10453-86-8)	March 17, 2021
Carbamic acid, 1H-benzimidazol-2-yl-, methyl ester (CAS RN 10605-21-7)	March 17, 2021
Copper, [μ-[carbonato(2-)-O:O’]]dihydroxydi- (CAS RN 12069-69-1)	March 17, 2021
Distannoxane, hexakis(2-methyl-2-phenylpropyl)- (CAS RN 13356-08-6)	March 17, 2021
Octanoic acid, copper salt (CAS RN 20543-04-8)	March 17, 2021
Carbamic acid, [1,2-phenylene bis(iminocarbonothioyl)]bis-, dimethyl ester (CAS RN 23564-05-8)	March 17, 2021

Risk Management Performance Measurement Evaluation

Performance measurement evaluations provide Canadians with information on the effectiveness of risk management actions in place for substances found to be toxic under CEPA 1999. The risk management, human health and environmental objectives are systematically evaluated using robust data and expert analysis.

In 2020-2021, ECCC and HC collaboratively published *Strategic performance measurement: Evaluating the effectiveness of risk management actions on toxic substances in protecting Canadians and their environment*. It is a performance measurement evaluation strategy prepared in response to a recommendation by the Commissioner for the Environment and Sustainable Development in the 2018 audit on Toxic Substances.

In 2020-2021, performance measurement evaluation reports were published for the following seven substances:

- bisphenol A (BPA) – ecological component
- PBDEs
- lead
- mercury
- isoprene
- pigment red 3
- butanone oxime (MEKO)

3.1.4 New substances risk assessment

Substances that are new to Canada require notification to the government prior to being imported into or manufactured in Canada.

In 2020-2021:

- **297 New Substances Notifications were assessed** pursuant to section 81 of CEPA and the *New Substances Notification Regulations (Chemicals and Polymers)*
- **65 new substances risk assessment summaries** were published online
- **56 waivers of information requirements were published** in the *Canada Gazette* for new chemical and polymer substances

Forty-two 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.

- For new substances in products regulated under the FDA, 62 notifications for chemical/polymer substances were assessed in 2020-2021.

New substances in COVID-19 vaccines and treatments

The environmental and indirect human health risk assessments of new substances in COVID-19 vaccines and treatments were prioritized by HC and ECCC to match accelerated timelines for clinical trial applications and new drug submissions. Furthermore, HC expedited the assessments of all new substances in COVID-related products to meet supply demands in various sectors. To accomplish this objective without compromising the integrity of its assessments, HC developed a new information sharing process to facilitate the assessment of information as it came in and contacted drug sponsors at the earliest possible opportunity to provide tailored guidance.

- In 2020-2021, the assessments of 9 New Substances Notification (NSN) for new substances in COVID-19 vaccines and treatments and the assessments of 15 NSN for new substances in COVID-related products were prioritized and either completed within accelerated timelines or expedited and completed early.

3.1.5 New substances risk management

When the assessment of a new substance identifies a risk to human health or the environment, CEPA allows the Minister of the Environment 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:

a. permit the manufacture or import of the substance subject to specified conditions
b. prohibit the manufacture or import of the substance
c. request additional information considered necessary for the purpose of assessment

In 2020-2021, the Minister of Environment and Climate Change issued 11 Notices of Ministerial Conditions for 7 new substances and issued a variation to 1 Ministerial Condition for an additional substance (Table 11).

Table 11. Notices of Ministerial Conditions for new substances from April 2020 to March 2021

Substance	Publication date*
Amides, tall-oil fatty, *N*-[3-(dimethylamino)propyl]	June 6, 2020
Sulfonic acids, branched alkane hydroxy and branched alkene, sodium salts	June 6, 2020
Bentonite, lanthanian	June 13, 2020
2-Pyrrolidinone, 1-butyl-	July 4, 2020
Amides, tall-oil fatty, *N*-[3-(dimethylamino)propyl]	July 4, 2020
1-Propanaminium, 3-amino-*N*-(carboxymethyl)-*N,N*-dimethyl-, *N*-C_{8-18} acyl derivs., inner salts	September 12, 2020
Bentonite, lanthanian**	October 10, 2020
Hexanoic acid, 3,5,5-trimethyl-, 2-ethylhexyl ester	November 21, 2020
Hexanoic acid, 3,5,5-trimethyl-, 2-ethylhexyl ester	October 31, 2020
1-Propanaminium, 3-amino-*N*-(carboxymethyl)-*N,N*-dimethyl-, *N*-C_{8-18} acyl derivs., inner salts	January 9, 2021
1-Propanaminium, 3-amino-*N*-(carboxymethyl)-*N,N*-dimethyl-, *N*-C_{8-18} acyl derivs., inner salts	January 9, 2021
1,2-Propanediol, dibenzoate	March 13, 2021

* The dates are those on which the Notices were published in the *Canada Gazette*, *Part I*.

** Variation to a Ministerial Condition.

A Significant New Activity (SNAc) requirement can be applied when a substance has been assessed and there is a suspicion that significant new activities may pose a risk to human health and/or the environment.

- In 2020-2021, 4 SNAc Notices were issued for 4 new substances (Table 12).

Table 12. Significant New Activity Notices and Order for new substances issued from April 2020 to March 2021

Substance	Publication date*
2-Alkenoic acid, methyl- , 2-ethylhexyl ester, polymer with hexadecyl alkyl-alkenoate, α-(methyl-oxo-alkenyl)-ω-hydroxy poly(oxy-1,2-ethanediyl), octadecyl alkyl-alkenoate and polyhaloalkyl alkyl-alkenoate	August 8, 2020
Graphene	November 28, 2020
Siloxanes and silicones, di-Me, alkene Me, [(alkenedimethylsilyl)oxy]-terminated, polymers with hydrogen-terminated di-Me siloxanes	December 5, 2020
1,2-Cyclohexanedicarboxylic acid, 1-(phenylmethyl) ester, ester with 2,2,4-trimethyl-1,3-pentanediol mono(2-methylpropanoate)	March 20, 2021

* The dates are those on which the Final Notices or Orders were published in the *Canada Gazette*, *Part I*.

3.1.6 Communications activities

ECCC and HC work together to communicate information to Canadians on the environmental and human health risks of substances of concern. Materials are published on Canada.ca and on ECCC and HC social media channels.

In 2020-2021, ECCC and HC continued to increase collaboration activities to raise awareness of the safe use and potential risks of chemicals. A variety of communications materials were developed and published to accompany the technical and scientific documents on chemicals. These products include information sheets, fact sheets, plain-language summary pages and social media campaigns. They provide supplemental and/or non-technical information about aspects of the program and about substances, for stakeholders and the general public.

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

- 24 ‘Information sheet’ webpage summaries of draft screening assessments and risk management scopes (where applicable)
- 20 ‘Information sheet’ webpage summaries of final screening assessments and risk management approach documents (where applicable)
- 4 ‘Information sheet’ webpage updates for performance measurement evaluations

- 15 ‘Information sheet’ webpage updates for risk management activities
- 5 plain language summaries for high profile substances
  - » 2 draft screening assessment summaries (decenes and quaternium-15)
  - » 3 final screening assessment summaries (phthalates, benzophenone, chlorocresol)
- 171 new substances notification assessment summaries on Canada.ca

Specific social media materials included:

- social media for phthalates: 2 Twitter posts (14 000 impressions), 2 Facebook posts (27,019 impressions) and 2 LinkedIn posts (3894 impressions)
- social media products related to the performance measurement and evaluation strategy for risk management of harmful substances and 4 performance measurement evaluation reports for lead, mercury, BPA and PBDEs
- social media products related to the Triclosan Pollution Prevention Planning Notice
- a news release and social media products related to the final science assessment of plastic pollution
- social media products for the guidance document for the notification and testing of new chemicals and polymers

Implementation of the new Healthy Home social marketing campaign has been ongoing. The campaign aims to raise awareness and to motivate Canadians to take action to protect themselves from the risks of chemicals and pollutants in and around the home. A mix of both traditional and digital marketing and communication tactics have been utilized:

- Digital engagement:
  - » 52 Facebook posts (837 799 impressions), 52 Twitter posts (458 093 impressions) and 16 LinkedIn posts (31 493 impressions) promoted the campaign and drove traffic to the Healthy Home website
  - » 4 new Healthy Home videos were published on the website in both English and French
- Media outreach:
  - » HC developed 18 plain-language articles addressing environmental health topics like asbestos, carbon monoxide, radon, lead, mould, chemical safety, and ventilation. These articles continue to be published by media outlets across Canada.

- Delivery of over 90 virtual outreach activities across the country to increase Canadians' awareness of the health risks of chemicals in and around the home and to provide information for them to take action to protect their health and that of vulnerable populations.
  - The activities targeted intermediary groups such as caregivers, early childhood educators, health care providers, and parents/guardians. This allowed the information to reach subpopulations that may be more vulnerable to chemicals or have greater exposure, such as Indigenous communities, new Canadians, seniors, pregnant women, children and youth.

3.2 Living organisms

Living organisms that are products of biotechnology 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 legislation meeting the CEPA standard is 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 activities

The Act requires that all 68 living organisms that were grandfathered to the DSL, because they were 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 jointly perform the screening assessment of micro-organisms listed on the DSL. In addition, living organisms that are new to the Canadian marketplace require notification to the government prior to being imported into or manufactured in Canada.

Risk assessment of existing animate products of biotechnology

On December 5, 2020, a Notice of Intent to delete 22 masked strains from the DSL was published (see Table 13) in the *Canada Gazette*, Part I, as these living organisms do not meet the criteria prescribed in subsection 105(1) of the Act.

Table 13. Living organisms proposed for deletion from the Domestic Substances List

Confidential substance identity number	Inanimate biotechnology product and living organism
18115-7	*Alcaligenes* species
18116-8	*Alteromonas* species
18120-3	*Bacillus* species 1
18118-1	*Bacillus* species 2
18119-2	*Bacillus* species 3
18121-4	*Bacillus* species 4
18122-5	*Bacillus* species 5
18129-3	*Bacillus* species 7
18130-4	*Cellumonas* species
18131-5	*Enterobacter* species
18124-7	*Flavobacterium* species
18125-8	*Micrococcus* species
18132-6	*Nitrobacter* species
18133-7	*Nitrosomonas* species
18117-0	*Pseudomonas* species 1
18123-6	*Pseudomonas* species 2
18126-0	*Pseudomonas* species 3
18127-1	*Pseudomonas* species 4
18134-8	*Pseudomonas* species 5
18135-0	*Pseudomonas* species 6
18136-1	*Rhodopseudomonas* species
18128-2	*Thiobacillus* species

Risk assessment of new animate products of biotechnology

During 2020-2021, 60 notifications of new animate products of biotechnology were assessed under the *New Substances Notification Regulations (Organisms)*.

For new substances in products regulated under the *Food and Drugs Act*, 36 notifications for new animate products of biotechnology were assessed in 2020-2021.

Also during 2020-2021:

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

Risk assessment of new higher organisms

The *Voluntary Public Engagement Initiative* on the risk assessment of higher organisms (for example, genetically modified plants and animals) was launched in 2018. This initiative promotes greater public engagement in the risk assessment of higher organisms. A public comment period was initiated in March 2021 on 3 new genetically modified fishes to inform risk assessments.

3.2.2 Risk management activities

When the assessment of a new living organism identifies a risk to human health or the environment, CEPA allows the Minister of the Environment to intervene prior to or during the earliest stages of its introduction into Canada. The Minister may permit a person to manufacture or import a substance subject to conditions, or may prohibit the manufacture or import of a substance.

In 2020-2021, the Minister of Environment and Climate Change issued 1 Notice of Ministerial Condition for 1 new living organism (Table 14).

Table 14. Notice of Ministerial Conditions for new living organisms from April 2020 to March 2021

Substance	Publication date*
Coxsackievirus A21, Kuykendall strain	October 17, 2020

* The dates are those on which the Final Notices were published in the *Canada Gazette*, *Part I*.

In 2020-2021, the Minister of Environment and Climate Change issued 1 variation to a SNAc Notice for a new living organism (Table 15).

Table 15. Significant New Activity Notice for new living organisms from April 2020 to March 2021

Substance	Publication date*
Atlantic salmon (*Salmo salar* L.) bearing a single copy of the α-form of the opAFP-GHc2 recombinant DNA construct at the α-locus in the EO-1α lineage**	July 18, 2020

* The dates are those on which the Final Notices or Orders were published in the *Canada Gazette*, *Part I*.

** SNAc variation.

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 Activities

HC assesses the overall impact of air pollution on the health of Canadians on an annual basis. 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 March 2021, HC published a new estimate of the health impacts of air pollution in Canada, reporting that air pollution contributes to 15 300 premature deaths per year in Canada along with 2.7 million asthma symptom days per year and 35 million acute respiratory symptom days per year. The total economic cost of all health impacts attributable to air pollution for 2016 was $120 billion (2016 CAD).

In June 2020, HC published a health assessment of the impact of traffic related air pollution (TRAP) on asthma, allergies and lung function and continued to assess the impact of TRAP on other health endpoints. HC continued work on a science assessment of the health effects of particulate matter ($PM_{2.5}$) and began development of Health Based Air Quality Objectives for a wider suite of air pollutants.

3.3.2 Risk management activities

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, 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 (CAAQS)
- local air zones and regional airsheds
- industrial emission requirements for several industrial sectors
- work to address emissions from mobile sources
- outdoor air pollutants monitoring program
- reporting to Canadians on the state of the air

CAAQS are environment- and health-based-standards that apply to the concentration of specific air pollutants in the outdoor air. They provide the drivers for air quality management actions across the country. ECCC and HC lead the process under the Canadian Council of Ministers of the Environment (CCME) to develop, review and amend CAAQS. Once agreed under the CCME, CAAQS are published by the Minister of the Environment and the Minister of Health as environmental quality and health objectives under CEPA. CAAQS have been developed for fine particulate matter ($PM_{2.5}$), ozone (O_3), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2).

In 2020-2021, work continued on the review of the CAAQS for fine particulate matter ($PM_{2.5}$). The new CAAQS for ozone, published in 2019, will replace the 2020 standard and come into effect on January 1, 2025. The 2025 ozone CAAQS are more stringent than the existing CAAQS and will drive continuous improvement in air quality across the country.

Industrial sector emissions

The *Multi-Sector Air Pollutants Regulations* (MSAPR) came into force in 2016 and established nationally consistent industrial emissions performance standards. The MSAPR limit nitrogen oxide (NO_x) emissions from large industrial boilers and heaters, as well as from stationary spark-ignition engines, used in several industrial sectors, that burn gaseous fuels (such as natural gas). The MSAPR also limit NO_x and SO_2 emissions from kilns at cement manufacturing facilities.

On September 30, 2020, the final *Multi-Sector Air Pollutants Regulations Amendment Regulations (Part 1 — Biomass)* were published in the *Canada Gazette, Part II*. The amendments to Part 1 of the MSAPR clarify that boilers and heaters that combust predominantly solid or liquid biomass are excluded from the MSAPR.

For stationary spark-ignition engines covered by the MSAPR, the online reporting system was updated to allow regulatees to submit compliance reports for pre-existing engines. Emissions requirements for modern engines are in force with annual compliance reports due by July 1, while emission requirements for pre-existing engines began to apply on January 1, 2021, with the first annual compliance report due by July 1, 2022.

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.

Equivalency agreements with Alberta and Saskatchewan for these regulations were published in the *Canada Gazette, Part I* on November 7, 2020 (see section 5.3). It was determined that regulations in each of these provinces would lead to reductions in emissions of methane at least as great as the *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)* and with these agreements the federal regulations have stood down in these jurisdictions.

As noted in section 3.1.3 the the final *Reduction in the Release of Volatile Organic Compounds Regulations (Petroleum Sector)* were published in the *Canada Gazette*, *Part II*. These regulations require the implementation of comprehensive leak detection and repair programs at Canadian petroleum refineries, upgraders and certain petrochemical facilities.

Vehicle and engine emissions

ECCC administers 6 vehicle and engine emission regulations and 9 fuel regulations under CEPA.

On December 23, 2020, the final *Off-road Compression-Ignition (Mobile and Stationary) and Large Spark-Ignition Engine Emission Regulations* were published in the *Canada Gazette*, *Part II*. These regulations set performance-based emissions standards for air pollutants from new stationary off-road diesel engines and large spark-ignition engines. These Regulations repeal and replace the *Off-Road Compression-Ignition Engine Emission Regulations*. Emission standards applicable to mobile off-road diesel engines remain unchanged. The Regulations will come into force on June 4, 2021.

ECCC also 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 from greenhouse gases and air pollutants including from vehicles, engines, and fuels.

On May 18, 2020, a second interim order was made by the Minister of Environment and Climate Change to delay the coming into force of the GHG emission standards for trailers in Canada under the *Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations* until May 18, 2021. On June 6, 2020, a Governor in Council *Order Approving the Interim Order Modifying the Operation of the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations (Trailer Standards)* was published in the *Canada Gazette*, *Part I*. This allowed the department time to assess concerns received from Canada's trailer industry on potential adverse economic impacts if Canada proceeded to implement the trailer standards without the corresponding standards of the U.S. EPA being in force due to legal challenges.

ECCC published the *Final Decision Document on the Mid-Term Evaluation of the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations* on February 12, 2021. The department determined that the standards for light-duty vehicles, which were aligned with the standards in the United States for up to model year 2026, were not stringent enough to meet Canada's emission reduction and climate goals and that Canada should work with the U.S. to develop more stringent standards. These more stringent standards are expected to be finalized in the U.S. in December 2021. Canada's regulations incorporate U.S. standards by reference and these more stringent standards will automatically apply in Canada once they are finalized in the U.S.

On December 23, 2020, ECCC published in *Canada Gazette, Part II*, final amendments to the *Sulphur in Gasoline Regulations*. The amendments maintain environmental quality standards while re-instituting a temporary sulphur compliance unit trading system for the years 2020 to 2025 to provide flexibility to fuel suppliers as they complete their transition to production or import of low sulphur gasoline.

Regulatory administration of vehicle, engine and fuel quality regulations

ECCC administers a compliance program under the vehicle, engine and fuels regulations. This includes processing of regulatory reports and importation declarations; managing notice of defects and recalls; testing of selected vehicles and engines; analyzing fuel samples; reviewing production and import records of fuel suppliers; and verifying compliance with the regulatory prohibitions and reporting requirements. In 2020-2021, to verify compliance and identify non-compliance, ECCC program staff assisted the Enforcement Branch in conducting 5 major inspections at fuels facilities, which included a detailed review of regulatory records.

Some transportation regulations require companies to submit annual compliance reports documenting fleet performance and the quantity of products. Fuel producers and importers are required to submit annual reports on the composition and volume of their liquid fuel products, as well as corporate pool averages, as applicable.

During 2020-2021, the department received approximately 198 regulatory reports for vehicles and engines and over 1150 reports and notices for fuels. ECCC conducts an annual risk-based review of each fuel supplier based on the reports submitted. In 2020-2021, ECCC assessed 83 fuels suppliers and worked directly with 52 of those suppliers to address their reporting and administrative issues.

In 2020-2021, ECCC processed about 270 Canada-unique[2] submissions and almost 1835 importation declarations for vehicles and engines. Additionally, the department processed 100 notices of defect and recall notifications covering almost 462 402 vehicles and engines. ECCC continues to provide basic information summarizing notices of defect and other company notifications received.

The administration of the transportation and fuel quality regulations is supported by ECCC laboratory emissions testing on vehicles and engines, and fuel quality testing done in order to verify compliance with the regulations. Occasionally, private laboratories will be used by ECCC to conduct testing. In 2020-2021, the department conducted testing on 41 vehicles and engines, and conducted 146 analyses on 72 fuel samples.

During 2020-2021, the department published the 2018 model year light-duty vehicle GHG performance report and the 2017 model year light-duty vehicle air pollutant report. These reports, compiled from the annual compliance reports submitted by automobile companies, document the overall fleet performance for all model years since the regulations were first introduced in 2010 (with the 2011 model year) for GHGs and the 2004 model year for air pollutants up to the titular model year. The department also made available aggregated data related to 3 fuel quality regulations (the *Fuels Information Regulations, No. 1*, the *Benzene in Gasoline Regulations*, and the *Renewable Fuels Regulations*) reported by the regulated community for the 2018 and 2019 calendar years.

During 2020-2021, ECCC responded to almost 1143 inquiries regarding the vehicles and engines regulations and over 500 regarding the fuels regulations.

More information on the Government of Canada's vehicle, engine and fuel regulations and data related to certain regulations is available online.

Clean fuel standard

On December 19, 2020, ECCC published the proposed *Clean Fuel Regulations* in the *Canada Gazette*, *Part I,* for a 75-day comment period. The proposed Regulations would require liquid fossil fuel primary suppliers (that is, producers and importers) to reduce the carbon intensity (CI) of the liquid fossil fuels they produce in and import into Canada from 2016 CI levels by 2.4 gCO_2e/MJ in 2022, increasing to 12 gCO_2e/MJ in 2030. The proposed Regulations would also establish a credit market whereby the annual CI reduction requirement could be met via 3 main categories of credit-creating actions: (1) actions that reduce the CI of the fossil fuel throughout its lifecycle, (2) supplying low-carbon fuels, and (3) specified end-use fuel switching in transportation. Parties that are not fossil fuel primary suppliers would be able to participate in the credit market as voluntary credit creators by completing certain actions (e.g. low-carbon fuel producers and importers). In addition, the proposed Regulations would 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 federal *Renewable Fuels Regulations*, which would be repealed.

2. 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.

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.

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. In 2020-2021, new Residential Indoor Air Quality Guidelines were published for Acrolein and for Carbon Dioxide.

In 2020-2021, HC published fact sheets and web information on indoor air quality including:

- Protecting your indoor air from outdoor pollutants,
- At home: Using ventilation and filtration to reduce the risk of aerosol transmission of COVID-19

HC's air quality program also provided support to the Public Health Agency of Canada in developing guidance on using ventilation to reduce aerosol transmission of COVID-19 in residences and in long-term care homes.

3.4 Drinking water quality

Work on water quality under CEPA includes leadership on the development of guidelines for water quality. HC works in collaboration with the provinces and territories to establish a list of priority contaminants for developing or updating 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. The GCDWQ are used by all provinces and territories as a basis to establish their own regulatory requirements regarding the quality of drinking water in their jurisdictions to manage the risk from drinking water.

Priorities for guideline development are established approximately every 4 or 5 years, using exposure information from federal, provincial and territorial sources and up-to-date science, international actions, as well as taking into consideration jurisdictional needs. A process for prioritizing the development and updating of GCDWQ was updated in November 2020. The list of priority contaminants was also finalized to form the basis for the workplan for the Federal-Provincial-Territorial Committee on Drinking Water (CDW).

New or updated GCDWQ are published in the *Canada Gazette*, *Part I*, while supporting technical documents are published on Health Canada'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.

Also to support transparency, each guideline compares the standards of international agencies and key foreign jurisdictions. Note that drinking water values for contaminants may vary internationally due to a number of factors. All leading international agencies and jurisdictions consider the science that has been used by other agencies. However, each jurisdiction must also consider its specific climate, geology, industrial usage and other contextual factors when establishing values, thus accounting for the potential for different values in different jurisdictions.

Table 16 lists the guidelines finalized in 2020-2021 and those under development.

Table 16. Guideline documents for Canadian drinking water quality from April 2020 to March 2021

Published final guidelines	In progress*
Aluminum (March 2021)	Bromoxynil (November 2020)
Cadmium (July 2020)	4-Chloro-2-methylphenoxcyacetic Acid (MCPA) (March 2021)
1,4-Dioxane (March 2021)	Cyanobacteria and their Toxins in Recreational Water (August 2020)
Enterococci (June 2020)	Dicamba (October 2020)
Natural organic matter (July 2020)	2,4-Dichlorophenoxyacetic acid (2,4-D) (August 2020)
Overview of the Microbiological Aspects of Drinking Water Quality (March 2021)	Diquat (July 2020)
Total coliforms (June 2020)	Malathion (March 2021)
	Metribuzin (June 2020)
	Monitoring the Biological Stability of Drinking Water in Distribution Systems (July 2020)
	Waterborne pathogens (December 2020)

* In progress refers to guidelines published for consultation

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 3.1.3 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.

The final *Science Assessment of Plastic Pollution* was published on October 7, 2020. The report evaluates the state of the science and looks at the presence and effects of plastic pollution on the environment and human health. It confirms that plastic pollution is everywhere and is negatively impacting our environment. The Science Assessment established the foundation for taking action under CEPA.

On October 7, 2020, ECCC also published a discussion paper on *A proposed integrated management approach to plastic products to prevent waste and pollution*. It includes a proposal to ban or restrict six single-use items (checkout bags, cutlery, food service ware made of problematic plastics, ring beverage carriers, stir sticks, and straws) and commitments to establish minimum recycled content requirements for plastic products and to contribute to improving extended producer responsibility in Canada.

On October 10, 2020, a proposed Order to list plastic manufactured items on Schedule 1 of CEPA was published in the *Canada Gazette*, *Part 1*, for a 60-day public comment period. Adding plastic manufactured items to Schedule 1 of CEPA would provide the Government with the authority to put forward regulatory requirements. All comments received during the consultation periods for both the proposed Order and discussion paper are being considered in the development of the proposed regulations.

These efforts are part of Canada's comprehensive zero plastic waste agenda 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 2020, Canada led a group working to help other countries to monitor for effects of disposal in the marine environment, 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.

Disposal at sea permits

From April 1, 2020 to March 31, 2021 , 84 permits were issued in Canada for the disposal of 8.4 million tonnes of waste and other matter at sea (Tables 17 and 18), compared to 85 permits for the disposal of 9.3 million tonnes in 2019-2020. While the number of permits is slightly less than our 10-year average, the quantity of waste is significantly higher than the 10-year average. This is largely due to the permitting of a few major projects for port development and the continued need to remove dredged material from harbours and waterways to keep them safe for navigation. Also permitted was excavated native till (geological matter) that is disposed of at sea in the lower mainland of British Columbia, where on-land disposal options for clean fill are extremely limited. Fish-processing waste was also permitted in remote communities where there is no access to reuse-and-recycling opportunities.

Table 17. Disposal at sea quantities permitted (in tonnes) and permits issued in Canada from April 2020 to March 2021

Material	Quantity permitted	Permits issued
Dredge material	6 861 790	43
Fisheries waste	32 320	28
Geological matter	1 560 000	11
Vessels	0	0
Organic matter	400	2
Total	**8 454 510**	**84**

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

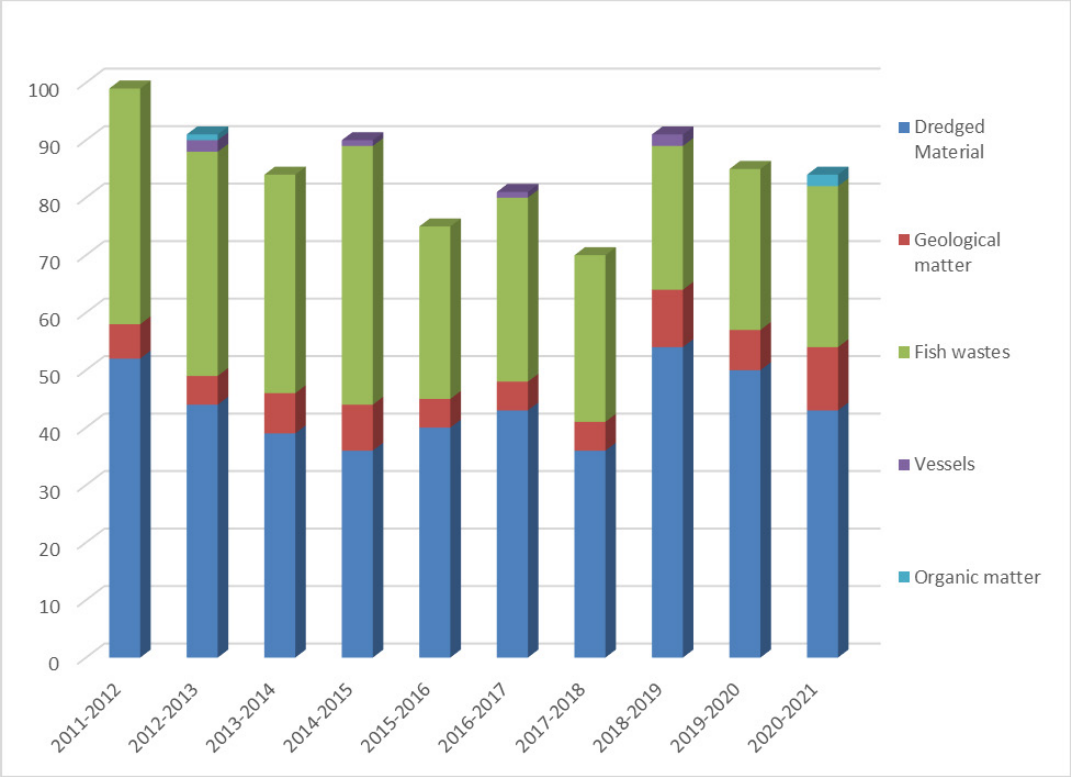
Table 18. Disposal at sea quantities permitted (in tonnes) and permits issued by region from April 2020 to March 2021

Material	Atlantic		Quebec		Pacific and Yukon	
	Quantity	Permits	Quantity	Permits	Quantity	Permits
Dredge material	1 506 050	14	478 400	10	4 877 340	19
Fisheries waste	31 170	25	1150	3	--	--
Geological matter	--	--	--	--	1 560 000	11
Vessels	--	--	--	--	0	0
Organic matter	400	2	--	--	--	--
Total	**1 537 620**	**41**	**479 550**	**13**	**6 437 340**	**30**

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

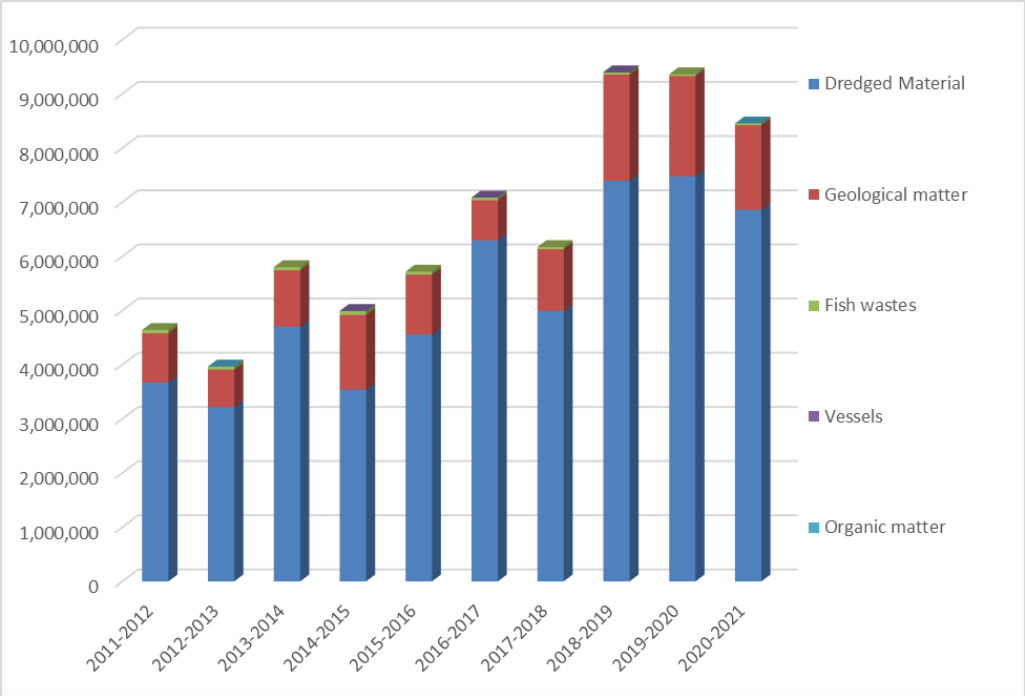
The trends in the number of permits issued over the last decade is illustrated in Figure 5, with the number of permits issued remaining consistent in 2020-2021 with the previous year.

Figure 5. 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 6. The quantities permitted continue to fluctuate from year to year. Building of infrastructure led to a high quantity permitted for both dredged material and inert, inorganic geological matter (excavated material) this fiscal year, similar to the quantities in the previous 2 years.

Figure 6. Annual disposal at sea quantities permitted (in millions of tonnes)



Further information on disposal at sea is available online.

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

Through the *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*, Canada implements its international obligations as a party to the:

- *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*
- Organization for Economic Co-operation and Development Decision on the Control of Transboundary Movement of Wastes Destined for Recovery Operations
- *Canada-United States Agreement on the Transboundary Movement of Hazardous Waste*

On March 17, 2021, the final *Cross-border Movement of Hazardous Waste and Hazardous Recyclable Material Regulations* were published in *Canada Gazette*, *Part II* and came into force on October 31, 2021. These regulations repeal and replace the 3 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.

In 2020, ECCC processed 2469 notices for proposed imports, exports and transits of hazardous wastes and hazardous recyclable materials under the *Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations*. From the notices received, 2175 permits were issued.

The notices received covered 42 037 waste streams, which exhibited a range of hazardous properties such as being flammable, acutely toxic, oxidizing, corrosive, dangerously reactive and environmentally hazardous.

Restrictions due to the COVID-19 pandemic impacted the compilation of data on the transboundary shipments of hazardous waste and hazardous recyclable material for both 2019 and 2020. As a result, the current report is providing an update on the transboundary shipments of hazardous waste and hazardous recyclable material that occurred in 2019. Sufficient data for the transboundary shipments that took place in 2020 was not available at the time of publication.

At least 38 054 individual transboundary shipments of hazardous waste and hazardous recyclable material were reported in movement documents received by ECCC for 2019. By comparison, in 2018, 32 765 individual transboundary shipments were done. It should be noted that these data are revised periodically as new information becomes available.

In 2019, almost all imports (99.8%) and exports (94.6%) of hazardous wastes and hazardous recyclable materials occurred between Canada and the United States. The remaining import exchanges occurred with Germany, France, Bahamas, Bolivarian Republic of Venezuela, United Arab Emirates, Brunei Darussalam, and Indonesia, while the remaining exports occurred with the Republic of Korea, Mexico, Belgium, Germany, and Austria.

The quantity of hazardous wastes and hazardous recyclable materials **imported into Canada** was 399 010 metric tonnes (t) in 2019. This represents an increase of 10 721 t or 2.8% compared to 2018.

Imported shipments destined for recycling totaled 249 874 t and represented about 62.6% of all imports in 2019. Imports of all hazardous wastes and hazardous recyclable materials in 2019 were shipped to authorized facilities in 5 provinces: Ontario, Quebec, British Columbia, New Brunswick and Alberta. Hazardous recyclable material imported into Canada in the greatest quantities were:

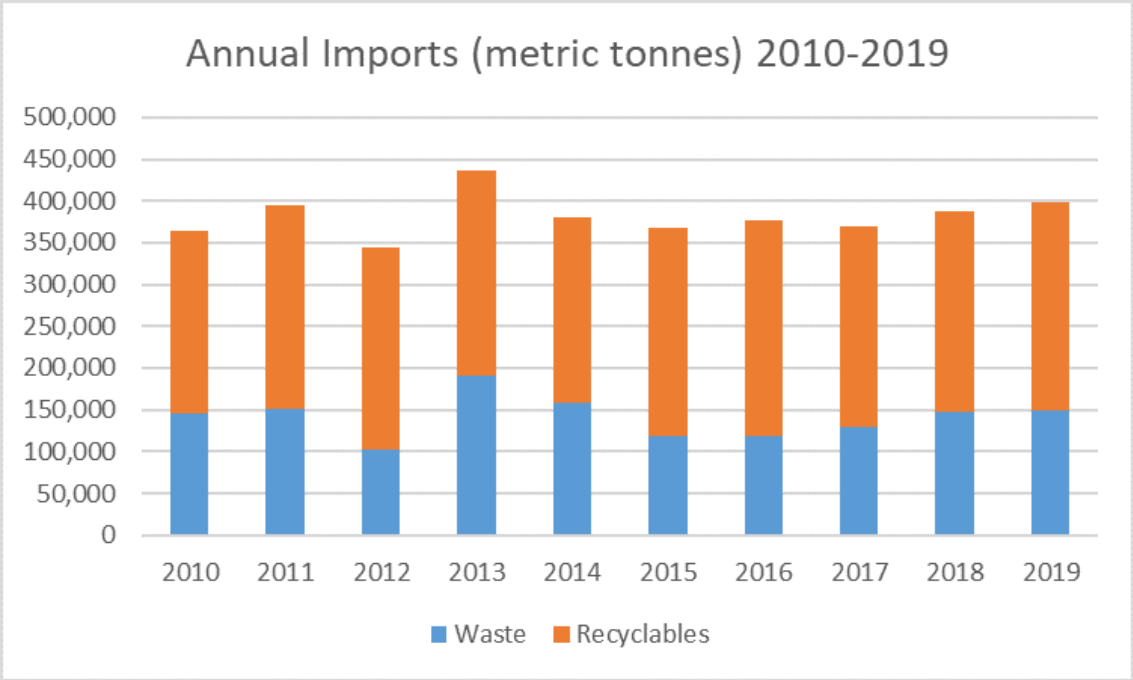
- hydraulic fluids (used oil)
- spent batteries (lead-acid and lithium)
- metal-bearing waste
- sulphuric acid, spent
- corrosive liquids
- flammable liquids

The remaining 149 136 t imported were hazardous wastes (about 37.4%) and were mostly composed of:

- metal-bearing waste having as constituents any of the following: metal carbonyls, hexavalent chromium compounds
- waste tarry residue from refining, distillation and pyrolytic treatment
- wastes from the production, formulation and use of biocides and phytopharmaceuticals, pesticides, and herbicides
- corrosive liquids
- waste oils/water, hydrocarbon/water mixtures, emulsions, organic solvents

Figure 7 shows the updated trends in the quantities of hazardous wastes and hazardous recyclable materials imported from 2010-2019, as compared to those shown in the 2019-2020 annual report.

Figure 7. Hazardous waste and hazardous recyclable material, imports, 2010-2019 (Metric tonnes)



The quantity of hazardous waste and hazardous recyclable materials **exported from Canada** was 367 465 t in 2019. This represents a decrease of 10 850 t or 2.9% from 2018.

Shipments exported for recycling totaled 306 642 t and represented about 83% of all exports in 2019. Exports of hazardous recyclable materials in 2019 originated from eight provinces: Ontario, New Brunswick, Quebec, Alberta, British Columbia, Saskatchewan, Manitoba and Newfoundland. The majority of hazardous recyclable material exported abroad for recycling included:

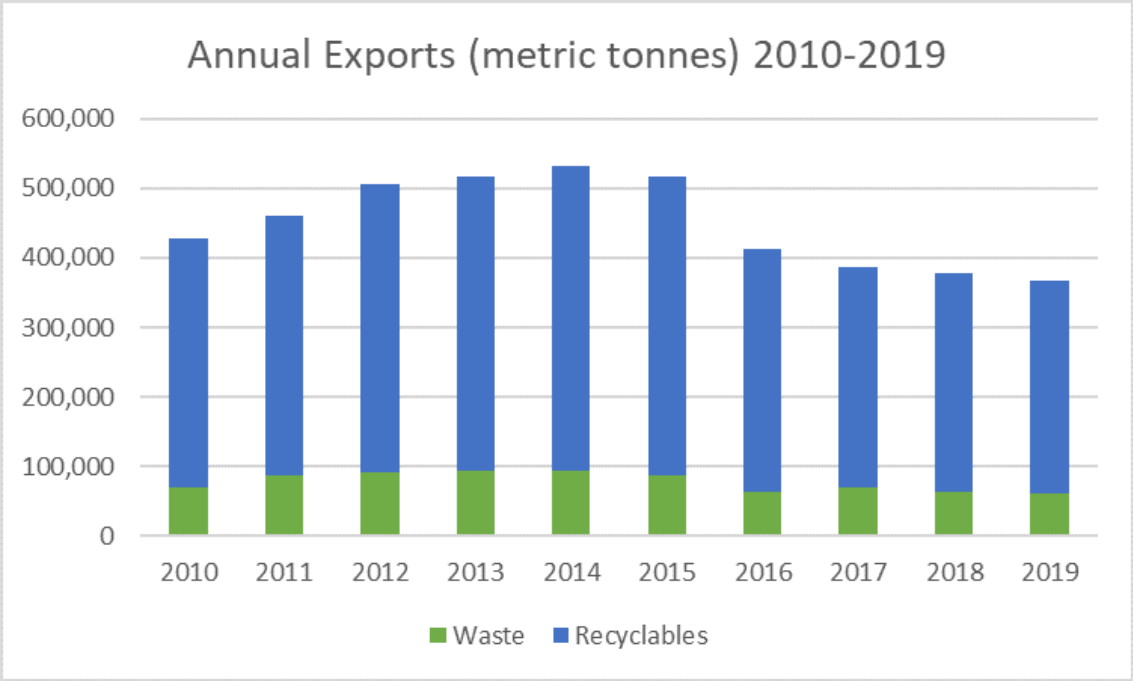
- sulphuric acid, spent
- batteries and other electrical cells
- waste oil/water, hydrocarbon/water mixtures, and emulsions (used oils)
- waste catalysts
- metal-bearing waste, waste from industrial pollution control devices
- treated cork and wood wastes

The remaining 60 823 t exported were hazardous wastes (17%) and were mostly composed of:

- waste consisting of or containing off specification or outdated chemicals
- corrosive solutions, sulphuric acid, spent
- waste oil/water, hydrocarbon/water mixtures, and emulsions (used oils)
- clinical and related wastes
- metal-bearing waste

Figure 8 shows the updated trends in the quantities of hazardous wastes and hazardous recyclable materials exported from 2010-2019, as compared to those shown in the 2019-2020 annual report.

Figure 8. Hazardous waste and hazardous recyclable material, exports, 2010-2019 (Metric tonnes)



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

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.

The Environmental Emergencies Division (EED) implements the departmental pollution incident notification system for persons required to notify federal and provincial/territorial governments of an environmental emergency or environmental occurrence (spill, release, etc.).

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. In the event of non-compliance, NEEC will work collaboratively with ECCC's Enforcement Branch.

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 2020-2021, NEEC recorded 536 notifications involving an uncontrolled, unplanned or accidental release of CEPA-regulated substances into the environment.

The *Environmental Emergency Regulations, 2019* came into force on August 24, 2019 and a new online reporting application was launched.

The Regulations require any person who owns, manages, or has the control of a regulated substance at a place in Canada, at or above the established threshold, to notify ECCC when this quantity threshold is met or when the maximum container capacity meets or exceeds this threshold.

If the total quantity and container capacity thresholds are both met, there is an additional requirement to prepare and exercise an environmental emergency (E2) plan for prevention, preparedness, response and recovery in the event of an environmental emergency.

The 9 most commonly identified substances requiring E2 plans are propane, anhydrous ammonia, gasoline, butane, natural gas, chlorine, natural gas condensates, ammonium nitrate solid, and hydrochloric acid.

More than 3582 facilities from different sectors, subject to the Regulations, have registered in the new application and 2278 have already informed ECCC that their E2 plan has been brought into effect.

In 2020-2021, ECCC's regional activities associated with the implementation of the Regulations included delivering presentations to the regulated community, and promoting and enforcing compliance with regulated persons.

3.7 Government operations and federal and aboriginal land

On November 11, 2020, the final *Regulations Amending the Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations (Miscellaneous Program)* were published in the *Canada Gazette, Part II*. The proposed amendments are in response to concerns, comments and recommendations from the Standing Joint Committee for the Scrutiny of Regulations (SJCSR) regarding a lack of clarity and some inconsistencies in the regulatory text. These regulations establish technical standards for the design and installation of storage tank systems under federal jurisdiction and include requirements for operation, maintenance, removal, reporting and record keeping.

On November 14, 2020, ECCC published the proposed *Federal Halocarbon Regulations, 2020* in the *Canada Gazette*, *Part I*. The proposed regulations would repeal and replace the current *Federal Halocarbon Regulations, 2003*. The Regulations aim to minimize releases of halocarbons to the environment from refrigeration, air conditioning and fire-extinguishing systems that are owned by federal departments, boards and agencies, Crown corporations, or federal works or undertakings; or are located on federal or Aboriginal lands. The proposed revisions will address administrative, operational and enforcement issues and will affect certain businesses under federal jurisdiction in the refrigeration, air conditioning, and fire extinguishing sectors.

- In 2020-2021, 13 permits to charge fire-extinguishing systems with a halocarbon and 3 permits to install fire-extinguishing systems with a halocarbon were issued under the *Federal Halocarbon Regulations, 2003*.

4. Reporting programs and emission inventories

There are 2 mandatory reporting programs under CEPA, which require facilities to report on their releases or emissions of specified substances into the environment, and ECCC compiles and maintains 5 inventories of substances released into the environment using the information reported.

4.1 Reporting programs

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

- National Pollutant Release Inventory
- Greenhouse Gas Reporting Program

Data for both programs is submitted through ECCC's Single Window Information Management (SWIM) system. Further information on the SWIM system is available online.

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 2019 reporting year was submitted to ECCC by July 31, 2020 (see section 4.2 below for details on the data). Reviewed data for 2019 was published on March 21, 2021. The deadlines for reporting on the 2019 data and its publication were delayed due to the COVID-19 pandemic.

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 2020-2021 included a number of virtual meetings and consultations on proposals for specific changes. Consultations focused on proposed changes to the requirements for 2022 reporting, including changes to reporting of air pollutants to provide more information for air quality modelling and for the addition of chlorhexidine (and its salts) to 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.

Greenhouse Gas Reporting Program

ECCC requires annual reporting of GHG emissions from facilities (mostly large industrial operations) through its Greenhouse Gas Reporting Program (GHGRP). The GHGRP is part of ECCC's ongoing effort to maintain and continuously enhance, in collaboration with the provinces and territories, 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 Canadians with consistent information on facility-level GHG emissions, to inform the development of the National GHG Inventory, and to support regulatory initiatives. The data collected are also shared with provinces and territories.

- In February 2020, a notice was published in the *Canada Gazette*, *Part I*, requiring the reporting of GHG emissions for the 2019 calendar year. An amendment was subsequently issued in May, extending the reporting deadline to provide facilities more time to submit their 2019 emission reports due to impacts related to the COVID-19 pandemic.
- The 2019 reporting cycle continued the additional requirements introduced in 2017 as part of an expansion to the GHG Reporting Program. The expansion to date includes enhanced reporting and methodological requirements for 14 industry sectors, as well as a drop in the reporting threshold (50 000 tonnes to 10 000 tonnes CO_2 equivalent). ECCC will continue to assess the need for further expansion in future years.

Information about the GHGRP is available online.

4.2 Emission and release inventories

ECCC compiles and maintains 5 inventories of substances released into the environment. These are the:

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

National Pollutant Release Inventory

NPRI information is 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 NRPI data available at the time of publication is for the 2019 reporting year. In 2019, 7362 facilities (Figure 9) reported to the NPRI approximately 4.89 million tonnes of pollutants covering over 320 substances (Figure 10):

- 2.94 million tonnes of pollutants were released directly to the environment
- 1.57 million tonnes were disposed to landfills, applied to land or injected underground, either on the facility site or off-site
- 379 185 tonnes were transferred off the facility site for treatment prior to final disposal or for recycling and energy recovery

Figure 9. Location of facilities that reported to the NPRI for the 2019 reporting year

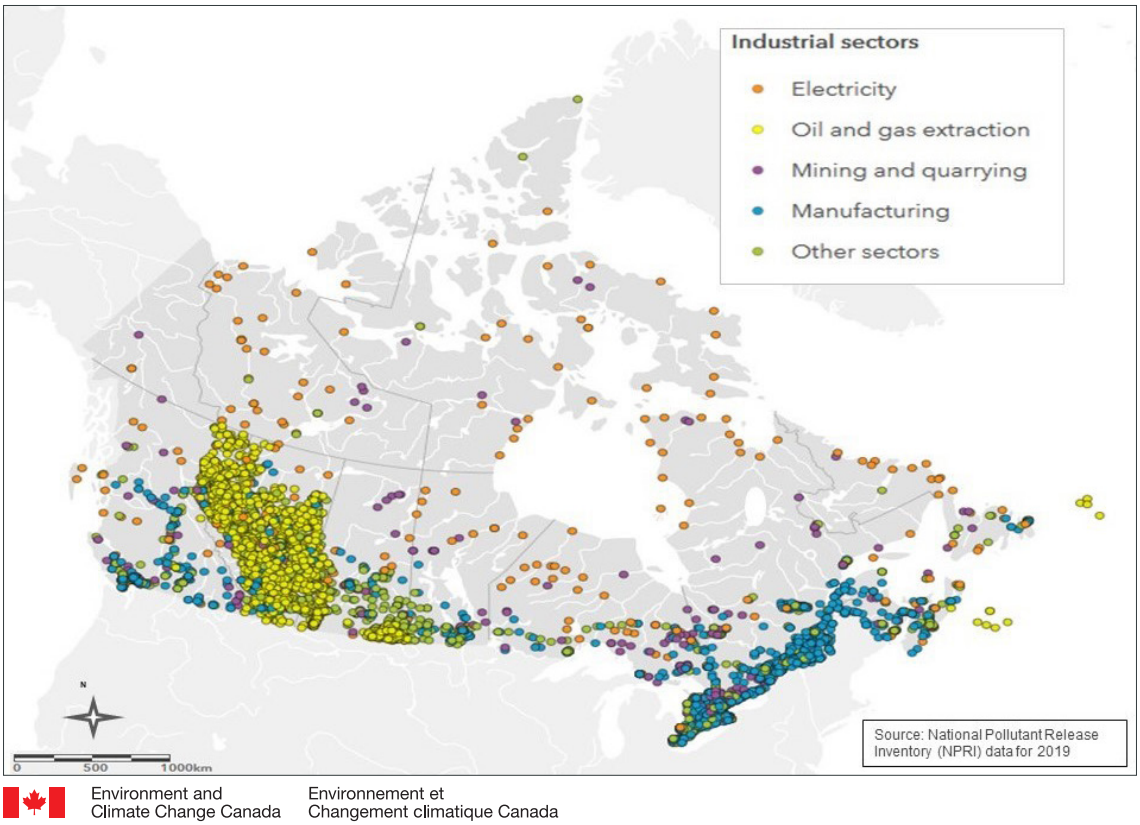
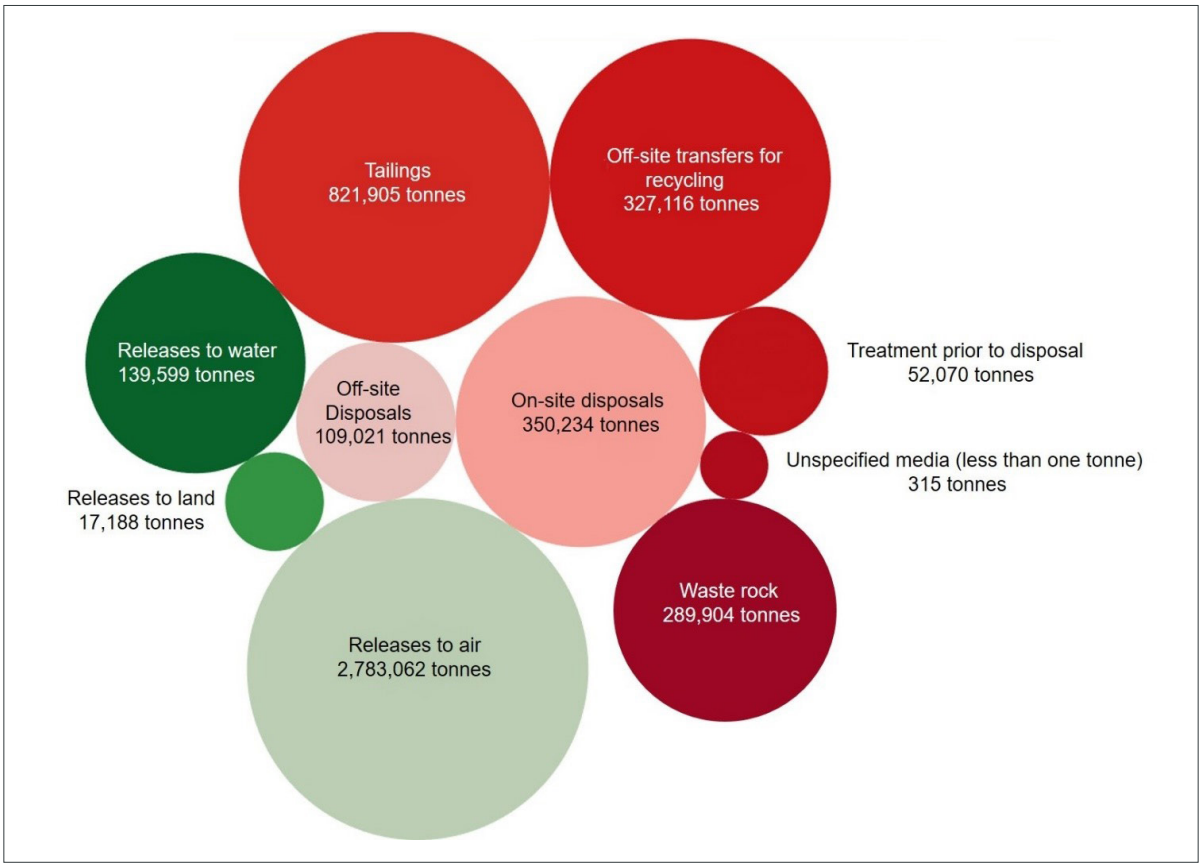


Figure 10. Breakdown of total quantities reported in 2019, by reporting category



Between 2010 and 2019, releases to the environment to all media reported to the NPRI **decreased** by 656 088 tonnes. In particular:

- releases to air decreased by 666 178 tonnes
- releases to water increased by 20 248 tonnes
- releases to land increased by 6012 tonnes
- releases of substances (i.e., unspecified media) where the total release quantity was less than 1 tonne increased by 130 tonnes

Between 2010 and 2019, total disposals and transfers **increased** by 24 945 tonnes. In particular:

- off-site disposals decreased by 609 872 tonnes
- on-site disposals increased by 100 575 tonnes
- off-site transfers for recycling decreased by 60 710 tonnes
- disposals of waste rock (rock removed to reach ore) increased by 272 470 tonnes
- disposals of tailings (materials left when minerals are removed from ore) increased by 149 329 tonnes

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 level 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 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 (D/F), 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).

The APEI also 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 Canadians about pollutants that affect their health and the environment.

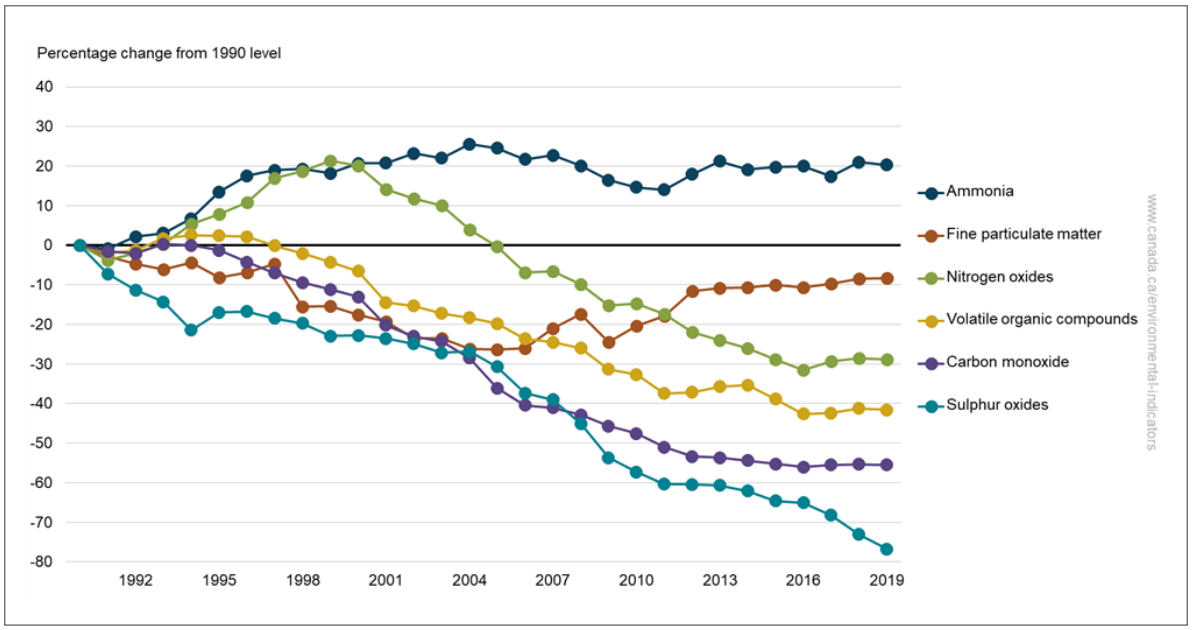
As of February 2021, the most recent estimates of air pollutant emissions are for 1990 to 2019. According to the APEI, 14 of the 17 reported air pollutants show decreases compared to historical levels (see Figure 11). A few key sources of pollutants account for a significant portion of the downward trends in emissions (see Table 19).

Table 19. Percentage reductions of air pollutants from 1990-2019 from major sources.

Source	Pollutant	Percentage decrease 1990-2019
Non-ferrous refining and smelting • smelter closures and effective risk management (including implementation of pollution prevention plans)	SO_x	95%
	Pb	92%
	Cd	97%
	Hg	99%
Home firewood burning • adoption of more modern wood combustion equipment	$PM_{2.5}$	43%
	VOC	39%
	CO (carbon monoxide)	19%
	PAH (polycyclic aromatic hydrocarbons)	4%
Coal-fired electric power generation • phasing out of coal-fired plants	SO_x	62%
	Hg	72%
	HCB (hexachlorobenzene)	98%
Light-duty gasoline trucks and vehicles • effective fuel and engine regulations	NO_x	58%
	PAH	63%
Transportation associated with combustion of gasoline • effective fuel and engine regulations	VOC	79%
	CO	64%
Waste incineration • improvements in incineration technologies	HCB	93%
	Dioxins and Furans	94%

Despite significant decreases in emissions of most pollutants, since 2005 emissions of particulate matter have risen by 49% (TPM), 44% (PM_{10}) and 25% ($PM_{2.5}$). These increases are largely due to increased transportation on unpaved roads as well as construction operations. Another exception to the general downward trends is the steady increase in emissions of ammonia (NH_3), which were 20% above 1990 levels in 2019, although 3% below 2005 levels. The upward trend in NH_3 emissions is driven by nitrogen fertilizer use in crop production.

Figure 11. Emissions trends for selected air pollutants in Canada, 1990 to 2019



Inventory of black carbon emissions

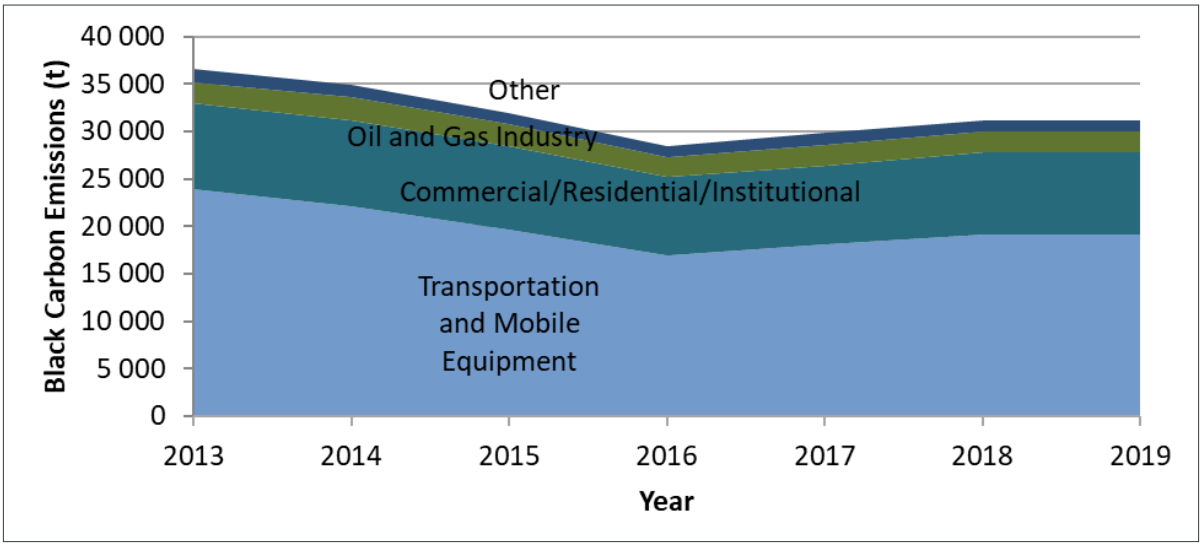
Canada produces an annual inventory of black carbon emissions as part of its commitments under the Arctic Council Framework for Action on Enhanced Black Carbon and Methane Emissions Reductions. The associated report serves to inform Canadians about black carbon emissions and provide valuable information for the development of air quality management strategies.

The data used to quantify black carbon emissions are based on fine particulate matter ($PM_{2.5}$) emissions from combustion-related sources, such as transportation and mobile equipment and home firewood burning, taken from the Air Pollutant Emission Inventory.

According to Canada's 2021 Black Carbon Emission Inventory report, the following trends are notable (see Figure 12).

- In 2019, approximately 31 kilotonnes (kt) of black carbon were emitted from vehicles, equipment, and combustion of fuel related to human activities.
- The largest sources of black carbon emissions are transportation and mobile equipment (notably diesel engines from on-road and off-road transport) and Commercial/Residential/Institutional category fuel combustion, most notably from home firewood burning, accounting for 19 kt (61%) and 8.6 kt (28%) respectively, of total emissions in 2019.
- Since 2013, black carbon emissions have decreased by 5.4 kt (15%), even though black carbon emissions have increased by 2.8 kt (9.8%) since 2016.

Figure 12. Canada's black carbon emissions trends, 2013 to 2019



Facility-level Greenhouse Gas Emissions Inventory

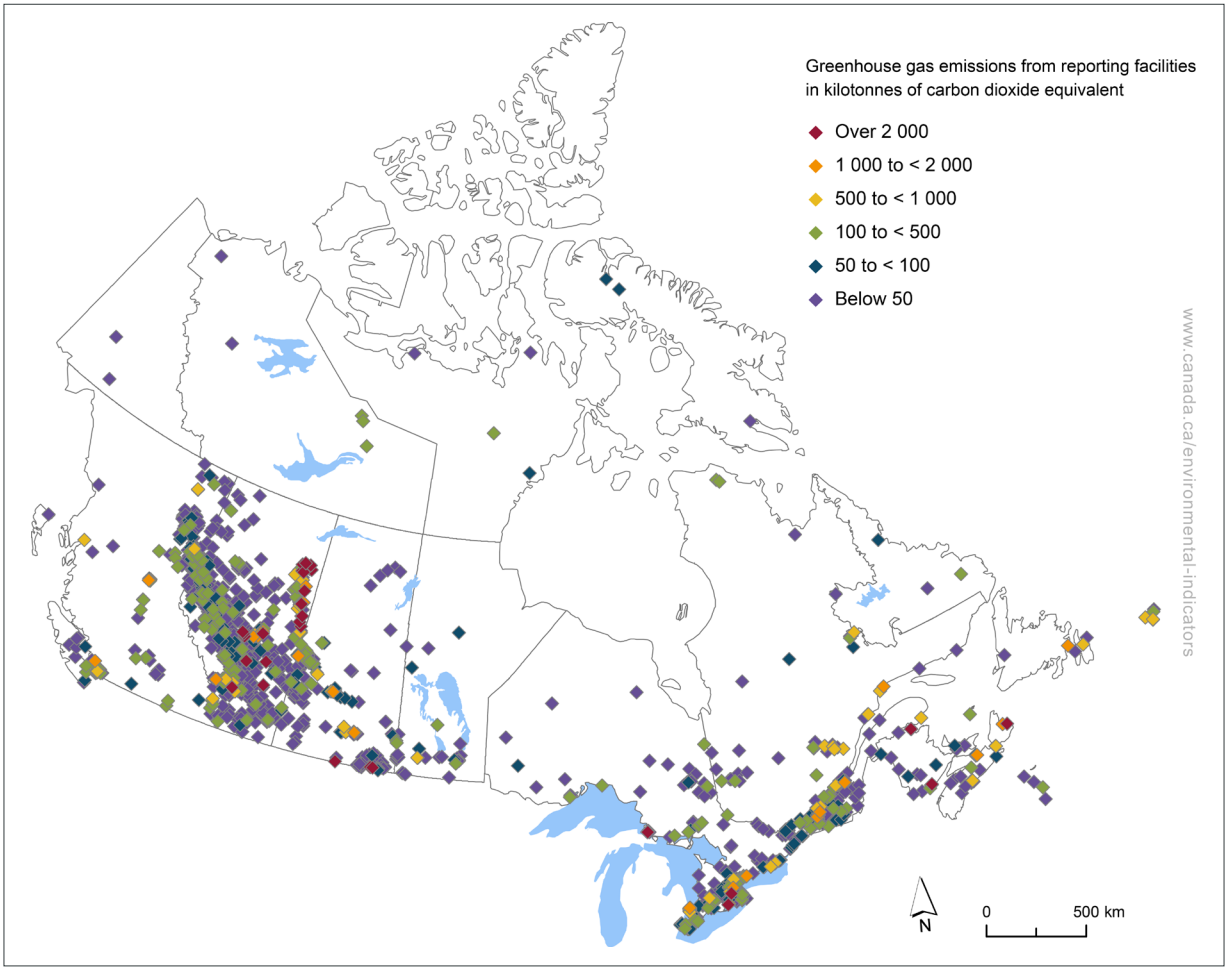
Accurate and consistent tracking of GHG emissions from individual facilities contributes to ECCC's efforts to monitor environmental performance and develop policies related to climate change by providing a more precise picture of emission levels from large emitters in Canada. The most recent data available is for the 2019 reporting year.

- In 2019, 1700 facilities reported their greenhouse gas (GHG) emissions (see Figure 13), totaling 293 megatonnes (Mt) of carbon dioxide equivalent (CO_2 eq). The 2019 reporting cycle is the third year under the expanded federal GHG reporting program (GHGRP) in which certain facilities are required to provide additional data. The reported emissions are largely distributed across 3 sectors: (1) Mining, Quarrying, and Oil and Gas Extraction (39%), (2) Manufacturing (30%), and (3) Utilities (24%).

The complete data set of greenhouse gas emissions from large 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 GHG Reporting Program, shows that emissions from the reporting facilities account for 40% of Canada's total GHG emissions in 2019.

Figure 13. Greenhouse gas emissions from large facilities in 2019



National Greenhouse Gas Inventory

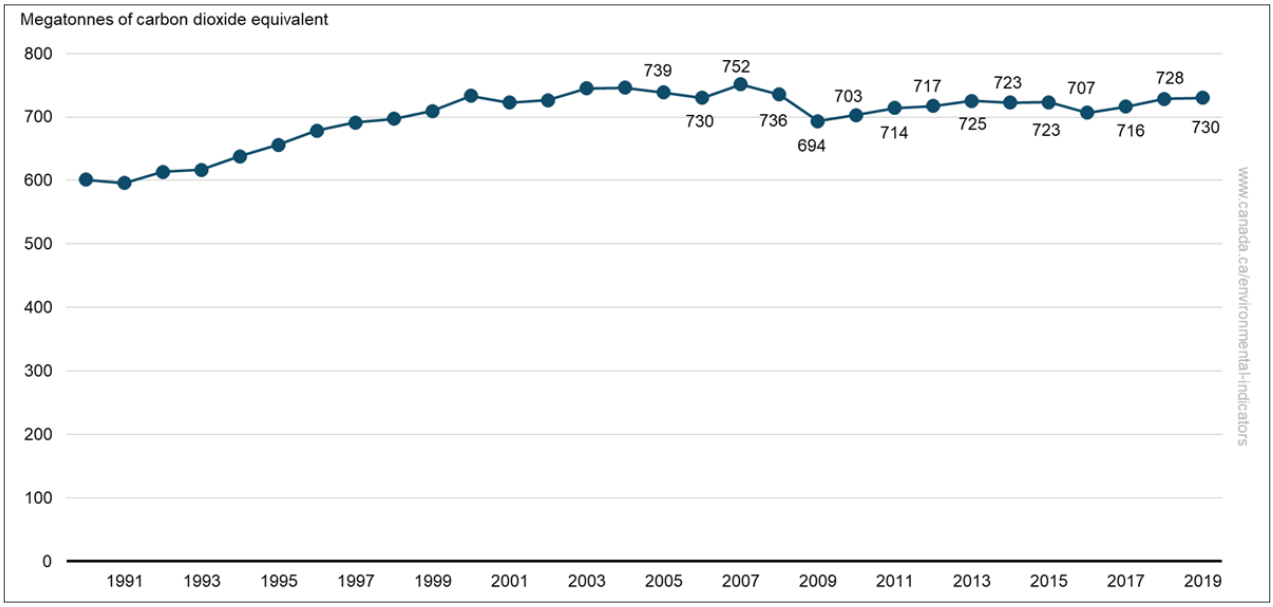
As a signatory to the *United Nations Framework Convention on Climate Change* (UNFCCC) Canada is obligated to prepare and submit an annual national greenhouse gas (GHG) inventory covering anthropogenic emissions by sources and removals by sinks. ECCC is responsible for preparing Canada's official national 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 NIR published in 2021 provides data up to 2019.

The National GHG Inventory shows the following trends:

- After fluctuations in recent years, in 2019 Canada's GHG emissions were 730 megatonnes of carbon dioxide (Mt CO_2 eq) (see Figure 14), about 1Mt or 0.2% increase from 2018 emissions and a net decrease of 9 Mt or 1.1% from 2005 emissions.
- Over the long term, 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 37% since 1990 and 23% since 2005.
- Emission trends since 2005 remain consistent, with emission increases in the Oil and Gas and Transportation sectors being offset by decreases in other sectors, notably Electricity and Heavy Industry.

Figure 14. Canada's greenhouse gas emissions trend, 1990 to 2019



Further information on the National GHG Inventory is available online.

Please note that inventories mentioned above are available on the Open Data Portal.

5. Administration and public participation

Administration and public participation covers stakeholder engagement and inter-jurisdictional relationships.

5.1 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 2020-2021, the CEPA NAC held 2 teleconference meetings, on May 4 and September 2. The NAC Secretariat corresponded regularly with Committee members regarding various initiatives implemented under CEPA. These initiatives included opportunities to comment on and be informed of numerous actions taken under the Act.

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

- 23 draft screening assessments, seven of which included a Risk Management Scope Document
- 7 Risk Management Approach Documents published with a final screening assessment
- 2 Proposed Orders, 1 adding Plastic Manufactured Items and 1 adding Chlorhexidine and its Salts to Schedule 1
- 2 Notices of Intent to apply the Significant New Activity (SNAc) Provisions
- Proposed *Federal Halocarbon Regulations 2020* (FHR)
- Draft Science Assessment of Plastic Pollution (extension on comment period)
- Consultation Document Related to the Proposed Removal of substances from the Revised In-Commerce List (R-ICL)
- Proposal to Renew the Federal Agenda on the Reduction of Emissions of Volatile Organic Compounds from Consumer and Commercial Product
- Proposed Equivalency Agreement on the equivalency of federal and Alberta regulations respecting the release of methane from the oil and gas sector in Alberta
- Proposed Equivalency Agreement on the equivalency of federal and Saskatchewan regulations respecting the release of methane from the oil and gas sector in Saskatchewan
- Science Approach Document on Bioactivity Exposure Ratio

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

- *Proposed Regulations Amending the Sulphur In Gasoline Regulations*
- *Proposed Clean Fuel Regulations*

Members were **informed** of:

- 22 final screening assessments
- 2 Final Orders, 1 to delete BNST from Schedule 1 and 1 to add Mitotane to Schedule 1
- *Cross-Border Movement of Hazardous Waste and Hazardous Recyclable Material Regulations*
- *Regulations Amending the Sulphur in Gasoline Regulations*
- *Reduction in the Release of Volatile Organic Compounds Regulations (Petroleum Sector)*
- Final Notice Requiring the Preparation and Implementation of Pollution Prevention Plans with Respect to Triclosan in Certain Products
- Final Code of Practice for Methylenediphenyl Diisocyantes (MDIs).
- Renewal of the Environmental Performance Agreement Respecting the Use of Tin Stabilizers in the Vinyl Industry
- Federal Environmental Quality Guidelines (FEQG) for Lead, Quinoline and Strontium
- Release Guidelines for Disperse Yellow 3 and 25 other Azo Disperse Dyes in the Textile Sector
- Information Gathering under Section 71 of CEPA
- Reviewed 2019 National Pollutant Release Inventory Data
- Reviewed 2018 National Pollutant Release Inventory Data
- 3 Orders amending the Domestic Substances List to apply the Significant New Activity (SNAc) provisions of CEPA to various substances
- Science Assessment of Plastic Pollution
- Strategy to Systematically Assess the Performance of the Risk Management Strategies or Approaches of Toxic Substances in Canada

5.2 Federal-provincial/territorial agreements

Part 1 of the Act allows the Minister of the Environment 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 20 indicates the administrative and equivalency agreements in place under sections 9 and 10 of CEPA and the activities under them during 2020-2021.

Table 20. Current administrative and equivalency agreements under CEPA by jurisdiction

Jurisdiction (s)	Agreement	Description	Activities for 2020-2021
British Columbia	Canada-British Columbia Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	• 79 notifications received • Annual review of agreement occurred • Preparation for the five-year renewal of the agreement and discussion of changes to the standard operating procedures were undertaken
	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. 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)*	• Annual compliance data for the first year of implementation (2020) to be received by December 31, 2021

Jurisdiction (s)	Agreement	Description	Activities for 2020-2021
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 information
	Canada-Alberta Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	• 113 notifications • Annual review of agreement occurred • Preparation for the five-year renewal of the agreement and discussion of changes to the standard operating procedures were undertaken

Jurisdiction (s)	Agreement	Description	Activities for 2020-2021
	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. 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)*	• Annual compliance data for the first calendar year of implementation (2020) to be received by December 31, 2021

Jurisdiction (s)	Agreement	Description	Activities for 2020-2021
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 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.	• 35 notifications received • Annual review of agreement occurred • Preparation for the five-year renewal of the agreement and discussion of changes to the standard operating procedures were undertaken
	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 for the first year of implementation (2020) to be received by December 31, 2021.

Jurisdiction (s)	Agreement	Description	Activities for 2020-2021
	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. 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)*	• Annual compliance data during the first calendar year of implementation (2020) to be received by December 31, 2021
Manitoba	Canada-Manitoba Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	• 13 notifications received • Annual review of agreement occurred • Preparation for the five-year renewal of the agreement and discussion of changes to the standard operating procedures were undertaken

Jurisdiction (s)	Agreement	Description	Activities for 2020-2021
Ontario	Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health	Administrative agreement (s.9) New draft agreement published – July 6, 2019. 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.	See the *Canada Water Act* Annual Report 2020-2021 for an update on progress under this Agreement.
	Canada-Ontario Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	• 91 notifications received • Annual review of agreement occurred • Preparation for the five-year renewal of the agreement and discussion of changes to the standard operating procedures were undertaken
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 for the first calendar year of implementation (2020) to be received by December 31, 2021

Jurisdiction (s)	Agreement	Description	Activities for 2020-2021
Northwest Territories	Canada-Northwest Territories Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	• 5 notifications received • Annual review of agreement occurred • Agreement expired in March 2021 and will not be renewed
Yukon	Canada-Yukon Environmental Occurrences Notification Agreement*	Administrative agreement (s.9) 2016	• 6 notifications received • Annual review of agreement occurred • Preparation for the five-year renewal of the agreement and discussion of changes to the standard operating procedures were undertaken
British Columbia **Alberta** **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 publically 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.

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 2020-2021.

On January 30, 2021, a new Memorandum of Understanding (MOU) between the federal government and the government of Quebec was published in the *Canada Gazette*, *Part I*. The MOU sets out the terms of cooperation and the respective responsibilities to ensure the continuity in the transmission of air quality data and air quality forecast and smog warnings production for Quebec's Info-Smog Program.

5.3 Public participation

CEPA Registry

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 2020 to March 2021, the CEPA Registry website had 304 104 visits.

Public consultation

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

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 55 opportunities posted on the Registry between April 1, 2020 and March 31, 2021 for stakeholders and the members of the public to provide comments on proposed initiatives under CEPA. These include

- 20 screening assessments
- 4 final decisions on assessments
- 6 results of investigations
- 2 proposed additions to the List of Toxic Substances
- 5 amendments to the Domestic Substances List
- 8 proposed guidelines
- 2 proposed Regulations
- 1 amendment to existing Regulations
- 2 notices related to equivalency agreements
- 2 orders declaring the application of specific regulations
- 1 proposed removal from the In Commerce List
- 2 risk management discussion papers

Please see the CEPA Registry public consultations, available online.

Pollution Prevention resource finder

Part 4 of CEPA provides the authority for the establishment of a national pollution prevention information clearinghouse to facilitate the collection, exchange and distribution of information regarding pollution prevention.

The Pollution Prevention resource finder (P2 finder) is Canada's largest publicly accessible database of links to practical resources that can help Canadians and Canadian organizations be more environmentally friendly. It received more than 27 000 views in 2020-2021. Users can search by keyword and/or filters to find resources of interest. The P2 finder contains links to resources for:

- employees or volunteers
- homeowners or renters
- travelers

- youth or educators
- businesses (including non-profit organizations)
- community groups
- governments
- health care facilities

CMP-related committees and activities

The CMP Science Committee supports a strong science foundation to CMP by providing external national and international scientific expertise to HC and ECCC on scientific issues.

- The Committee held its final meeting of its mandate online on February 17-19, 2021 to discuss the evolution of risk assessment under CEPA. Meeting records and report are made available online.

The goal of the CMP Stakeholder Advisory Council (CMP SAC) was to obtain advice from stakeholders and Indigenous partners for implementing the CMP and to foster dialogue with the government, and among different groups.

- In 2020-2021, the government hosted a final virtual CMP SAC meeting to reflect on an evaluation of SAC Members' experiences throughout the current mandate, as well as to seek insight on some forward looking considerations. The formal mandate of the SAC ended March 31, 2021.

Also in 2020-2021, ECCC and HC laid the groundwork for consultations to be held in 2021-2022 on supply chain transparency and labeling. The objective of this work is to improve supply chain transparency and enhance mandatory labeling for certain consumer products, to give Canadians greater access to information about the substances to which they are exposed. Responses to the voluntary survey ECCC launched for Canadian industry stakeholders to help identify barriers and challenges to supply chain transparency for chemicals in products will help prepare for these consultations (see section 3.1.1). In addition, ECCC collaborated with Innovation, Science and Economic Development Canada and industry partners to support the development and testing of distributed ledger ("block chain") technology solutions for the secure sharing of data about chemicals within supply chains.

6. Compliance promotion and enforcement

To achieve greater compliance with the Act and its risk management tools, both compliance promotion activities and enforcement measures are used.

The goal of compliance promotion is to increase awareness of and voluntary compliance with regulatory and non-regulatory instruments in an effort to limit harm to the environment and human health and consequential enforcement actions. Compliance promotion officers across Canada provide information to regulated communities on what is required to comply with CEPA, the benefits of compliance, and the consequences of non-compliance.

Enforcement activities are conducted in accordance with the Compliance and Enforcement Policy for CEPA. CEPA provides enforcement officers with a wide range of powers to enforce the Act, including the powers of a peace officer.

6.1 Compliance promotion priorities

Each year, ECCC develops a list of priorities for delivery of compliance promotion activities on issues such as chemical management, air pollutants, and greenhouse gas emissions. Factors that influence the identification of priority activities include the recent publication of new or amended regulatory and non-regulatory instruments; new requirements coming into force; level of compliance; and need to maintain awareness, understanding, or compliance for specific requirements. Resources are aligned with the identified compliance promotion priorities.

In 2020-2021, compliance promotion activities were carried out on 24 priority regulatory and non-regulatory CEPA instruments, namely:

- *Chromium Electroplating, Chromium Anodizing and Reverse Etching 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*
- *Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations*
- *Federal Halocarbon Regulations, 2003*
- *Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations*
- *Marine Spark-Ignition Engine, Vessel and Off-Road Recreational Vehicle Emission Regulations*
- *Microbeads in Toiletries Regulations*
- *Multi-Sector Air Pollutants Regulations (MSAPR)*
- *New Substances Notification Regulations (Organisms)*
- *Off-road Compression-Ignition (Mobile and Stationary) and Large Spark-Ignition Engine Emission Regulations*

- *Off-Road Small Spark-Ignition Engine Emission Regulations*
- *On-Road Vehicle and Engine Emission Regulations*
- *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations*
- *PCB Regulations*
- *Products Containing Mercury Regulations*
- *Prohibition of Asbestos and Asbestos Products Regulations*
- *Prohibition of Certain Toxic Substances Regulations*
- *Reduction in the Release of Volatile Organic Compounds Regulations (Petroleum Sector)*
- *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)*
- *Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations*
- *Sulphur in Gasoline 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*

6.2 Compliance promotion activities

The COVID-19 pandemic restrictions did not allow for any in-person contact, such as meetings, site visits, conferences, multi-instrument sessions, or training. As such, the majority of compliance promotion activities focused on virtual opportunities to reach larger audiences, through virtual conferences and webinar events, as well as email campaigns, article publications, and phone calls. Many of these activities were carried out in collaboration with provincial and territorial governments, as well as non-governmental organizations and associations.

In 2020-2021, 17 938 known or potential regulatees received compliance promotion material and 813 stakeholders were contacted by ECCC for clarification of regulatory requirements and/or additional information. In addition, responses were provided to numerous enquiries received by email, fax, letter and telephone.

ECCC launched a number of compliance promotion initiatives:

- facilitating easier communications with ECCC by redesigning the business reply form to include auto-generated and pre-populated electronic response options for the 15 464 stakeholders potentially interested in knowing more about the *New Substances Notification Regulations (Organisms)*
- creating a tailored Frequently Asked Questions with succinct and focused answers and specific guidance products that improve the awareness of the *Multi-Sector Air Pollutants Regulations*
- improving reporting by varying the timing and number of reminders sent for *Chromium Electroplating, Chromium Anodizing and Reverse Etching Regulations*; an increase in submission of reports after the reminders, indicated the effectiveness of the compliance promotion activities

- publishing a sponsored article with banners in *Recycling Product News* magazine as well as on the *Association canadienne des industries du recyclage* website that informed the industry about the new international *Basel Convention* requirements on waste plastics which trigger application of the *Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations*
- revamping the reporting package for *Tetrachlorethylene (Use In Dry Cleaning And Reporting Requirements) Regulations* by sending pre-stamped return envelopes as an incentive for timely reporting; whether the quality and number of reports submitted improves as result of improving the quality of information and user-friendliness of the compliance promotion package provided to regulates, will be assessed
- providing information, fact sheets and guidance documents to inform stakeholders on various provisions of the *Ozone-depleting Substances and Halocarbon Alternatives Regulations* that came into force in January 2020 and January 2021
- providing compliance promotion information, on vehicle and engine emissions regulations and fuels regulations, to regulatees via webinars and mail outs

6.3 Enforcement priorities

Each year, ECCC develops an Integrated Enforcement Plan (IEP) that sets out the enforcement activities to be carried out in that fiscal year, including activities to address non-compliance with CEPA. Factors that influence the identification of priority activities include the risk to the environment and human health represented by the regulated substance or activity, governmental and departmental priorities, suspected non-compliance, recent publication of new and amended regulations, and domestic and international commitments and obligations.

In 2020-2021, the following CEPA instruments were given priority in the IEP:

- *Off-Road Compression-Ignition Engine Emission Regulations*
- *Benzene in Gasoline Regulations*, *Sulphur in Gasoline Regulations*, *Sulphur in Diesel Fuel Regulations* and *Renewable Fuels Regulations*
- *Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations*
- *Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations*

In addition to the planned inspections carried out under the IEP, enforcement activities also include a large number of inspections resulting from responses to complaints, notifications from partners, intelligence or departmental referrals, reported spills and incidents, or other information.

ECCC initiated a series of risk assessments in 2018-2019 to assess and determine the risk of non-compliance with its laws and regulations - including those under CEPA. In 2019-2020, a threat risk assessment on toxic substances was completed and the results were used to inform 2020-2021 planning. In 2020-2021, a series of risk-based projects were launched based on the results of the threat risk assessments. These projects focus on increased inspections for Ammonia, Siloxane D4, the Metallurgical Project, and Textile Mill Effluent. 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.

6.4 Enforcement activities

Enforcement activities undertaken between April 1, 2020 and March 31, 2021 are summarized in the following 4 tables:

- Table 21 provides the number of on-site and off-site inspections for each regulation
- Table 22 provides the breakdown of investigations for each regulation for which at least 1 investigation occurred or closed
- Table 23 provides the total number of enforcement measures resulting from inspections and investigations that were imposed for each regulation
- Table 24 provides the number of prosecutions for each regulation

6.4.1 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 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 21 details the 1 021 inspections conducted under CEPA for fiscal year 2020-2021. 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.

Table 21. Number of inspections under CEPA from April 1, 2020 to March 31, 2021

Instrument	Inspections*		
	On-site	Off-site	Total
Total	**299**	**722**	**1021**
2-Butoxyethanol Regulations	11	0	**11**
Benzene in Gasoline Regulations	8	0	**8**
CEPA – various section(s)	29	39	**68**
Chromium Electroplating, Chromium Anodizing and Reverse Etching Regulations	16	4	**20**
Concentration of Phosphorus in Certain Cleaning Products Regulations	1	0	**1**
Disposal at Sea Regulations	2	30	**32**
Environmental Emergency Regulations	34	60	**94**
Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations	35	19	**54**
Federal Halocarbon Regulations, 2003	16	25	**41**
Fuels Information Regulations, No. 1	1	2	**3**
Interprovincial Movement of Hazardous Waste Regulations	0	1	**1**
Multi-Sector Air Pollutants Regulations	1	0	**1**
Microbeads in Toiletries Regulations	2	0	**2**
National Pollutant Release Inventory	0	18	**18**
New Substances Notification Regulations (Chemicals and Polymers)	12	0	**12**
New Substance Notification Regulations (Organisms)	1	0	**1**
Notice s. 85(1) SNAc (Chemicals and Polymers)	3	0	**3**
Notice s. 56 for a Pollution prevention plan	1	1	**2**

Instrument	Inspections*		
	On-site	Off-site	Total
Off-Road Compression-Ignition Engine Emission Regulations	16	4	**20**
Off-Road Small Spark-Ignition Engine Emission Regulations	1	0	**1**
On-Road Vehicle and Engine Emission Regulations	5	0	**5**
Ozone-depleting Substances and Halocarbon Alternatives Regulations	1	6	**7**
PCB Regulations	11	36	**47**
Products Containing Mercury Regulations	0	1	**1**
Prohibition of Asbestos and Products Containing Asbestos Regulations	8	10	**18**
Prohibition of Certain Toxic Substances Regulations, 2012	15	13	**28**
Pulp and Paper Mill Defoamer and Wood Chip Regulations	0	1	**1**
Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations	0	3	**3**
Renewable Fuels Regulations	6	0	**6**
Solvent Degreasing Regulations	1	1	**2**
Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations	15	41	**56**
Sulphur in Diesel Fuel Regulations	11	3	**14**
Sulphur in Gasoline Regulations	9	0	**9**
Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations	1	404	**405**
Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations	18	0	**18**
Volatile Organic Compound (VOC) Concentration Limits for Automotive Refinishing Products Regulations	8	0	**8**

* Only those regulations under which an inspection occurred during the time period are listed in this table.

6.4.2 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 22 describes the number of investigations under CEPA for fiscal year 2020-2021. It should be noted that 2 investigations started and ended in 2020-2021. Therefore, the total number of investigations under CEPA in 2020-2021 is 60.

Table 22. Breakdown of investigations from April 1, 2020 to March 31, 2021

Instrument**	Investigations*		
	Started before 2020-2021 and still ongoing at the end of 2020-2021	Started in FY 2020-2021	Ended in FY 2020-2021
Total	**30**	**8**	**24**
2-Butoxyethanol Regulations	1	-	-
Chromium Electroplating, Chromium Anodizing and Reverse Etching Regulations	-	-	1
CEPA – various section(s)	8	3	8
Disposal at Sea Regulations	2	-	3
Environmental Emergency Regulations	1	-	-
Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations	-	1	-
Federal Halocarbon Regulations, 2003	1	-	-
Off-Road Compression-Ignition Engine Emission Regulations	1	1	2
Off-Road Small Spark-Ignition Engine Emission Regulations	1	-	-
On-Road Vehicle and Engine Emission Regulations	1	-	1
PCB Regulations	5	-	5

Instrument**	Investigations*		
	Started before 2020-2021 and still ongoing at the end of 2020-2021	Started in FY 2020-2021	Ended in FY 2020-2021
PCB Waste Export Regulations, 1996	-	-	-
Prohibition of Certain Toxic Substances Regulations, 2012	-	1	-
Renewable Fuels Regulations	1	-	-
Sulphur in Diesel Fuel Regulations	-	-	-
Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations	2	2	2
Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations	2	-	1
Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations	1	-	-
Volatile Organic Compound (VOC) Concentration Limits for Automotive Refinishing Products Regulations	3	-	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.

** Only those regulations under which an investigation occurred during the time period are listed in this table.

6.4.3 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 (AMP) provide a financial disincentive to non-compliance.

Table 23 sets out the number of written warnings, EPCOs, and AMPs issued under CEPA during fiscal year 2020-2021. Only those regulations or other instruments under which enforcement measures were issued during the time period are listed in this table.

Table 23. Number of enforcement measures taken from April 1, 2020 to March 31, 2021

Instrument	Enforcement measures* from inspections and investigations			
	Written warnings**	Number of subjects involved in EPCOs***	EPCOs**	AMPs**
Total	**156**	**13**	**10**	**116**
CEPA – various section(s)	54	7	5	38
Chromium Electroplating, Chromium Anodizing and Reverse Etching Regulations	2	-	-	-
Disposal at Sea Regulations	-	-	-	2
Environmental Emergency Regulations	9	-	-	-
Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations	25	1	1	10
Federal Halocarbon Regulations, 2003	6	-	-	5
Fuels Information Regulations, No. 1	2	-	-	4
Gasoline and Gasoline Blend Dispensing Flow Rate Regulations	1	-	-	-
Microbeads in Toiletries Regulations	4	-	-	-
Notice s. 46 Greenhouse Gases	1	-	-	-
Notice s. 71 Toxics	2	-	-	-
Off-Road Compression-Ignition Engine Emission Regulations	12	-	-	38

Instrument	Enforcement measures* from inspections and investigations			
	Written warnings**	Number of subjects involved in EPCOs***	EPCOs**	AMPs**
Off-Road Small Spark-Ignition Engine Emission Regulations	1	-	-	-
On-Road Vehicle and Engine Emission Regulations	1	-	-	-
Ozone-Depleting Substances and Halocarbon Alternatives Regulations	2	-	-	-
PCB Regulations	3	2	1	-
Prohibition of Certain Toxic Substances Regulations, 2012	-	1	1	-
Products Containing Mercury Regulations	1	-	-	-
Renewable Fuels Regulations	7	-	-	1
Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations	17	2	2	12
Sulphur in Diesel Fuel Regulations	4	-	-	6
Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations	1	-	-	-
Volatile Organic Compound (VOC) Concentration Limits for Automotive Refinishing Products Regulations	1	-	-	-

* Enforcement measures shown were issued between April 1, 2020 and March 31, 2021. It is possible that the initial inspection was conducted in a different fiscal year than when the measure was issued.

** Written warnings, EPCOs, and AMPs are tabulated by number of measures issued at the regulation level. For example, if 1 warning was issued for 2 different regulations, the number of warnings would be 2.

*** 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.

6.5 Prosecutions, tickets and EPAMs

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 (DPP) 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.

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 24 outlines the number of prosecutions and tickets under CEPA for fiscal year 2020-2021. No EPAMs were issued in 2020-2021. Only those regulations or other instruments under which prosecutions or tickets resulted during the time period are listed in this table.

Table 24. Number of prosecutions, tickets and penalties from April 1, 2020 to March 31, 2021

Instrument	Prosecutions		Tickets	Penalties		
	Convicted subjects*	Guilty counts**		Environmental Damages Fund (EDF)	Administrative Monetary Penalty (AMPs)	Total Penalty Amount
***Canadian Environment Protection Act*, 1999 – Total**	**8**	**17**	**3**	**$1,145,500**	**$189,000**	**$1,334,500**
CEPA – various section(s)	1	1	-	$130,000	$78,200	$208,200
Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations	-	-	-	-	$16,800	$16,800

Instrument	Prosecutions		Tickets	Penalties		
	Convicted subjects*	Guilty counts**		Environmental Damages Fund (EDF)	Administrative Monetary Penalty (AMPs)	Total Penalty Amount
Disposal at Sea Regulations	1	4	-	$400,000	$4,000	$404,000
Federal Halocarbon Regulations, 2003	-	-	-	-	$25,000	$25,000
Fuels Information Regulations, No. 1	-	-	-	-	$4,000	$4,000
Off-Road Compression-Ignition Engine Emission Regulations	1	1	-	$25,000	$42,000	$67,000
PCB Regulations	3	3	-	$205,000	-	$205,000
Renewable Fuels Regulations	-	-	-	-	$1,000	$1,000
Sulfur in Diesel Fuel Regulations	-	-	-	-	$6,000	$6,000
Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations	2	6	-	$375,000	$12,000	$387,000
Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations	1	2	3	$10,500	-	$10,500

* Convicted subjects are the number of subjects convicted during the reporting period and are based on date sentenced. The total of convicted subjects is 8 instead of 9 because 1 subject had been convicted under more than 1 regulation.

** Counts are 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.

6.6 Enforcement highlights

In 2020-2021, 8 subjects were convicted and sentenced for offences related to CEPA and its regulations and $1,145,500 in fines was directed to the Environmental Damages Fund (EDF).

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.

Below are highlights of prosecutions that occurred under CEPA and its regulations in 2020-2021.

Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations

On May 21, 2020, Scamp Industries Ltd., a fuel supplier based in Western Canada, was fined $200,000 in the Provincial Court of British Columbia after pleading guilty to 5 counts of transferring petroleum products into a storage-tank system where storage-tank-system identification numbers were not visible, in contravention with the *Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations*. The penalty was directed to the EDF.

In March 2015, ECCC enforcement officers inspected several gas stations on federal and Indigenous land in the south-central area of British Columbia, including the Kamloops and Salmon Arm areas, to monitor compliance with the Regulations. During these inspections, the enforcement officers found that Scamp Industries Ltd. had been delivering fuel to a number of unregistered tank systems and a number of tank systems that did not display the required identification numbers.

Disposal at sea

On August 19, 2020, Seleine Mines, a division of K+S Windsor Salt Ltd., was fined a total of $400,000 after pleading guilty to 4 counts of violating provisions in the *Act related to disposal at sea*. The penalty was directed to the EDF.

An investigation by ECCC enforcement officers revealed that Seleine Mines had disposed of dredged material on 4 occasions between August 10 and August 14, 2014, outside of the disposal area authorized by the disposal at sea permit issued by ECCC.

PCB Regulations

On September 1, 2020, 4422236 Canada Inc. was fined $260,000 after pleading guilty to 2 counts of violating the *PCB Regulations* and the *Canadian Environmental Protection Act, 1999*. The penalty was directed to the EDF.

An investigation conducted by ECCC officers revealed that in September 2018, 4422236 Canada Inc., owner of the Baltex Building in Montréal, was using a transformer containing polychlorinated biphenyls (PCBs) at a concentration greater than 500 ppm. The investigation also found that as of June 2019, the company had not complied with the environmental protection compliance order issued by an enforcement officer in November 2018, requiring it to dispose of the transformer.

Environmental Offenders Registry and Enforcement Notifications

The Environmental Offenders Registry contains information on convictions of corporations obtained under certain federal environmental laws including CEPA, since June 18, 2009. This tool allows the media and the public to search for corporate convictions using the name of the corporation, its home province, the province where the offence occurred, or the legislation under which the conviction was obtained.

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

6.7 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 2020, ECCC also participated in the World Customs Organization (WCO) Demeter IV operation, which focused on addressing illegal waste and illegal trade in ozone-depleting substances. Canada's participation in the operation focused on the export of illegal waste and was conducted jointly with the Canada Border Services Agency.

7. Report on research

ECCC and HC conduct a wide range of research to help inform assessment and management of the risks associated with various substances to human health or the environment. This research is often done in collaboration with scientists in other agencies and universities across Canada and the world. This section provides highlights of the research published in 2020-2021.

7.1 Chemical substances

Research on chemical substances is designed primarily to:

- 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, complex environmental mixtures, and other substances of concern on the environment and human health
- determine the extent of ecological and human health exposure to contaminants
- investigate the toxicity of chemicals, including effects on endocrine systems
- investigate the health effects of chemicals on human health

In addition, HC undertakes research to support the development of regulations, guidelines and air quality objectives with the goal of reducing population exposure to pollutants and improving human health.

During 2020-2021, 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 Program, Genome Canada and the Great Lakes Protection Initiative.

7.1.1 Environment and Climate Change Canada research

In 2020-2021, work on 19 new CMP research projects initiated in 2019-2020 continued, but at a slower pace than expected due to the COVID-19 pandemic and related suspension of laboratory and fieldwork for the entire year. Some of the latter work was able to progress for those research projects conducted in partnership with universities that only experienced short shutdown periods. It is worth noting that significant progress was made for all research projects in terms of data analysis and publication of manuscripts. Thirty-five papers related to chemicals in the atmosphere were published by ECCC scientists in 2020-2021, with references to a selection of these articles provided below as examples.

7.1.1.1 Chemicals in the atmosphere

Persistent organic pollutants (POPs), organic flame retardants and other priority substances

Focus of research: Long-term trends on Arctic concentrations of POPs and other chemicals of concern, indoor and outdoor concentrations of flame retardants and other chemicals of concern and potential for exposure.

Results: In the Arctic, while some POPs showed declining trends at all monitoring sites, others were stable, increasing, or showed different trends at different locations. Phthalate concentrations in air are linked to both primary sources such as urban activity and traffic, and to secondary sources such as volatilization from water bodies. Landfill air was found to be a potential source of exposure to organic flame retardants. Liquid crystal monomers (LCMs) used in television and smartphone displays give off particles that were found to be more persistent in air than expected and whose oxidation produces many transformation products.

Publications: Wong, F., Hung, H., Dryfhout-Clark, H., Aas, W., Bohlin-Nizzetto, P., Breivik, K., Mastromonaco, M.N., Lundén, E.B., Ólafsdóttir, K., Sigurðsson, Á., Vorkamp, K., Bossi, R., Skov, H., Hakola, H., Barresi, E., Sverko, E., Fellin, P., Li, H., Vlasenko, A., Zapevalov, M., Samsonov, D., Wilson, S. 2021. *Time trends of persistent organic pollutants (POPs) and Chemicals of Emerging Arctic Concern (CEAC) in Arctic air from 25 years of monitoring*. Science of the Total Environment, 775, art. no. 145109, DOI: 10.1016/j.scitotenv.2021.145109.

Vasiljevic, T., Su, K., Harner, T. 2020. *A first look at atmospheric concentrations and temporal trends of phthalates in distinct urban sectors of the Greater Toronto Area*. Atmospheric Pollution Research, Vol. 12, Issue 2, pp 173-182, DOI: 10.1016/j.apr.2020.10.019.

Navaranjan, G., Diamond, M.L., Harris, S.A., Jantunen, L.M., Bernstein, S., Scott, J.A., Takaro, T.K., Dai, R., Lefebvre, D.L., Azad, M.B., Becker, A.B., Mandhane, P.J., Moraes, T.J., Simons, E., Turvey, S.E., Sears, M.R., Subbarao, P., Brook, J.R. 2021. *Early life exposure to phthalates and the development of childhood asthma among Canadian children*. Environmental Research, 197, art. no. 110981, DOI: 10.1016/j.envres.2021.110981.

Kerric, A., Okeme, J., Jantunen, L., Giroux, J.-F., Diamond, M.L., Verreault, J. 2021. *Spatial and temporal variations of halogenated flame retardants and organophosphate esters in landfill air: Potential linkages with gull exposure*. Environ. Pollut., 271, art. no. 116396, DOI: 10.1016/j.envpol.2020.116396.

Liu, Q., Liggio, J., Wentzell, J., Lee, P., Li, K., Li, S.-M. 2020. *Atmospheric OH Oxidation Chemistry of Particulate Liquid Crystal Monomers: An Emerging Persistent Organic Pollutant in Air*. Environmental Science and Technology Letters, 7 (9), pp. 646-652. DOI: 10.1021/acs.estlett.0c00447.

Microplastics and other man-made particles

Focus of research: Measurement of microplastics and other man-made particles in the Canadian environment.

Results: Microplastics or other anthropogenic particles were found in 85-90% of Arctic samples analyzed, highlighting the presence of microplastics across the eastern Canadian Arctic, in multiple media, and offering evidence of long-range transport via ocean and atmospheric currents. Denim fabrics were found to be a major contributor.

Publications: Huntington, A., Corcoran, P.L., Jantunen, L., Thaysen, C., Bernstein, S., Stern, G.A., Rochman, C.M. 2020. *A first assessment of microplastics and other anthropogenic particles in Hudson Bay and the surrounding eastern Canadian Arctic waters of Nunavut*. Facets, 5 (1), pp. 432-454. DOI: 10.1139/FACETS-2019-0042.

Athey, S.N., Adams, J.K., Erdle, L.M., Jantunen, L.M., Helm, P.A., Finkelstein, S.A., Diamond, M.L. 2020. *The Widespread Environmental Footprint of Indigo Denim Microfibers from Blue Jeans*. Environmental Science & Technology Letters 2020 7 (11), 840-847, DOI: 10.1021/acs.estlett.0c00498.

Polycyclic aromatic hydrocarbons (PAHs) and polycyclic aromatic compounds (PACs) in Canada

Focus of research: Long-term trends and sources of PAHs and PACs in Canada.

Results: PAHs in the Canadian Great Lakes Basin atmosphere significantly decreased between 1997 and 2017, as anthropogenic emissions declined. Tailings ponds of Athabasca oil sands operations were found to be a source of fugitive emissions of PACs and specific activities within oil sands operations were identified as potential sources of PACs.

Publications: Li, W., Park, R., Alexandrou, N., Dryfhout-Clark, H., Brice, K., Hung, H. 2021. *Multi-year analyses reveal different trends, sources, and implications for source-related human health risks of atmospheric polycyclic aromatic hydrocarbons in the Canadian Great Lakes basin*. Environ. Sci. Technol., 55 (4), pp. 2254-2264. DOI: 10.1021/acs.est.0c07079.

Moradi, M., You, Y., Hung, H., Li, J., Park, R., Alexandrou, N., Moussa, S.G., Jantunen, L., Robitaille, R., Staebler, R.M. 2020. *Fugitive emissions of polycyclic aromatic compounds from an oil sands tailings pond based on fugacity and inverse dispersion flux calculations*. Environ. Pollut., Vol. 269, 116115, DOI: 10.1016/j.envpol.2020.116115.

Wnorowski, A., Aklilu, Y.-A., Harner, T., Schuster, J., Charland, J.-P. 2021. *Polycyclic aromatic compounds in ambient air in the surface minable area of Athabasca oil sands in Alberta (Canada)*. Atmospheric Environment, 244, art. no. 117897, DOI: 10.1016/j.atmosenv.2020.117897.

Review of Polycyclic Aromatic Compounds (PACs) in Canadian environments

Focus of research: A State of Knowledge report for PACs with focus on the Canadian environment

Results: A state of knowledge report on PACs in the Canadian environment was published as a Special Issue in the Environmental Pollution journal. Scientists from the Canadian government and academia authored the Special Issue's seven main papers. Five papers follow the environmental chain of events from emissions and releases to effects on wildlife, with additional papers examining the challenges of ecological risk assessment and the links between PACs and global change. Wildfire emissions were found to be by far the largest source of PACs in the Canadian atmosphere, followed by non-industrial sources (such as, residential firewood burning and mobile sources), and industrial sources. Significant PAC releases result from exploitation of fossil fuels containing naturally-derived PACs. Major cities within the Great Lakes watershed, act as diffuse sources of PACs, and result in coronas of contamination emanating from urban centres. A review of long-term trends in PAC concentrations in the atmosphere found that except near industries that had reduced emissions, trends were modest or negligible. The results also suggest that motor vehicles are a larger source than currently reported in national inventories. Considerable knowledge gaps limit current understanding of PAC sinks, environmental transformations and transboundary flows, as well as ecological impacts in Canada. In general, PAC concentrations in Canadian wildlife tissue were below guidelines.

Publications: Galarneau, E. 2021. *Editorial to "Polycyclic aromatic compounds (PACs) in the Canadian environment: Overview of results and knowledge gaps from the special issue"*. Environmental pollution. 285. 117607.

Wallace, S.J., de Solla, S.R., Head, J.A., Hodson, P.V., Parrott, J.L., Thomas, P.J., Berthiaume, A., Langlois, V.S. 2020. *Polycyclic aromatic compounds (PACs) in the Canadian environment: Exposure and effects on wildlife*. Environmental Pollution. 265:114863. DOI: 10.1016/j.envpol.2020.114863.

Hodson, P.V., Wallace, S.J., de Solla, S.R., Head, S.J., Hepditch, S.L.J., Parrott, J.L., Thomas, P.J., Berthiaume, A., Langlois, V.S. 2020. *Polycyclic aromatic compounds (PACs) in the Canadian environment: The challenges of ecological risk assessments*. Environmental Pollution. 265:115165.

Ahad, J.M.E., Macdonald, R.W., Parrott, J.L., Yang, Z., Zhang, Y., Siddique, T., Kuznetsova, A., Rauert, C., Galarneau, E., Studabaker, W.B., Evans, M., McMaster, M.E., Shang, D. 2020. *Polycyclic aromatic compounds (PACs) in the Canadian environment: A review of sampling techniques, strategies and instrumentation.* Environmental Pollution. 266:114988.

Berthiaume, A., Galarneau, E., Marson, G. 2020. *Polycyclic aromatic compounds (PACs) in the Canadian environment: Sources and emissions*. Environmental Pollution Vol. 269, 116008, DOI: 10.1016/j.envpol.2020.116008.

Tevlin, A., Galarneau, E., Zhang, T., Hung, H. 2021. *Polycyclic aromatic compounds (PACs) in the Canadian environment: Ambient air and deposition.* Environmental Pollution, 271. 116232.

Muir, D.C.G., Galarneau, E. 2021. *Polycyclic aromatic compounds (PACs) in the Canadian environment: Links to global change*. Environmental Pollution. 273: 116425.

Marvin, C.H., Berthiaume, A., Burniston, D.A., Chibwe, L., Dove, A., Evans, M., Hewitt, L.M., Hodson, P.V., Muir, D.C.G., Parrott, J., Thomas, P.J., Tomy, G.T. 2021. *Polycyclic aromatic compounds in the Canadian Environment: Aquatic and terrestrial environments*. Environmental Pollution 285 (2021) 117442.

7.1.1.2 Impact of chemicals on wildlife and fish

Review of biological effects of wildlife exposed to chemicals of emerging Arctic concern

Focus of research: A review of the state-of-the-knowledge regarding chemicals of emerging Arctic concern (CEACs) and the general lack of information on the potential biological adverse effects on Arctic wildlife.

Results: Recent advances in environmental analytical chemistry have identified the presence of a large number of CEACs being transported long range to the region. There has been very limited temporal monitoring of CEACs and it is therefore unknown whether they are of increasing or decreasing concern. Likewise, information on potential biological adverse effects from CEACs on Arctic wildlife is lacking compared with legacy persistent organic pollutants (POPs) found at levels associated with health effects in marine mammals. Hence, there is a need to monitor CEACs along with POPs to support risk and regulatory CEAC assessments.

Publication: Sonne, C., Dietz, R., Jenssen, B.M., Lam, S.S., Letcher, R.J. 2021. *Emerging contaminants and biological effects in Arctic wildlife.* Trends in Ecology and Evolution – Opinion, Volume 26, 421-429, DOI: 10.1016/j.tree.2021.01.007.

Comparative review of the distribution and burden of contaminants in the body of polar bears

Focus of research: Historical (or legacy) contaminants, such as metals and persistent organic pollutants (POPs; such as polychlorinated biphenyls) have been measured in circumpolar subpopulations of polar bears, especially from Hudson Bay, East Greenland, and Svalbard, but substantially less is currently known about new and/or emerging contaminants such as polychlorinated naphthalenes, current-use pesticides, organotins, and polycyclic aromatic compounds (PACs).

Results: The polar bear (*Ursus maritimus*) is an apex Arctic predator that accumulates high levels of bioaccumulative POPs and mercury (Hg), but there is currently no comprehensive profiling of the present knowledge on contaminants in tissue and body compartments in polar bears. Based on current literature reports and data, and including archived museum samples (as far back as the 1300s) and up to 2018, results showed that (1) the kidneys are one of the most important tissue depots of contaminants in polar bears; (2) there is a critical lack of data concerning the presence of metals of concern, other than Hg; and (3) there is currently no data available on the concentrations of many newer and emerging contaminants, such as polycyclic aromatic compounds (PACs), which is especially relevant given the increasing oil and gas development in regions, such as in the Beaufort Sea, Canada.

Publication: Dominique, M., Letcher, R.J., Rutter, A., Langlois, V.S. 2020. *Comparative review of the distribution and burden of contaminants in the body of polar bears.* Environmental Sciences and Pollution Research 27, 2020, 32456-32466, DOI: 10.1007/s11356-020-09193-2.

Influence of diet specialization on persistent organic pollutants in Icelandic killer whales

Focus of research: The focus of this study was on the inter-individual variation in prey specialization in Icelandic killer whales (*Orcinus orca*) and intra-population variation in exposure to persistent organic pollutants.

Results: Polychlorinated biphenyl (PCB) concentrations in blubber were >300-fold higher in the most contaminated individual killer whales relative to the least contaminated, ranging from 1.3 to 428.6 mg/kg lipid weight. Mean PCB concentrations were 6-to-9-fold greater in individuals with a mixed diet including marine mammals than in fish specialist individuals, whereas males showed PCB concentrations 4-fold higher than females. Given PCBs have been identified as potentially impacting killer whale population growth, and levels in mixed feeders specifically exceeded known thresholds, the ecology of individuals must be recognized to accurately forecast how contaminants may threaten the long-term persistence of the world's ultimate marine predator.

Publication: Remili, A., Letcher, R.J., Samarra, F.I.P., Dietz, R., Sonne, C., Desforges, J.P., Vikingsson, G., Blair, D., McKinney, M.A. 2021. *Individual prey specialization drives PCBs in Icelandic killer whales.* Environmental Science and Technology Volume 55, 2021, 4923-4931, DOI: 10.1021/acs.est.0c08563.

Mercury in gull eggs and fish under a warming climate

Focus of research: Understanding changes in environmental mercury concentrations is important for assessing the risk to human and wildlife populations from this potent toxicant. Herring gull (*Larus argentatus*) eggs were used to evaluate temporal changes in total mercury availability from 2 locations on Great Slave Lake, Northwest Territories, Canada.

Results: Temporal trends in mercury in herring gull (*Larus argentatus*) eggs from Great Slave Lake (GSL), Northwest Territories, Canada were evaluated. Although diet-adjusted mercury concentrations in eggs showed no long-term trend, consistent with the lack of trends in GSL fish, egg mercury concentrations were greater following years of lower lake levels and greater wildfire extent. Climate change may increase wildfire extent with impacts on Hg bioaccumulation in northern ecosystems. The study emphasizes the importance of ancillary datasets in elucidating Hg trends; such information will be critical for evaluating the effectiveness of Hg mitigation strategies implemented as part of the Minamata Convention.

Publication: Hebert, C.E., Chételat, J., Beck, R., Dolgova S, Fordy K, Kirby P., Martin, P., Rabesca, M. 2021. *Inter-annual variation of mercury in aquatic bird eggs and fish from a large subarctic lake under a warming climate*. Science of the Total Environment, 2021, 766, 144614.

Priority perfluroalkyl substances in predatory birds: diet, biology and ecology factors

Focus of research: Perfluoroalkyl substances (PFAS) are a large, diverse group of chemicals and several perfluoroalkyl acids (PFAAs) are known environmental contaminants. Wildlife exposure to PFAAs and precursors has been shown, but less is known regarding replacements such as shorter-chain PFAS. In the present study, exposure to a suite of PFAAs and associations with dietary, biological and ecological factors were investigated in populations of a sentinel apex species – the peregrine falcon (*Falco peregrinus*).

Results: Peregrine nestling blood and sibling eggs were sampled in 2016 and 2018 from nests in rural and urban regions across the Laurentian Great Lakes Basin, Canada. Analytical results reveal that exposure to PFAAs in peregrine falcons is likely mediated by dietary factors such as foraging location and trophic position. Moreover, results suggest that compared to rural nestlings, urban nestlings may be more exposed to perfluorinated carboxylic acids (PFCAs) and prone to their potential physiological impacts. Findings highlight the importance of integrating dietary, biological and ecological factors when studying PFAS exposure in birds.

Publication: Sun, J., Letcher, R.J., Eens, M., Covaci, A., Fernie, K.J. 2020. *Perfluoroalkyl acids and sulfonamides and dietary, biological and ecological associations in peregrine falcons from the Laurentian Great Lakes Basin*. Environmental Research volume 191, 2020, 110151, DOI: 10.1016/j.envres.2020.110151.

Assessing the lethal and sublethal toxicity of perfluorooctanoic acid (PFOA) to *Hyalella azteca* and *Pimephales promelas*.

Focus of Research: PFOA, which is widely used in a variety of residential, commercial, and industrial products, belongs to the broader chemical class of perfluoroalkyl substances (PFAS). It has been measured in the Canadian aquatic environment and is known to be extremely environmentally persistent, but little information exists on its toxicity to aquatic organisms. The objective of this study was to assess the toxicity of PFOA to two sensitive and important freshwater species relevant to the Canadian environment: a small, shrimp-like crustacean (amphipod, *Hyalella azteca*) and a fish (fathead minnow, *Pimephales promelas*).

Results: Exposure to PFOA decreased survival, growth, and reproduction in amphipods, and caused abnormal swimming behaviour in fathead minnow larvae. Amphipod growth and reproduction were the most sensitive endpoints tested. The toxic effects of PFOA observed in this study occurred at concentrations more than 75-fold higher than those that have been measured in Canadian freshwaters; however, due to its environmental persistence, more research is needed to determine if PFOA causes toxicity at lower concentrations after longer exposure periods.

Publication: Bartlett, A.J., De Silva, A.O., Schissler, D.M., Hedges, A.M., Brown, L.R., Shires, K., Miller, J., Sullivan, C., Spencer, C., Parrott, J.L. 2021. *Lethal and sublethal toxicity of perfluorooctanoic acid (PFOA) in chronic tests with Hyalella azteca and early-life stages with Pimephales promelas (fathead minnow).* Ecotoxicology and Environmental Safety 207:111250.

Toxicity of naphthalene sulfonic acids (NSAs) in aquatic organisms

Focus of Research: Assessment of the aquatic toxicity of naphthalene sulfonic acids (NSAs), which are high production volume chemicals used primarily as additives in a wide range of industrial products.

Results: The effects of NSAs, which are used extensively in industrial applications as dispersants in dyes, rubbers, and pesticides, and as anti-corrosive agents in coatings, gels, and sealants, were assessed in several invertebrates and fish. The organic carbon content of the sediment appears to have acted as a sink and reduced NSA toxicity by decreasing bioavailability to aquatic organisms. However, for one NSA (dinonylnaphthalene sulfonic acid), the Biota-Sediment Accumulation Factor indicated a potential biomagnification concern if this compound were to occur in the aquatic environment.

Publications: Matten, K.J., Bartlett, A.J., Milani, D., Gillis, P.L., Parrott, J.L., Toito, J, Balakrisknan, V.K., Prosser, R.S. 2020. *The influence of organic carbon on the toxicity of sediment-associated dinonylnaphthalene sulfonic acids to the benthic invertebrates Tubifex tubifex and Hyalella azteca*. Environmental Pollution 267:115604 DOI: 10.1016/j.envpol.2020.115604.

Matten, K.J., Gillis, P.L., Milani, D. Parrott, J.L., Bartlett, A.J., Toito, J., Balakrishnan, V.K., Prosser, R.S. 2021. *Bioaccumulation of sediment-associated dinonylnaphthalene sulfonates in the freshwater mussel Lampsilis siliquoidea and oligochaete Tubifex tubifex*. Chemosphere 264:128391 DOI: 10.1016/j.chemosphere.2020.128391.

Determining the effects of bisphenol A (BPA) replacement alternatives in avian species

Focus of research: Several screening studies using high-throughput approaches were conducted using primary avian hepatocytes and early-life stage chicken embryos as part of a prioritization effort to determine the effects of this priority chemical class. Cytotoxic and transcriptomic effects of 5 BPA replacement alternatives were determined and 1 early-life stage chicken embryo exposure evaluating two BPA alternatives was performed.

Results: Many BPA replacement alternatives were more cytotoxic and disrupted more gene expression in avian cells than BPA. The effects were most pronounced in cells derived from chicken compared to a wild avian species, double-crested cormorant, for gene expression. However, cormorant cells were typically more sensitive to overt toxicity/cell death. Taken together, these studies indicate that additional research is required to characterize the toxic mechanisms of action of several substances proposed to be suitable replacements for BPA in commercial/industrial applications.

Publications: Sharin, T., Williams, K.L., Chiu, S., Crump, D., O'Brien, J.M. 2021. *Toxicity Screening of Bisphenol A Replacement Compounds: Cytotoxicity and mRNA Expression in Primary Hepatocytes of Chicken and Double-Crested Cormorant*. Environ. Tox. Chem 40 (5): 1368-1378.

Sharin, T., Gyasi, H., Williams, K., Crump, D., O'Brien, J.M. 2021. *Effects of Two Bisphenol A Replacement Compounds, Bisphenol AF and 1,7-bis (4-Hydroxyphenylthio)-3,5-dioxaheptane, on Pipping Success, Development, and mRNA Expression Levels in Chicken Embryos*. Ecotox. Environ Safety 215: 112140.

Effects of neonicotinoid insecticides on non-target aquatic organisms

Focus of research: The study assessed the effects of neonicotinoid insecticides on tadpole stress metrics to understand the sublethal effects of chronic exposure to these compounds on sensitive non-target vertebrates. Specifically, blood cell profiles, measures of oxidative stress and concentrations of a stress hormone, corticosterone were assessed.

Results: Northern leopard frogs (*Rana* (*Lithobates) pipiens*) were found to show signs of mild stress based on blood cell profiles and some indication for oxidative damage when exposed to clothianidin (a neonicotinoid). Furthermore, thiamethoxam (also a neonicotinoid) altered some blood cell profiles, but neither clothianidin nor thiamethoxam affected corticosterone concentrations. These studies indicate that northern leopard frog tadpoles exposed to some neonicotinoids for prolonged periods have increased stress responses, but the implications on overall health are unclear.

Publication: Gavel, M.J., Young, S.D., Dalton, R.L., Soos, C., McPhee, L., Forbes, M.R., Robinson, S.A. 2021. *Effects of two pesticides on northern leopard frog (Lithobates pipiens) stress metrics: Blood cell profiles and corticosterone concentrations*. Aquatic Toxicology 235:105820 DOI: 10.1016/j.aquatox.2021.105820.

Evaluation of estrogenic and thyroid-disrupting activities of brominated organophosphate flame retardant

Focus of research: The study assessed the effects of a new alternative phosphate flame retardant, the brominated organophosphate ester flame retardant, tris(tribomoneopentyl) phosphate (TTBrNP, CAS 19186-97-1). Canadian native frogs (wood frogs (*Rana* (*Lithobates) sylvaticus*) and northern leopard frogs (*R. pipiens*)) were used to determine if embryo or tadpole survival was affected after 96 hours of exposure or if the compound affected metamorphosis, growth, sexual differentiation or bioconcentrated in tadpole tissues after 30 days of exposure.

Results: Acute 96-hour exposures did not affect embryo or tadpole survival for either species. There was also no sub-chronic effects after 30 days of exposure, where size, developmental stage and sex ratio did not differ compared to the control at any of the exposure concentrations. Tadpoles bioconcentrated TTBrNP, but the low bioconcentration factor suggested the compound is being biotransformed or has limited bioavailability. Hence, TTBrNP was found to have no overt detrimental effects on these 2 frog species.

Publication: Robinson, S.A., Young, S.D., McFee, A., Brinovkar, C., De Silva, A.O. 2020. *Ecotoxicity assessment and bioconcentration of a highly brominated organophosphate ester flame retardant in two amphibian species*. Chemosphere 260: 127631 DOI: 10.1016/j.chemosphere.2020.127631.

Priority perfluroalkyl substances: Uptake, bioaccumulation and toxic effects in terrestrial and marine birds

Focus of research: The goal of this research was to characterize the exposure of raptors and tree swallows to high-priority perfluorinated compounds, and to determine the possible effects to the birds of these chemicals and to model chemical movements through the terrestrial food web.

Results: Peregrine falcon chicks were sampled across urban and rural regions of the Canadian Great Lakes Basin (2016, 2018) to investigate possible relationships of thyroid hormones (THs), specifically free (F) and total (T) thyroxine (FT4; TT4) and triiodothyronine (FT3; TT3), and the expression of an immune-related microRNA biomarker (i.e., miR-155), with the concentrations of 11 perfluoroalkyl acids (PFAAs). Five of the 18 measured PFAA homologues were repeatedly and positively related with measurements of thyroid activity in the nestling peregrines suggesting probable disruption of the thyroid system of the peregrine falcon nestlings. Multiple environmental and biological stressors, including PFAA-exposure, influenced thyroid activity and immune function in these nestlings. Further research is warranted to identify the mechanisms and additional impacts of PFAA-related thyroid and immune disruption on the growth, development, and health risks in developing birds.

Publication: Sun J., Letcher, R.J., Waugh, C.A., Jaspers, V.L.B., Covaci, A., Fernie, K.J. 2021. *Influence of perfluoroalkyl acids and other parameters on circulating thyroid hormones and immune-related microRNA expression in free-ranging nestling peregrine falcons.* Sci. Tot. Environ. DOI: 10.1016/j.scitotenv.2021.145346.

Priority Short Chain Chlorinated Paraffins and Wildlife: Toxic effects to predatory birds

Focus of research: The goal of this research was to characterize the possible toxic effects of high-priority short chain chlorinated paraffins in birds.

Results: Short chain chlorinated paraffins (SCCPs) are complex mixtures of polychlorinated *n*-alkanes, shown to bioaccumulate but with unknown effects in wild birds. Embryonic exposure to technical Chloroparaffin® ($C_{10\text{-}13}$, 55.5% Cl) at concentrations measured in wild bird eggs had sex-specific effects on uptake. SCCPs suppressed glandular total thyroxine (TT4) and reduced circulating triiodothyronine (TT3) in male hatchlings only when compared to control males, but had no effect on glandular TT3 or circulating TT4 in male or female kestrels. Both sexes experienced significant structural (histological) changes indicative of thyroid gland activation. Because changes in thyroid function were evident at concentrations measured in wild bird eggs, similar changes may occur in wild nestlings.

Publication: Fernie K.J., Karoun-Renier, N.K., Letcher, R.J., SL Schultz, S.L., Palace, V., Peters, L., Henry, P.F.P. 2020. *Endocrine and physiological responses of hatchling American kestrels (Falco sparverius) following embryonic exposure to technical short chain chlorinated paraffins ($C_{10\text{-}13}$, 55.5% Cl)*. Environ. International. DOI: 10.1016/j.envres.2020.106087.

Elimination and toxicity of PCBs to turtles

Focus of research: Polychlorinated biphenyls (PCBs) remain the most abundant organic contaminant in most wildlife. This study examined the effects of PCBs in an understudied taxonomic group: freshwater turtles.

Results: Juvenile snapping turtles were exposed to PCBs (Aroclor 1254) through diet. Accumulation was relatively low, but a 1.8-fold increase in hepatic expression of cytochrome P450 1a was observed at the highest dosage (12.7 µg/g; range 0–12.7 µg/g), which corresponded to egg burdens that have been observed in the Great Lakes.

Publication: Colson, T.-L.L., de Solla, S.R., Langlois, V.S. 2021. *Bioaccumulation and physiological responses of the turtle Chelydra serpentina exposed to polychlorinated biphenyls during early life stages*. Chemosphere, 263, art. no. 128146.

Accumulation and toxicity of substituted phenylamine antioxidants to turtles

Focus of research: Exposure of substituted phenylamine antioxidants (such as, N-phenyl-1-naphthylamine; PNA) is not well known in aquatic amniotes. This study exampled molecular response of turtles to exposure of PNA through diet.

Results: Juvenile snapping turtles were chronically exposed to PNA through diet. At the highest exposure (µg/g), cytochrome P450 1a was induced but cytochrome P450 2b was inhibited, indicating alteration in genes associated with metabolism and elimination.

Publication: Colson, T.-L.L., de Solla, S.R., Balakrishnan, V.K., Toito, J., Langlois, V.S. 2020. *N-phenyl-1-naphthylamine (PNA) Accumulates in Snapping Turtle (Chelydra serpentina) Liver Activating the Detoxification Pathway.* Bulletin of Environmental Contamination and Toxicology, 105 (6), pp. 813-818.

Effects of calcium dinonylnaphthalenesulfonate to amphibians

Focus of research: This study estimated the toxicity of naphthalene sulfonic acids (calcium dinonylnaphthalenesulfonate [CaDNS]), to Western clawed frogs (*Silurana tropicalis*) and the mechanisms of toxicity of CaDNS using targeted gene expression and metabolomics.

Results: Frog embryos were exposed to water overlying sand spiked with a range of concentrations of CaDNS (17–1393 µg/g) over a 72-h period. Although not acutely toxic until 672 µg/g CaDNS in the sand (14 ng/mL CaDNS in the water), an overall decrease in the mRNA of genes in the glutathione redox cycle was observed; these changes in mRNA were reflected in the metabolic responses (decreases in the glutathione and glutathione disulfide metabolite concentrations). In addition, transcript levels of genes involved in antioxidant capacity and essential amino acid metabolites decreased significantly in embryos exposed to low levels of CaDNS.

Publication: Wallace, S.J., Leclerc, A.J.A., Prosser, R., de Solla, S.R., Balakrishnan, V., Langlois, V.S. 2020. *Sub-lethal effects of calcium dinonylnaphthalenesulfonate on Western clawed frog embryos*. Comparative Biochemistry and Physiology - Part D: Genomics and Proteomics, 34, art. no. 100658.

Environmental fate, effects and bioaccumulation of priority nanomaterials in soil

Focus of research: The effect of metal nanomaterials (nano copper (II) oxide and nano cerium (IV) oxide) on indigenous microorganisms in agricultural soil were examined, with and without biosolid amendment.

Results: This project determined the conditions and concentrations at which selected metal nanomaterials exert adverse effects on different aspects of the soil ecosystem: soil microbial growth, activity and diversity. The research demonstrated the utility of alternate metrics to measure bioavailability and toxicity.

Publications: Samarajeewa, A.D., Velicogna, J.R., Schwertfeger, D.M., Princz, J.I., Subasinghe, R.M., Scroggins, R.P., Beaudette, L.A. 2021. *Ecotoxicological effects of copper oxide nanoparticles (nCuO) on the soil microbial community in a biosolids-amended soil*. Science of the Total Environment 763: 143037.

Abdulsada, Z., Kibbee, R., Ormeci, B., DeRosa, M., Princz, J. 2021. *Impact of anaerobically digested silver and copper oxide nanoparticles in biosolids on soil characteristics and bacterial community*. Chemosphere 263:128173.

Toxicity of rare earth elements in rainbow trout and hydra

Focus of research: To determine the toxicity and the mechanism of action of rare earth elements.

Results: The toxicity and mode of action for over 10 rare earth elements were examined in rainbow trout and hydra. The lethal toxicity could be predicted by the electronegativity and ionic radius in fish and hydra. The mode of action studies revealed that rare earth elements could damage (denature) proteins, alter bone formation and damage DNA at concentrations 200 times below the acute toxicity values.

Publications: Hanana, H., Taranu, Z.E., Turcotte, P., Gagnon, C., Kowalczyk, J., Gagné, F. 2020. *Evaluation of general stress, detoxification pathways, and genotoxicity in rainbow trout exposed to rare earth elements dysprosium and lutetium*. Ecotoxicology and Environmental Safety, 2021, 208, 111588.

Hanana, H., Taranu, Z.E., Turcotte, P., Kowalczyk, J., Gagné, F. 2021. *Sublethal effects of terbium and praseodymium in juvenile rainbow trout.* Science of the Total Environment, 2021, 777, 146042.

7.1.2 Health Canada Research

HC funded 27 CMP research projects in 2020-2021. These projects address departmental and international priorities and cover a number of subjects such as characterization of nanomaterials, toxicological response to nanomaterials, carcinogenic potential of chemicals, genetic toxicity assessment, effects of chemicals on human health, and hazard characterization.

7.1.2.1 Methods

Derivation of biomonitoring equivalents for organics and inorganics for interpreting biomonitoring data

Focus of research: Biomonitoring can provide valuable data on the presence of trace levels of chemicals in human blood, urine or breast milk; however, it is not enough to establish the potential risk to human health. A biomonitoring equivalent (BE) is the concentration of a chemical in human tissue or fluid that corresponds to an allowable exposure guidance value, such as a reference dose (RfD) or tolerable daily intake (TDI), that is considered safe. The objective is to derive BEs for rare earth metals to interpret biomonitoring data in support of the chemical risk assessments.

Results: BEs for bismuth and titanium were developed and published. In addition, a database was produced to help analyze different biomonitoring values from various health agencies.

Publications: Poddalgoda, D., Hays, S.M., Nong, A. 2020. *Derivation of biomonitoring equivalents (BE values) for bismuth*. Regul. Toxicol. Pharmacol. 2020 Jul;114:104672. DOI: 10.1016/j.yrtph.2020.104672.

Ramoju, S., Andersen, M.E., Nong, A., Karyakina, N., Shilnikova, N., Krishnan, K., Krewski, D. 2020. *Derivation of whole blood biomonitoring equivalents for titanium for the interpretation of biomonitoring data*. Regul. Toxicol. Pharmacol. 2020 Jul;114:104671. DOI: 10.1016/j.yrtph.2020.104671.

Development and validation of rapid methods to assess endocrine toxicity

Focus of research: There are growing concerns that exposures to commercial chemicals cause harm by interfering with the hormonal control of growth and development of the brain, reproductive tract and lead to metabolic and stress-related problems. Developing rapid methods to identify chemicals posing these hazards is a critical need for safety assessment. This project will (1) develop rapid methods to detect chemical toxicity to thyroid hormone signalling and 2) identify, characterize and develop assays for the enzymes that are inhibited by some organophosphate flame retardants (OPFR) leading to toxicity to the ovary and adrenal gland.

Results: Innovative methods are used to identify proteins that react with the flame retardant molecules. Early results show that these are enzymes involved in cholesterol metabolism. Assays for these enzymes are currently being developed and will be used to compare the potency across all phosphate flame retardants used in Canada. This project contributes to a global initiative to characterize the molecular targets influenced by hazardous substances and to develop validated, high throughput methods to rapidly screen chemicals for toxicity.

Publication: Allais, A., Albert, O., Lefèvre, P.L.C., Wade, M.G., Hales, B.F., Robaire, B. 2020. *In Utero and Lactational Exposure to Flame Retardants Disrupts Rat Ovarian Follicular Development and Advances Puberty*. Toxicol Sci Jun 1;175(2):197-209. DOI: 10.1093/toxsci/kfaa044.

Developing in vitro screening methods for metabolic disruptors in adipocytes

Focus of research: There is increased concern that chemicals can act as endocrine disruptors and contribute to the development of endocrine cancers, as well as metabolic disease. The adipose tissue is an endocrine organ responsible for the energy homeostasis of the organism. This project employs cell-based models to investigate chemical effects on adipose mass and functional changes in the adipocyte that may indicate broader metabolic effects.

Results: To date, there is limited information and no high content or validated screening method for the functionality of the fat cells exposed to chemicals. This project is working to develop a screening method, which can both identify substances that drive fat cell formation and determine if they contribute to metabolic disease.

Publications: Peshdary, V., Styles, G., Rigden, M., Caldwell, D., Kawata, A., Sorisky, A., Atlas, E. 2020. *Exposure to Low Doses of Dechlorane Plus Promotes Adipose Tissue Dysfunction and Glucose Intolerance in Male Mice*. Endocrinology. 2020 Aug 1;161(8):bqaa096. DOI: 10.1210/endocr/bqaa096.

Peshdary, V., Hobbs, C., Maynorc, T., Shepard, K., Gagné, R., Williams, A., Kuo, B., Chepelev, N., Recio, L., Yauk, C., Atlas, E. *Transcriptomic pathway and benchmark dose analysis of Bisphenol A, Bisphenol S, Bisphenol F, and 3,3',5,5'-Tetrabromobisphenol A in H9 human embryonic stem cells*. Toxicol In Vitro 2021 Apr;72:105097. DOI: 10.1016/j.tiv.2021.105097.

GeneTox21 – An integrated, high-throughput (HT) platform for in vitro genetic toxicity assessment of new and existing chemicals

Focus of research: Chemical screening programs routinely assess a chemical's ability to damage genetic material (i.e., genetic toxicity). Traditional assessment tools (i.e., bioassays) are laborious and not conducive to high-throughput (HT), high-content chemical screening using tools that employ cultured cells (i.e., *in vitro* bioassays). This project is developing a NAMs (New Approach Methodologies)-based platform, comprised of high(er) throughput (HT) in vitro bioassays, for effective and efficient assessment of chemically-induced genetic toxicity. The NAMs-based platform, which is called GeneTox21, will be internationally promoted to encourage its adoption for robust genetic toxicity assessment of new and existing substances.

Results: In-house standardised operating procedures (SOPs) have been established for efficient and effective assessment of genetic mutations, DNA breaks, and chromosome abnormalities. These SOPs are being employed to assess the genetic toxicity of a carefully-chosen set of reference compounds, as well as numerous data-poor substances prioritized for regulatory evaluation. Work includes advancement towards validation of the MutaMouse FE cell *in vitro* mutagenicity assay, and the development of an *in vitro* mutagenicity assay based on cultured murine liver cells. Additional work developed a beta version of a bioinformatics tool to integrate, visualise and interpret complex, multi-assay genetic toxicity assessment data. The tool is called IATGA – Integrated Analysis Tool for Genotoxicity Assessment.

Publications: Höltz-Armstrong, L., Naevisdal, A., Cox, J.A., Long, A.S., Cheplev, N.L., Phillips, D.H., White, P.A. and Arlt, V.M. 2020. *In vitro mutagenicity of selected environmental chemicals and their metabolites in MutaMouse FE lung epithelial cells*. Mutagenesis 35:453-463.

Madia, F., Kirkland, D., Morita, T., White, P.A., Asturiol, D., Corvi, R. 2020. EURL ECVAM *Genotoxicity and Carcinogenicity Database of Substances Eliciting Negative Results in the Ames Test: Construction of the Database*. Mutation Research 854-855:503199.

Assessing somatic and germ cell mutations using the OECD's transgenic rodent test guideline TG 488 and the MutaMouse model

Focus of research: The objective is to harmonize the experimental design to identify somatic and germline mutations at a single time point. This integrated approach will significantly reduce the number of animals that are needed for the testing of chemicals for regulatory purposes.

Results: Data generated by this project resulted in an update of the recommended experimental design for germ cells in an Organisation for Economic Cooperation and Development (OECD) test guideline that is routinely used to assess the ability of chemicals to induce mutations (that is, changes in the sequence of the DNA). Ongoing work is contributing to identify a common sampling time for somatic tissues and germ cells.

Publication: Marchetti, F., Zhou, G., LeBlanc, D., White, P., A., Williams, A., Yauk, C.L., Douglas, G.R. 2021. *The 28+28 day design is an effective sampling time for analyzing mutant frequencies in rapidly proliferating tissues of MutaMouse animals*. Archives of Toxicology, 95:1103-1116. Epub: January 28, 2021.

Development and application of novel tools and new approach methodologies (NAM)

Focus of research*:* HC and ECCC continue to increase efforts in support of the progressive advancement of risk science through the exploration, development and application of computational tools and NAM to effectively leverage and integrate existing and emerging data.

Results: In 2020-2021, the focus was on building risk-based science approaches and illustrative examples for the application of NAM, including predictive models and *in vitro* high-throughput screening assays, to rapidly and effectively identify and assess the potential for hazard and/or risk in support of assessment modernization. This and ongoing work is being done through strong partnerships and collaborations between the research and regulatory communities within the Government of Canada and internationally to ensure alignment and increase global confidence in application.

Publications: Rowan-Carroll, A., Reardon, A., Leingartner, K., Gagné, R., Williams, A., Meier, M.J., Kuo, B., Bourdon-Lacombe, J., Moffat, I., Carrier, R., Nong, A., Lorusso, L., Ferguson, S.S., Atlas, E., Yauk, C. 2021. *High-Throughput Transcriptomic Analysis of Human Primary Hepatocyte Spheroids Exposed to Per- and Polyfluoroalkyl Substances as a Platform for Relative Potency Characterization*. Toxicol Sci. 2021 May 27;181(2):199-214. DOI: 10.1093/toxsci/kfab039.

Yang C., Rathman J.F., Magdziarz T., Mostrag A., Kulkarni S., Barton-Maclaren T.S. 2021. *Do Similar Structures Have Similar No Observed Adverse Effect Level (NOAEL) Values? Exploring Chemoinformatics Approaches for Estimating NOAEL Bounds and Uncertainties*. Chem Res Toxicol. 2021 Feb 15;34(2):616-633. DOI: 10.1021/acs.chemrestox.0c00429.

Validation of the zebrafish (*Brachydanio rerio*) model as a whole organism NAM for risk assessment

Focus of Research: Within the context of global efforts to meet the 3 Rs (refinement, reduction and replacement) of animal use in chemical risk assessment, HC is developing the zebrafish embryo model as a NAM whole organism model to transition from animal to non-animal models. Specifically, Health Canada is researching the utility of the zebrafish embryo test for assessment of chemicals for endocrine disruption and the zebrafish larval test as an alternative whole organism model to the 28-day rodent assay for assessments of general toxicity.

Results: Building on previous research, the toxicity profiles of 20 compounds were compared using the General and Behavioral Toxicity (GBT) assay and the Zebrafish Embryo Toxicity (ZET) assay. The results show partially overlapping toxicity profiles along with unique information provided by each assay. It appears from this work that these two assays applied together can strengthen the use of zebrafish embryos/larvae as standard toxicity testing models.

Publication: Achenbach, J.C., Leggiadro, C., Sperker, S., Woodland, C., Ellis, L.D. 2020. *Comparison of the Zebrafish Embryo Toxicity Assay and the General and Behavioural Embryo Toxicity Assay and New Approach Methods for Chemical Screening*. Toxics 2020, 8, 126; DOI: 10.3390/toxics8040126.

Development of an integrated approach for the testing and assessment of chemical non-genotoxic carcinogens

Focus of research: There is no unifying mechanism of action for the induction of cancers by non-genotoxic carcinogens (NGTxC). The NGTxCs are chemicals that do not have the inherent capacity at creating DNA damage. There are no validated OECD assays for the identification of NGTxC. OECD has created an expert working group to overcome this internationally recognized gap.

Results: The expert working group is developing an integrated approach to the testing and assessment (IATA) of NGTxC. This involves a strategy to organize existing and new toxicological information using adverse outcome pathway concepts and common hallmarks of cancers, performing literature searches and evaluating chemical carcinogenicity assays, and identifying those that can be used in the IATA to reduce uncertainties in predicting the carcinogenicity of NGTxC thereby reducing public health hazards.

Publication: Jacobs, M.N., Colacci, A., Corvi, R., Vaccari, M., Aguila, M.C., Corvaro, M., Delrue, N., Desaulniers, D., Ertych, N., Jacobs, A., Luijten, M., Madia, F., Nishikawa, A., Ogawa, K., Ohmori, K., Paparella, M., Kumar Sharma, A., Vasseur, P. 2020. *Chemical carcinogen safety testing: OECD expert group international consensus on the development of an integrated approach for the testing and assessment of chemical non-genotoxic carcinogens*. Archives of Toxicology, 94:2899-2923. DOI: 10.1007/s00204-020-02784-5.

Non-targeted screening analysis approaches for identifying emerging metabolites and chemicals in human fluids

Focus of research: There is a gap between pre-selected targets and our capability of qualitatively and quantitatively determining unknown and new substances of emerging concern (also known as emerging substances) in human biofluids. As a result, non-targeted approaches have gained much attention in risk assessment of human exposure to unknown and emerging chemical contaminants. The goal of this project is to develop new non-targeted analytical methods, which aims to rapidly screen and identify new metabolites of these chemicals and some parent compounds in human biofluids as potential biomarkers for assessment of human exposure to substances, including CMP priority chemicals and other emerging chemicals.

Results: Newly developed analytical methods will provide valuable screening information for metabolites and parent compounds as to the identification of potential emerging contaminants for future assessments under CMP. Models will be developed to provide semi-quantitative information of identified unknown chemicals without using standards. In addition, they will generate meaningful knowledge regarding metabolites derived from emerging chemicals in human biofluids.

Publications: Feng, Y.-L., Liao, X., Chen, D., Takser, L., Cakmak, S., Chan, P., Zhu, J. 2020. *Correlations of phthalate metabolites in urine samples from fertile and infertile men: Free-form concentration vs. conjugated-form concentration.* Environmental Pollution, 2020, 263. DOI: 10.1016/j.envpol.2020.114602.

Guo, Z., Huang, S., Wang, J., Feng, Y.-L. 2020. *Recent advances in non-targeted screening analysis using liquid chromatography - high resolution mass spectrometry to explore new biomarkers for human exposure*. Talanta, 219 (2020) 121339. DOI: 10.1016/j.talanta.2020.121339.

Meshref, S., Li, Y., Feng Y.-L. 2020. *Prediction of liquid chromatographic retention time using quantitative structure-retention relationships to assist non-targeted identification of unknown metabolites of phthalates in human urine with high-resolution mass spectrometry*. 2020 J Chromatogr A,1634 (2020) 461691. DOI: 10.1016/j.chroma.2020.461691.

7.1.2.2 Exposure Characterization

Characterization of residential exposures to CMP metals and organics

Focus of research: The study focuses primarily on childhood exposures to house dust through normal hand-to-mouth ingestion behavior, but also looks at potential inhalation exposures by characterizing metals in re-suspended house dust.

Results: Settled house dust samples collected from 1025 homes in 13 cities under the Canadian House Dust Study (CHDS) were examined to provide a representative national baseline. Dust lead (Pb) concentrations and loadings from the CHDS were combined with smaller U.S. datasets to help support new, tighter U.S. Environmental Protection Agency standards for lead in dust on floors and window sills to protect children from the harmful effects of lead exposure. The house dust samples were analyzed for 16 bisphenol analogues. It was found that bisphenol A, S and F (BPA, BPS and BPF) were predominant.

Publications: Glorennec P., Shendell D.G., Rasmussen P.E., Waeber R., Egeghy P., Azuma K., Pelfrêne A., Le Bot B., Esteve W., Perouel G., Pernelet Joly, V., Noack, Y., Delannoy M., Keirsbulck, M., Mandin C. (2020) *Towards setting public health guidelines for chemicals in indoor settled dust?* Indoor Air, DOI: 10.1111/ina.12722. DOI: 10.1111/ina.12722.

Bevington, C., Gardner, H.D., Cohen, J., Henning, C., Rasmussen, P.E. (2020) *Relationship between Residential Dust-Lead Loading, and Dust-Lead Concentration across Multiple North American Datasets.* Building and Environment. 188 DOI: 10.1016/j.buildenv.2020.107359.

Fan, X., Katuri, G.P. Caza, A., Rasmussen, P.E., Kubwabo, C. 2020. *Simultaneous measurement of 16 bisphenol analogues in house dust and evaluation of two sampling techniques*. Emerging Contaminants vol 7. DOI: 10.1016/j.emcon.2020.12.001.

Multimedia exposure to replacement chemicals of emerging concern and selected CMP3 chemicals

Focus of research: Many alternative chemicals have been introduced into the market as replacements for chemicals that have shown to exhibit a range of health effects. However, the exposure and potential health risks for these replacement chemicals have not yet been assessed in Canada. The goal of this project is to generate Canadian exposure data for a variety of priority compounds including bisphenol analogues, in environmental and biological matrices, as well as children's products (such as, baby bottles).

Results: An integrated and sensitive method was developed for the analysis of 16 bisphenol A (BPA) analogues in house dust. Bisphenol A (BPA) was detected in 100% of house dust samples. The BPA replacement chemicals, bisphenol S, bisphenol F and bisphenol M were detected in more than 75% of house dust samples. BPA and BPA replacement chemical concentrations in dust sampled from household vacuum bags compared well with concentrations observed in fresh dust collected from the same homes, suggesting that vacuum cleaner bag sampling could be a cost-effective alternative to fresh dust sampling in future studies.

Publication: Fan, X., Katuri, G. P., Caza, A. A., Rasmussen, P. E., Kubwabo, C. 2021. *Simultaneous measurement of 16 bisphenol A analogues in house dust and evaluation of two sampling techniques*. Emerging Contaminants 7: 1-9. DOI: 10.1016/j.emcon.2020.12.001.

7.1.2.3 Effects of chemicals on human health

Hepatic investigation of vanadium toxicity

Focus of research: Vanadium is considered as "possibly carcinogenic to humans" (V_2O_5, IARC Group 2B), yet uncertainties persist related to the toxicity mechanisms of the multiple forms of vanadium. Co-exposures of vanadium with polycyclic aromatic hydrocarbons (PAH) occurs in urbanized population and in occupational settings. PAH can be transformed to carcinogens by enzymes that are particularly abundant in the liver. Therefore, using two human liver cell lines (HepG2 and HepaRG) and aflatoxin-B1 (AFB1) (a mycotoxin) as a model chemical that is transformed into a carcinogen by liver enzymes, the current study investigated the ability of vanadium (in the soluble form of sodium metavanadate $NaVO_3$) to modulate the enzymatic activities required to transform AFB1 into a carcinogen.

Results: Low concentration of $NaVO_3$ caused important cell proliferation only in HepaRG cells. As a binary mixture, $NaVO_3$ did not modify the effects of AFB1. High concentration of $NaVO_3$ increased DNA methylation in HepG2 cells. The fact that both cell lines responded differently to $NaVO_3$ supports the importance of investigating more than one cell line. Overall, the adverse effect of $NaVO_3$ might reside at low concentrations by stimulating the proliferation of tumorigenic cells.

Publication: Desaulniers D, Cummings-Lorbetskie, C., Leingartner, K., Xiao, G.-H., Zhou, G., Parfett, C. 2021. *Effects of vanadium (sodium metavanadate) and aflatoxin-B1 on cytochrome p450 activities, DNA damage and DNA methylation in human liver cell lines*. Toxicology in Vitro (2021), 70: 105036. DOI: 10.1016/j.tiv.2020.105036.

Regional analysis of CHMS biomonitoring data

Focus of research: The Canadian Health Measures Survey (CHMS) involves the collection of extensive data on blood and urinary concentration of environmental chemicals that are used to assess chemical exposures in Canadians. Although the data collected is only nationally representative within each cycle of CHMS, combining data from multiple cycles of the CHMS allows calculation of chemical concentrations that are representative at the regional level. The aim of this ongoing project is to develop statistically robust estimates of concentrations of chemicals at the regional level.

Results: In the first-ever regional analysis of CHMS data, blood and/or urinary concentrations of several environmental chemicals for the provinces of Quebec and Ontario, were compared to concentrations in the rest of Canada. The analysis showed several regional differences in exposures to chemicals and helped assess contributing factors. The concentration of urinary fluoride was significantly higher in Ontario as compared to Quebec and the rest of Canada. Blood manganese and urinary fluoride were significantly lower in Quebec compared to the rest of Canada, and blood and urinary selenium were significantly lower in Ontario compared to the rest of Canada.

Publication: Valcke, M., Karthikeyan, S., Walker, M., Gagné, M., Copes, R., St-Amand, A. 2020. *Regional variations in human chemical exposures in Canada: A case study using biomonitoring data from the Canadian Health Measures Survey for the provinces of Quebec and Ontario*. Int J Hyg Environ Health 225: 113451. DOI: 10.1016/j.ijheh.2020.113451.

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 and fetal/early life exposure to priority environmental chemicals and potential adverse health effects on the pregnancy, as well as newborn and infant/childhood growth and development. It encompasses the original MIREC Study of Canadian pregnant women and the follow-up studies of some of their infants (MIREC-Infant Development: MIREC-ID), young children (MIREC-Child Development at age 3: MIREC-CD3 and MIREC- Early Childhood Biomonitoring and Neurodevelopment: MIREC-CD Plus) and now in adolescents (MIREC - Pubertal Timing, Endocrine and Metabolic Function: MIREC-ENDO). The Platform also includes a repository of MIREC data and biospecimens, the MIREC Biobank, for future research on the health of mothers and their children.

Results: In 2020-2021, 10 MIREC research platform papers were published. This included studies of environmental exposures and outcomes in children and infants (preterm birth, the development of reproductive systems, BMI and cognitive outcomes) and pregnant women (gestational hypertension and preeclampsia). Some of these publications highlighted sex and gender based differences. For example, the effects of environmental chemicals on IQ were observed in boys but not in girls, and the effects of PFAS on gestational hypertension and preeclampsia depended on the sex of the fetus the mother was carrying. The project continues to generate new knowledge on early life cumulative exposure to endocrine disrupting chemicals and potential health risks in vulnerable populations of pregnant women, fetuses, infants, and young children that contributes to risk assessment and management of chemicals.

Publications: Arbuckle, T.E., MacPherson, S.H., Fisher, M., Muckle, G., Foster, W., Sathyanarayana, S., Monnier, P., Lanphear, B., Fraser, W.D. 2020. *Prenatal perfluoroalkyl substances and newborn anogenital distance in a Canadian cohort.* Reprod Toxicol. 2020 Jun;94:31-39. DOI: 10.1016/j.reprotox.2020.03.011.

Borghese, M.M., Walker, M., Helewa, M.E., Fraser, W.D., Arbuckle, T.E. 2020. *Association of perfluoroalkyl substances with gestational hypertension and preeclampsia in the MIREC study.* Environment International, 141, art. no. 105789. DOI: 10.1016/j.envint.2020.105789.

Ashley-Martin, J., Dodds, L., Arbuckle, T.E., Lanphear, B., Muckle, G., Foster, W.G., Ayotte, P., Zidek, A., Asztalos, E., Bouchard, M.F., Kuhle, S. 2021. *Urinary phthalates and body mass index in preschool children: The MIREC Child Development Plus study*. International Journal of Hygiene and Environmental Health. Volume 232, March 2021, Article number 113689. DOI: 10.1016/j.ijheh.2021.113689.

Lukina, A. O., Fisher, M., Khoury, C., Than, J., Guay, M., Paradis, J.-F., Arbuckle, T.E., Legrand, M. 2021. *Temporal variation of total mercury levels in the hair of pregnant women from the Maternal-Infant Research on Environmental Chemicals (MIREC) study*. Chemosphere, 264, 128402.

Cao X.L., Sparling, M., Zhao, W., and Arbuckle, T.E. 2021. *GC-MS Analysis of Phthalates and Di-(2-thylhexyl) Adipate in Canadian Human Milk for Exposure Assessment of Infant Population.* Journal of AOAC International 2021 Mar 5;104(1):98-102. DOI: 10.1093/jaoacint/qsaa108.

Hu, J.M.Y., Arbuckle, T.E., Janssen, P., Lanphear, B.P., Braun, J.M., Platt, R.W., Chen, A., Fraser, W.D., McCandless, L.C. 2020. *Associations of prenatal urinary phthalate exposure with preterm birth: the Maternal-Infant Research on Environmental Chemicals (MIREC) Study*. Canadian Journal of Public Health, 111 (3), pp. 333-341. DOI: 0.17269/s41997-020-00322-5.

Romao, R.L.P., Dodds, L., Ashley-Martin, J., Monnier, P., Arbuckle, T.E. 2020. *Prenatal exposure to phthalates and male reproductive system development: Results from a Canadian pregnancy cohort study.* Reproductive Toxicology, 95, pp. 11-18. DOI: 10.1016/j.reprotox.2020.04.078.

Louopou, R.C., Trottier, H., Arbuckle, T.E., Fraser, W.D. 2020. *Dental amalgams and risk of gestational hypertension in the MIREC study*. Pregnancy Hypertension, 21, pp. 84-89. DOI: 10.1016/j.preghy.2020.04.015.

Nkinsa, P.N., Muckle, G., Ayotte, P., Lanphear, B.P., Arbuckle, T.E., Fraser, W.D., Bouchard, M.F. 2020. *Organophosphate pesticide exposure during fetal development and IQ scores in 3 and 4-year old Canadian children*. Environmental Research 2020 Aug 7:110023. DOI: 10.1016/j.envres.2020.110023.

Azar, N., Booij, L,. Muckle, G., Arbuckle, T.E., Séguin, J.R., Asztalos, E., Fraser, W.D., Lanphear, B.P., Bouchard, M,F. 2020. *Prenatal exposure to polybrominated diphenyl ethers (PBDEs) and cognitive ability in early childhood.* Environ Int. 2021 Jan; 146:106296. Epub 2020 Dec. DOI: 10.1016/j.envint.2020.106296.

7.1.2.4 Nanomaterials

The impact of dissolution behaviour of metal oxide nanomaterials on toxicological response

Focus of research: The toxicological behavior of nanomaterials (NMs) is closely associated with their distinct physical-chemical properties. This research is investigating the influence of dissolution behaviour of NMs on their toxic potential.

Results: Experimental results showed that the dissolution behaviour of three nano-metal oxides and their bulk analogues (nickel, zinc and copper) was different in cell culture medium compared to distilled water. By participating in an international validation exercise led by Germany under Project 1.4 of the Working Group of the National Coordinators for the Test Guidelines Programme (WNT), the HC research team contributed to the development of an OECD Test Guideline on Particle Size Distribution.

Publications: Avramescu, M-L., Chénier, M., Palaniyandi, S., Rasmussen, P.E. 2020. *Dissolution behaviour of metal oxide nanomaterials in cell culture medium versus distilled water*. J. Nanoparticle Research, Vol. 22, 222 DOI: 10.1007/s11051-020-04949-w. DOI: 10.1007/s11051-020-04949-w.

Boyadzhiev, A., Avramescu, M.-L., Wu, D., Williams, A., Rasmussen, P., Halappanavar S. 2021. *Impact of copper oxide particle solubility on lung epithelial cell toxicity: response characterization using global transcriptional analysis*. Nanotoxicology DOI: 10.1080/17435390.2021.1872114.

Levesque, L., Wiseman, C.L.S., Beauchemin, S., Rasmussen, P.E. 2021. *Thoracic Fraction (PM10) of Resuspended Urban Dust: Geochemistry, Particle Size Distribution and Lung Bioaccessibility.* Geosciences 11, 87. DOI: 10.1080/17435390.2021.1872114.

Relative toxic potency of silica and titanium dioxide nanoparticle variants

Focus of research: The objective is to assess composition, size and surface coating characteristics of nanomaterial (NMs), and test toxicity in lung cells including cells from biopsy samples from healthy lungs and those affected by pulmonary diseases (for example, cystic fibrosis).

Results: Influence of composition, size and surface coating characteristics of these NMs on their toxicity in lung epithelial cells and macrophages, and in cells from biopsy samples from healthy and pulmonary diseases (such as, cystic fibrosis) are being assessed. Oxidizing ability of these particles were determined. Also, uptake of amorphous silica nanoparticles into the macrophage cells were examined. This work will advance understanding of the health consequences of exposure to NMs, in providing toxicity information to contribute to the risk assessment of these materials, and can assist in the design of less toxic NMs.

Publication: Breznan, D., Nazemof, N., Kunc, F., Hill, M., Vladisavljevic, D., Gomes, J., Johnston, L.J., Vincent, R., Kumarathasan, P. 2020. *Acellular oxidative potential assay for screening of amorphous silica nanoparticles.* Analyst. 2020 Jul 21;145(14):4867-4879. DOI: 10.1039/d0an00380h.

Characterization of metal nanoparticles

Focus of Research: HC has identified a number of priority nanomaterials (NMs) on the Domestic Substances List (DSL), for which test data on physico-chemical characterization and toxicity are lacking for regulatory human health risk assessment. To fulfill these data needs, this research project was carried out to characterize the physico-chemical properties of several commercially available nano scale DSL substances, including aluminum oxide, copper oxide, titanium dioxide, and zinc oxide.

Results: The characterizations of different nanoforms of the selected NMs were performed to determine their size, shape, surface area, surface charge, type and quantity of surface coating or surface modification. Data obtained from this project allow Health Canada to evaluate the relationships between NM properties and will allow for toxicological testing to determine if there are contrasting effects between nanoforms. The work will also serve to fill the data gaps for making regulatory decisions on the priority DSL NMs.

Publication: Bushell, M., Beauchemin, S., Kunc, F., Gardner, D., Ovens, J., Toll, F., Kennedy, D., Nguyen, K., Vladisavljevic, D., Rasmussen, P.E., Johnston, L.J. 2020. *Characterization of Commercial Metal Oxide Nanomaterials: Crystalline Phase, Particle Size and Specific Surface Area*. Nanomaterials 2020, 10, 1812. DOI: 10.3390/nano10091812.

7.2 Air pollutants and greenhouse gases

Air quality research efforts help quantify priority air pollutants and determine trends, improve and validate air quality predictions both in the near term and into the future within the national and global context. These efforts also enhance understanding of the impacts of air pollution on Canadians and the environment. The research also tackles emerging issues, and underpins and informs evidence-based policy and regulatory development.

7.2.1 ECCC 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. Over 44 research papers on the topics of air pollutants and GHGs were published in peer-reviewed scientific journals in 2020-2021. The following are representative examples of that body of work.

Understanding atmospheric particulate matter

Focus of research: Trends, characteristics and composition of atmospheric aerosols and trace elements in particulate matter in Canada.

Results: Three separate studies on atmospheric particulate matter indicated: 1) Analysis of samples from three monitoring stations in the Great Lakes Basin over a thirty-year span found concentrations of most trace elements in particulate matter were significantly decreased, but some levels are still close to or higher than acceptable cancer risk levels. 2) Long-term trends (2004-2017) in the chemical composition and sources of $PM_{2.5}$ (particulate matter smaller than 2.5 µm in diameter) in Toronto showed that non-tailpipe emissions (brake wear and resuspension of road dust) are rising, while the overall level of $PM_{2.5}$ has markedly decreased mainly due to reduced emissions from fossil fuel combustion and tailpipe emissions. Quantifying the oxidative potential of $PM_{2.5}$ from several Canadian cities found that traffic emissions resulted in the highest oxidative potential, followed by industrial emissions and resuspended crustal matter.

Publications: Li, W., Dryfhout-Clark, H., Hung, H. 2020. *PM_{10}-bound trace elements in the Great Lakes Basin (1988-2017) indicates effectiveness of regulatory actions, variations in sources and reduction in human health risks*. Environment International, art. no. 106008, DOI: 10.1016/j.envint.2020.106008.

Jeong, C.-H., Traub, A., Huang, A., Hilker, N., Wang, J.M., Herod, D., Dabek-Zlotorzynska, E., Celo, V., Evans, G.J. 2020. *Long-term analysis of $PM_{2.5}$ from 2004 to 2017 in Toronto: Composition, sources, and oxidative potential*. Environmental Pollution, 263, art. no. 114652. DOI: 10.1016/j.envpol.2020.114652.

Shahpoury, P., Zhang, Z.W., Arangio, A., Celo, V., Dabek-Zlotorzynska, E., Harner, T., Nenes, A. 2020. *The influence of chemical composition, aerosol acidity, and metal dissolution on the oxidative potential of fine particulate matter and redox potential of the lung lining fluid* (2021) Environment International, 148, art. no. 106343, DOI: 10.1016/j.envint.2020.106343.

Emissions and trends of ammonia, sulphur oxides and nitrogen oxides

Focus of research: Improved emissions estimates through satellite measurements.

Results: 1) A global study identified regions of high or changing ammonia concentrations and linked these to various human activities; high emission areas in North America were characterized by high agricultural activity. 2) A comparison of satellite-derived and reported sulphur dioxide (SO_2) emissions from the Canadian oil sands found that although satellite-derived SO_2 emissions remained relatively constant since 2013, reported emissions dropped by a factor of two; no clear explanation for the discrepancy was found. 3) Analysis of satellite measurements of nitrogen dioxide (NO_2) combined with air quality modelling estimated a 40% decrease in NO_2 emissions in the Greater Toronto Area due to COVID-19 related reductions on vehicle and aircraft traffic and on industry.

Publications: Evangeliou, N., Balkanski, Y., Eckhardt, S., Cozic, A., Van Damme, M., Coheur, P.-F., Clarisse, L., Shephard, M. W., Cady-Pereira, K. E., and Hauglustaine, D. 2021. *10-year satellite-constrained fluxes of ammonia improve performance of chemistry transport models*. Atmos. Chem. Phys., 21, 4431-4451, DOI: 10.5194/acp-21-4431-2021, 2021.

McLinden, C.A., Adams, C.L.F., Fioletov, V., Griffin, D., Makar, P.A., Zhao, X., Kovachik, A., Dickson, N., Brown, C., Krotkov, N., Li, C., Theys, N., Hedelt, P., Loyola, D.G. 2021. *Inconsistencies in sulfur dioxide emissions from the Canadian oil sands and potential implications*. Env. Res. Lett., 16 (1), art. no. 014012.

Griffin, D., McLinden, C.A., Racine, J., Moran, M.D., Fioletov, V., Pavlovic, R., Mashayekhi, R., Zhao, X., Eskes, H. 2020. *Assessing the Impact of Corona-Virus-19 on Nitrogen Dioxide Levels over Southern Ontario, Canada.* Remote Sens. 12, 4112.

Feng, J., Vet, R., Cole, A., Zhang, L., Cheng, I., O'Brien, J., Macdonald, A.-M. 2021. *Inorganic chemical components in precipitation in the eastern U.S. and Eastern Canada during 1989-2016: Temporal and regional trends of wet concentration and wet deposition from the NADP and CAPMoN measurements.* Atmospheric Environment, 254, art. no. 118367, DOI: 10.1016/j.atmosenv.2021.118367.

Observing historic lows in tropospheric and stratospheric ozone levels

Focus of research: Long-term monitoring of trends in atmospheric ozone concentrations.

Results: Observed tropospheric ozone in the northern hemisphere in the spring and summer of 2020 was the lowest in at least 20 years. This was linked to COVID-19 related emissions reductions. A record seasonal loss of stratospheric ozone was observed over the Arctic in spring 2020. This was determined to be due to unusually low temperatures, demonstrating that weather may cause short-term reversals in the long-term improvement in ozone levels as the use of ozone-depleting substances declines.

Publications: Steinbrecht, W., Kubistin, D., Plass-Dülmer, C., Davies, J., Tarasick, D.W., Gathen, P.V.D., Deckelmann, H., Jepsen, N., Kivi, R., Lyall, N., Palm, M., Notholt, J., Kois, B., Oelsner, P., Allaart, M., Piters, A., Gill, M., Van Malderen, R., Delcloo, A.W., Sussmann, R., Mahieu, E., Servais, C., Romanens, G., Stübi, R., Ancellet, G., Godin-Beekmann, S., Yamanouchi, S., Strong, K., Johnson, B., Cullis, P., Petropavlovskikh, I., Hannigan, J.W., Hernandez, J.-L., Diaz Rodriguez, A., Nakano, T., Chouza, F., Leblanc, T., Torres, C., Garcia, O., Röhling, A.N., Schneider, M., Blumenstock, T., Tully, M., Paton-Walsh, C., Jones, N., Querel, R., Strahan, S., Stauffer, R.M., Thompson, A.M., Inness, A., Engelen, R., Chang, K.-L., Cooper, O.R. 2021. *COVID-19 Crisis Reduces Free Tropospheric Ozone Across the Northern Hemisphere*. Geophys. Res. Lett., 48 (5), art. no. e2020GL091987, DOI: 10.1029/2020GL091987.

Wohltmann, I., von der Gathen, P., Lehmann, R., Maturilli, M., Deckelmann, H., Manney, G.L., Davies, J., Tarasick, D., Jepsen, N., Kivi, R., Lyall, N., Rex, M. 2020. *Near-Complete Local Reduction of Arctic Stratospheric Ozone by Severe Chemical Loss in Spring 2020*. Geophysical Research Letters, 47 (20), art. no. e2020GL089547, DOI: 10.1029/2020GL089547.

Emissions from oil and gas operations

Focus of research: Improving air pollutant emissions estimates from Canadian oil and gas operations and understanding the sources and composition of air pollution events in the Athabasca oil sands.

Results: A study was conducted of air pollution events in the Athabasca oil sands region to characterize the components of complex air pollutant mixtures and to identify pollution sources. The study found that these events often involve multiple chemical mixtures, indicating limitations to current risk assessments that are based on a small number of air quality standards. Atmospheric measurements and modelling produced improved estimates of methane emissions from Canadian oil and gas operations, which were significantly higher than those reported to inventories.

Publications: Wren, S.N., Mihele, C.M., Lu, G., Jiang, Z., Wen, D., Hayden, K., Mittermeier, R.L., Staebler, R.M., Cober, S.G., Brook, J.R. 2020. *Improving Insights on Air Pollutant Mixtures and Their Origins by Enhancing Local Monitoring in an Area of Intensive Resource Development*, Environ. Sci. Technol. 2020, 54, 23, 14936-14945, DOI: 10.1021/acs.est.0c06055.

Chan, E., Worthy, D.E.J., Chan, D., Ishizawa, M., Moran, M.D., Delcloo, A., Vogel, F. 2020. Eight-Year *Estimates of Methane Emissions from Oil and Gas Operations in Western Canada Are Nearly Twice Those Reported in Inventories*. Environ. Sci. Technol. 2020, 54, 14899–14909, DOI: 10.1021/acs.est.0c04117.

Atmospheric emissions from wildfires and other biomass burning

Focus of research: Understanding the composition and chemical transformations, long-range transport and global warming impacts of emissions from wildfires and other burning of biomass.

Results: A study of the chemical composition and atmospheric chemical reactions associated with wildfire smoke found a complex mixture of diverse organic compounds. Studies of emissions from wildfires and anthropogenic biomass burning activities demonstrated the long-range transport of these emissions, with increased tropospheric ozone generated from transformations of wildfire smoke measured far from the source. In addition, carbon monoxide and fine particulate matter from wildfires in Siberia were found in western Canada.

Publications: Ditto, J. C., He, M., Hass-Mitchell, T. N., Moussa, S. G., Hayden, K., Li, S.-M., Liggio, J., Leithead, A., Lee, P., Wheeler, M. J., Wentzell, J. J. B., and Gentner, D. R. 2021. *Atmospheric evolution of emissions from a boreal forest fire: the formation of highly functionalized oxygen-, nitrogen-, and sulfur-containing organic compounds*. Atmos. Chem. Phys., 21, 255-267, DOI: 10.5194/acp-21-255-2021.

Moeini, O., Tarasick, D.W., McElroy, C.T., Liu, J., Osman, M.K., Thompson, A.M., Parrington, M., Palmer, P.I., Johnson, B., Oltmans, S.J., Merrill, J. 2020. *Estimating wildfire-generated ozone over North America using ozonesonde profiles and a differential back trajectory technique*. Atmospheric Environment: X, 7, art. no. 100078, DOI: 10.1016/j.aeaoa.2020.100078.

Tao, J., Surapipith, V., Han, Z., Prapamontol, T., Kawichai, S., Zhang, L., Zhang, Z., Wu, Y., Li, J., Li, J., Yang, Y., Zhang, R. (2020) *High mass absorption efficiency of carbonaceous aerosols during the biomass burning season in Chiang Mai of northern Thailand*. Atmospheric Environment, 240, art. no. 117821, DOI: 10.1016/j.atmosenv.2020.117821.

Johnson, M.S., Strawbridge, K., Knowland, K.E., Keller, C., Travis, M. 2021. *Long-range transport of Siberian biomass burning emissions to North America during FIREX-AQ*) Atmos. Environ., 252, art. no. 118241, DOI: 10.1016/j.atmosenv.2021.118241.

7.2.2 Health Canada research

In 2020-2021, HC continued to conduct research on human exposure to indoor and outdoor air pollutants and their health impacts in order to guide actions to address air pollution by governments, industries, other organizations and individuals. HC scientists published approximately 58 articles in peer reviewed scientific journals. These addressed issues such as implications of air pollution exposure on the number of COVID-19 cases in communities; the effect of air pollutants on birth outcomes and on the development of diseases such as asthma, diabetes, and cancer; the risks associated with elevated exposure to traffic and industrial pollutants; and the interactions between air pollution and physiological and psychological stress.

The following includes a list of some of the projects in which HC was engaged in during 2020-2021.

Role of non-chemical stressors and stress susceptibility in modifying the effects of air pollutants on health

Focus of research: Non-chemical stressors are important determinants of health that may also modify or contribute to the adverse health effects associated with air pollution. The objective is to assess the extent to which non-chemical stressors and inter-individual differences in stress response modify health effects of air pollution.

Results: The study produced the first evidence that individual differences in stress reactivity are associated with differential sensitivity to pulmonary impacts of ozone. The first national profile of allostatic load, a measure of cumulative physiological dysfunction associated with chronic exposure to stressors, was published. Results identified a spatial association between psychological distress and ambient air pollution levels in Canada. Poor mental health was associated with increased risk of mortality from air pollutants in the Canadian population. This work provides insight into factors governing susceptibility to inhaled pollutants. The allostatic load profile provides a tool for assessing combined and cumulative impacts of exposure to multiple stressors.

Publications: Pinault L., Thomson, E.M. Christidis, T., Colman, I., Tjepkema, M., van Donkelaar, A., Martin, R.V., Hystad, P., Shin, H., Crouse, D.L., Burnett, R.T. 2020. *The association between ambient air pollution concentrations and psychological distress*. Health Rep. 2020 Jul 29;31(7):3-11. DOI: 10.25318/82-003-x202000700001-eng. PMID: 32761579.

Thomson, E.M., Christidis, T., Pinault, L., Tjepkema, M., Colman, I., Crouse, D.L., van Donkelaar, A., Martin, R.V., Hystad, P., Robichaud, A., Ménard, R., Brook, J.R., Burnett, R.T. 2020. *Self-rated stress, distress, mental health, and health as modifiers of the association between long-term exposure to ambient pollutants and mortality*. Environ Res. 2020 Aug 15;191:109973. DOI: 10.1016/j.envres.2020.109973.

Crouse, D.L., Pinault, L., Christidis, T., Lavigne, E., Thomson, E.M., Villeneuve, P.J. 2021. *Residential greenness and indicators of stress and mental well-being in a Canadian national-level survey*. Environ Res. 2021 Jan;192:110267. doi: 10.1016/j.envres.2020.110267. Epub 2020 Oct 4. DOI: 10.1016/j.envres.2020.110267.

Willey J.B., Pollock, T., Thomson, E.M., Liang, C.L., Maquiling, A., Walker, M., St-Amand, A. 2021. *Exposure Load: Using biomonitoring data to quantify multi-chemical exposure burden in a population*. Int J Hyg Environ Health. 2021 May;234:113704. DOI: 10.1016/j.ijheh.2021.113704. Epub 2021 Mar 6. PMID: 33690093-21.

Role of stress and stress reactivity in mediating impacts of air pollutants on the brain and lungs

Focus of research: Exposure to air pollution is associated with increased risk of neurological and mental health disorders, but underlying mechanisms are unclear. The brain is exquisitely sensitive to stress, and chronic stress exerts profound biochemical and structural effects on the brain that contribute to local and systemic disease processes. This project investigates the role of stress responses in mediating impacts of pollutant inhalation on the brain and lungs, using *in vivo* and *in vitro models*, a human chamber study, and a birth cohort.

Results: Study findings directly link pollutant-induced release of stress hormones with effects in the brain. These findings substantiate the hypothesis that activation of the stress axis is involved in mediating adverse central nervous system impacts of air pollutants. Experimental work showed that air pollution produced effects in the brain that have been associated with reduced cognitive function and depression. Exposure to diesel exhaust increased blood cortisol levels, particularly in people diagnosed with asthma or with genetic variations that impact their ability to mount an antioxidant response. Brain imaging of a cohort of preadolescents showed associations between air pollution exposure and brain morphology, with patterns broadly consistent with effect of early-life stress. By linking results from experimental models to humans, ongoing work will provide mechanistic support for the causal basis of epidemiological associations, and inform effective risk assessment and management strategies through identification of characteristics that underlie vulnerability.

Publications: Rose, M., Filiatreault, A., Guénette, J., Williams, A., Thomson, E.M. 2020. *Ozone Increases Plasma Kynurenine-Tryptophan Ratio and Impacts Hippocampal Serotonin Receptor and Neurotrophic Factor Expression: Role of Stress Hormones*. Environ Res. 2020 Jun;185:109483. DOI: 10.1016/j.envres.2020.109483.

Lubczyńska, M,J., Muetzel, R.L., El Marroun, H., Hoek, G., Kooter, I.M., Thomson, E.M., Hillegers, M., Vernooij, M.W., White, T., Tiemeier, H., Guxens, M. 2020. *Air pollution exposure during pregnancy and childhood and brain morphology in preadolescents*. Environ Res. 2020 Nov 19:110446. DOI: 10.1016/j.envres.2020.110446.

Thomson, E.M., Filiatreault, A., Williams, A., Rider, C.F., Carlsten, C. 2021. *Exposure to Diesel Exhaust and Plasma Cortisol Response: A Randomized Double-Blind Crossover Study*. Environ Health Perspect. 2021 Mar;129(3):37701. DOI: 10.1289/EHP8923. Epub 2021 Mar 26. PMID: 33769847; PMCID: PMC7997608.

Air Quality Health Index and other communications tools

Focus of research: The Air Quality Health Index (AQHI) is the Government of Canada's tool to communicate daily air quality conditions and forecasts to Canadians. It was developed by HC as a means to convey to the public the health risk associated with the air pollution mixture and to guide actions by individuals and organizations to address episodes when the risk is elevated. In order to remain accurate and relevant ongoing scientific research is needed to evaluate, update and improve the AQHI.

Results: The AQHI was originally formulated based on the association of three air pollutants with increased risk of all-cause mortality. Further investigations have demonstrated that the index also reflects other health outcomes such as emergency department visits. Wildfires smoke and residential wood combustion present specific circumstances for the deterioration in air quality and communication tools to specifically address these conditions are needed.

Publications: Trieu, J., Yao, J., McLean, K.E., Stieb, D.M., Henderson, S.B. 2020. *Evaluating an Air Quality Health Index (AQHI) amendment for communities impacted by residential woodsmoke in British Columbia, Canada.* J Air Waste Manag Assoc. 2020 Oct;70(10):1009-1021. DOI: 10.1080/10962247.2020.1797927.

Szyszkowicz, M. 2020. *The air quality health index and emergency department visits for injury*. Polish J Pubic Health. 130(1):52-56. DOI: 10.2478/pjph-2020-0012.

Long-term exposure to industrial air pollution emissions and the incidence of childhood asthma, and adult hypertension and diabetes

Focus of research: Industrial emissions are important sources of ambient air pollution, and contribute to local and regional air pollutant concentrations. However, knowledge on the scale of population health impact by Canadian industrial emissions is still limited. Asthma has been reported to be affected by air pollution. In collaboration with the Institut National de Santé Publique du Québec and universities, HC studied the long-term exposure of all children born in the province of Quebec, Canada, between 2002 and 2011, to outdoor fine particulate matter ($PM_{2.5}$), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) emitted from industrial sources. The study focused on whether these exposures were related to incident cases of childhood asthma.

Results: The study found that long-term exposure to outdoor air pollutants emitted from industrial sources may lead to increased new cases of childhood asthma. Specifically, increases in $PM_{2.5}$, SO_2, and NO_2 from 25th to 75th percentile in outdoor concentrations were significantly associated with 19% to 23% increase in new cases of childhood asthma.

Publication: Buteau,S., Shekarrizfard, M., Hatzopolou, M., Gamache, P., Liu, L., Smargiassi, A. 2020. *Air pollution from industries and asthma onset in childhood: a population-based birth cohort study using dispersion modeling*. Environ.Res. june 2020. 185:109180. DOI: 10.1016/j.envres.2020.109180.

Exposure to outdoor air pollution and risk of fatal cardiac arrhythmias in patients with implantable cardio defibrillators (ICDs)

Focus of research: The influence of daily changes in air pollution in the province of Ontario, Canada on the frequency of discharges from implantable cardio defibrillators (ICDs), which occur in response to potentially life threatening arrhythmias, were assessed.

Results: No evidence was found that the concentrations of ambient air pollution observed in the study were a risk factor for potentially fatal cardiac arrhythmias in patients with ICDs.

Publication: Dales, R., Lee, D.S., Wang, X., Cakmak, S., Szyszkowicz, M., Shutt, R., Birnie, D. 2020. *Do acute changes in ambient air pollution increase the risk of potentially fatal cardiac arrhythmias in patients with implantable cardioverter defibrillators?* Environ Heal A Glob Access Sci Source. 2020;19(1). DOI: 10.1186/s12940-020-00622-w.

Blood volatile organic compounds (VOCs) and changes in hematologic and biochemical profiles

Focus of research: The influence of volatile organic compound (VOC) levels in blood, on hematological and serum biochemical parameters in the Canadian population was investigated.

Results: This study provides evidence that VOCs in blood, at levels found in the Canadian population, may influence blood cell counts and indicators of liver and kidney function. The study showed an inverse association between serum VOC and creatinine.

Publication: Cakmak, S., Cole, C., Hebbern, C., Andrade, J., Dales , R. 2020. *Associations between blood volatile organic compounds, and changes in hematologic and biochemical profiles, in a population-based study.* Environment International, 145, 106121. DOI: 10.1016/j.envint.2020.106121.

Factors influencing volatile organic compounds in Canadian homes

Focus of research: Volatile organic compounds, several of which may impact health, have many possible indoor sources. To further investigate this, we tested the association between indoor concentrations of 47 passively collected volatile organic compounds and both home characteristics and occupant behaviours in a Canadian population-based sample of 3454 participants.

Results: Homes with a door connecting to an attached garage had greater concentrations of hexanal, benzaldehyde, all the measured alkyl benzenes and ketones, most of the simple hydrocarbons and terpenes. Major home renovations within the past month were associated with higher concentrations of most or all of the volatile organic compounds in the categories of alcohols, alkyl benzenes, ketones, simple hydrocarbons and terpenes. Using paints and stains within the past week were associated with an increase in concentrations of the majority of alcohols, alkyl benzenes and simple hydrocarbons. Several building characteristics and occupant's behaviours appear to increase exposure to volatile organic compounds.

Publication: Cakmak, S., Kauri, L. M., Andrade, J., & Dales, R. .2020. *Factors influencing volatile organic compounds in Canadian homes*. Indoor and Built Environment, 1420326X2092622. DOI: 10.1177/1420326X20926229.

Health effects of exposure to ultrafine particles (UFPs)

Focus of research: This study investigates long-term exposure to UFPs on the risk of developing cancer in adults and children using data from case-control and cohort studies.

Results: Childhood exposure to UFPs and the development of childhood cancers was investigated in the city of Toronto. Ambient UFPs exposure during the first trimester of pregnancy was positively associated with overall childhood cancer incidence before 6 years of age.

Publication: Lavigne, E., Lima, I., Hatzopoulou, M., Van Ryswyk, K., van Donkelaar, A., Martin, R.V., Chen, H., Stieb, D.M., Crighton, E., Burnett, R.T., Weichenthal, S. 2020. *Ambient ultrafine particle concentrations and incidence of childhood cancers.* Environment International. 2020 Dec 1;145:106135.

Multi-City Multi-Country (MCC) Collaborative Research Network

Focus of research: Numerous studies have examined the associations between short-term particulate matter (PM) exposures and daily mortality. However, most evidence has been obtained from studies in single cities, regions, or countries. There are challenges in comparing these results and in synthesizing effect estimates because of different modeling approaches and potential publication bias. The MCC Collaborative Research Network was designed to address these limitations by performing international, multicenter studies that adopt the same analytic protocol and model specifications to estimate globally representative associations of ozone, PM_{10} and $PM_{2.5}$ exposures with daily mortality.

Results: The research provides key evidence on the independent and linear associations between short-term exposure to NO_2 and increased risk of total, cardiovascular, and respiratory mortality.

Publication: Meng, X., Liu, C., Chen, R., Sera, F., Vicedo-Cabrera, A.M., Milojevic, A., Guo, Y., Tong, S., Coelho, M.D., Saldiva, P.H., Lavigne, E. 2021. *Short term associations of ambient nitrogen dioxide with daily total, cardiovascular, and respiratory mortality: multilocation analysis in 398 cities*. bmj. 2021 Mar 24;372.

Air Pollution Exposure linked to the Ontario Population Health and Environment Cohort

Focus of research: The Ontario Population Health and Environment Cohort (ONPHEC) is a large, retrospective cohort in the province of Ontario, created in 2014 by linking multiple large-scale health administrative databases. It is comprised of virtually the entire Canadian-born population of Ontario who were 35 years or older in 1996 (~ 4.9 million), with follow-up until 2014. The primary objectives of ONPHEC are to investigate the independent and combined effects of environmental stressors (such as air pollution, traffic-related noise) on the incidence of chronic diseases and their interactions with 'healthy' environmental factors (for example, green areas).

Results: The research found that air pollution was associated with a higher incidence of chronic obstructive pulmonary disease (COPD) but was not associated with a higher incidence of adult-onset asthma.

Publication: Shin, S., Bai, L., Burnett, R.T., Kwong, J.C., Hystad, P., van Donkelaar, A., Lavigne, E., Weichenthal, S., Copes, R., Tu, K., Martin, R.V., Kopp, A., and Chen, H. 2021. *Air Pollution as a Risk Factor for Incident Chronic Obstructive Pulmonary Disease and Asthma: 15-Year Population-Based Cohort Study*. American Journal of Respiratory and Critical Care Medicine. May 1;203(9):1138-1148. DOI: 10.1164/rccm.201909-1744OC.

Health impacts of wildfire smoke

Focus of research: Air pollution from wildfires poses a serious health risk for Canadians, particularly from May to September. Wind can carry harmful smoke long distances from wildfires, affecting communities thousands of kilometers away.

Results: HC, ECCC, and the BC Centre for Disease Control used results from ECCC's FireWork model to estimate the impact of wildfires on air quality. These estimates were then used as input into HC's Air Quality Benefits Assessment Tool (AQBAT) to estimate the mortality rate and other health impacts specifically caused by wildfire smoke. The study found that in a 5- year period hundreds to thousands of deaths and many more illnesses annually are attributable to air pollution from wildfires.

Publication: Matz, C.J., Egyed, M., Xi, G., Racine, J., Pavlovic, R., Rittmaster, R,. Henderson, S.B., Stieb, D.M. 2020. *Health impact analysis of $PM_{2.5}$ from wildfire smoke in Canada (2013-2015, 2017-2018)*. Sci Total Environ. 2020 Jul 10;725:138506. DOI: 10.1016/j.scitotenv.2020.138506.

Traffic-related air pollution

Focus of research: Traffic-related air pollution (TRAP) is one of the major sources of air pollution exposure in urban areas. Much of the Canadian population is regularly exposed to TRAP as a result of daily activities, such as commuting, and a significant portion of the population resides in close proximity to major roadways. Investigation of the health impacts of TRAP can guide future air quality management measures and identify the role of pollutants versus noise and other built environment factors.

Results: Improved understanding of how exposure to air pollution while commuting contributes to health risk estimation. Two systematic reviews and meta-analyses allow the integration of research results from multiple studies and the evaluation of the impact of TRAP on population health. Original studies found links between TRAP exposure and the development of cardiovascular disease suggesting part of the mechanism by which pollution leads to severe illness and death.

Publications: Stieb, D.M., Zheng, C., Salama, D., Berjawi, R., Emode, M., Hocking, R., Lyrette, N., Matz, C., Lavigne, E., Shin, H.H. 2020. *Systematic review and meta-analysis of case-crossover and time-series studies of short term outdoor nitrogen dioxide exposure and ischemic heart disease morbidity*. Environ Health. 2020 May 1;19(1):47. DOI: 10.1186/s12940-020-00601-1.

Stieb DM, Berjawi R., Emode M., Zheng C, Salama D., Hocking R., Lyrette N., Matz C., Lavigne E., Shin HH. *Systematic review and meta-analysis of cohort studies of long term outdoor nitrogen dioxide exposure and mortality*. PLoS One. 2021 Feb 4;16(2):e0246451. DOI: 10.1371/journal.pone.0246451.

Van Ryswyk, K., Evans, G.J., Kulka, R, Sun, L., Sabaliauskas, K., Rouleau, M., Anastasopolos, A.T., Wallace, L., Weichenthal, S. 2020. *Personal exposures to traffic-related air pollution in three Canadian bus transit systems: the Urban Transportation Exposure Study*. Journal of Exposure Science & Environmental Epidemiology. 2020 Jul 16:1-3.

Johnson, M., Brook, J.R., Brook, R.D., Oiamo, T.H., Luginaah, I., Peters, P.A., Spence, J.D. 2020. *Traffic-related air pollution and carotid plaque burden in a Canadian city with low-level ambient pollution*. Journal of the American Heart Association. 2020 Apr 9;9(7):e013400.

Bai, L., Shin, S., Oiamo, T.H., Burnett, R.T., Weichenthal, S., Jerrett, M., Kwong, J.C., Copes, R., Kopp, A., Chen, H. 2020. *Exposure to road traffic noise and incidence of acute myocardial infarction and congestive heart failure: a population-based cohort study in Toronto, Canada*. Environmental health perspectives. 2020 Aug 12;128(8):087001.

Health impacts of early life exposure to air pollution

Focus of research: Exposure to air pollution in-utero and throughout childhood is believed to contribute to many adverse health outcomes including immune related diseases. Several approaches are being undertaken to elucidate this relationship using different methods to characterize air pollution exposure and link it to birth outcomes and childhood disease.

Results: Air pollution was seen to increase the risk of adverse health outcomes at birth and in early childhood development across several different research methods and considering pollutants from different sources. Studies identified links with the development of asthma, inflammatory bowel disease and early-onset paediatric type 1 diabetes.

Publications: Nielsen, C.C., Amrhein, C.G., Shah, P.S., Stieb, D.M., Osornio-Vargas, A.R.; Canadian Neonatal Network, DoMiNO Team. 2020. *Space-time hot spots of critically ill small for gestational age newborns and industrial air pollutants in major metropolitan areas of Canada*. Environ Res. 2020 Jul;186:109472. DOI: 10.1016/j.envres.2020.109472.

Lavigne, É., Talarico, R., van Donkelaar, A., Martin, R.V., Stieb, D.M., Crighton, E., Weichenthal, S., Smith-Doiron, M., Burnett, R.T., Chen, H. 2021. *Fine particulate matter concentration and composition and the incidence of childhood asthma*. Environment International. 2021 Jul 1;152:106486.

Elten, M., Benchimol ,E.I., Fell, D.B., Kuenzig, M.E., Smith, G., Chen, H., Kaplan, G.G., Lavigne, E. 2020. *Ambient air pollution and the risk of pediatric-onset inflammatory bowel disease: A population-based cohort study*. Environment international. 2020 May 1;138:105676.

Elten, M., Donelle, J., Lima, I., Burnett, R.T., Weichentha, I. S., Stieb, D.M., Hystad, P., van Donkelaar, A., Chen, H., Paul, L.A., Crighton, E. 2020. *Ambient air pollution and incidence of early-onset paediatric type 1 diabetes: A retrospective population-based cohort study.* Environmental research. 2020 May 1;184:109291.

Air pollution and the built environment

Focus of research: The impact of air pollution on health cannot be addressed without consideration of other environmental factors and processes that interact with it, both in the environment itself and through the body's response to multiple stressors, like noise, allergens, heat, and other circumstance. The built environment can be a mediator of air pollution health impacts both directly and by influencing distribution of populations made vulnerable by socioeconomic status. A better understanding of these relationships is needed to support risk assessments, and to provide guidance to policy makers in urban planning for green space, transportation, and neighbourhood design.

Results: Green space is an important characteristic of the urban landscape that can be beneficial to health directly by moderating heat, noise and air pollution. In investigations of the association of greenspace on health outcomes, increased exposure to urban green space was associated with reduced incidence of dementia and stroke. Living in urban areas with more green spaces was associated with improved cardiovascular health in people free of acute myocardial infarction (AMI) and heart failure (HF), but not among individuals who have already developed these conditions.

Publications: Paul, L.A., Hystad, P., Burnett, R.T., Kwong, J.C., Crouse, D.L., van Donkelaar, A., Tu, K., Lavigne, E., Copes, R., Martin, R.V., Chen H. 2020. *Urban green space and the risks of dementia and stroke*. Environmental research. 2020 Jul 1;186:109520.

Chen, H., Burnett, R.T., Bai, L., Kwong, J.C., Crouse, D.L., Lavigne, E., Goldberg, M.S., Copes, R., Benmarhnia, T., Ilango, S.D., van Donkelaar, A. 2020. *Residential greenness and cardiovascular disease incidence, readmission, and mortality.* Environmental health perspectives. 2020 Aug 25;128(8):087005.

Outdoor Pollution Exposure Risk Assessment (OPERA)

Focus of research: Outdoor Pollution Exposure and Risk Assessment (OPERA) represents a new paradigm in how to conduct burden of disease studies to support evidence-based decision making in climate and air quality management. The project consists of two main components: construction of multi-pollutant concentration response functions for different health outcomes; and estimation of disease burden by source of pollution and geographic area.

Results: Improved air pollution exposure methodologies were applied to Canadian and global cohorts and found associations between air pollution exposure for a range of health outcomes including diabetes, preterm birth and mortality. A large international collaboration has made a significant contribution to the estimation of the global burden of disease associated with air pollution. The toxic action of particulate matter can be better understood by evaluation of the chemical components that contribute to oxidative stress in the lungs. Epidemiological studies in Toronto have found associations between long term exposure to metals characteristic of non-tailpipe vehicle emissions and respiratory and cardiovascular disease outcomes. A study on Quebec population cohort found that the onset of dementia may be related to residential long-term exposure to $PM_{2.5}$, NO_2, and distance to major roads.

Publications: Zhang, Z., Weichenthal, S., Kwong, J.C., Burnett, R.T., Hatzopoulou, M., Jerrett, M., van Donkelaar, A., Bai, L., Martin, R.V., Copes, R., Lu, H. 2021. *A Population-Based Cohort Study of Respiratory Disease and Long-Term Exposure to Iron and Copper in Fine Particulate Air Pollution and Their Combined Impact on Reactive Oxygen Species Generation in Human Lungs*. Environmental Science & Technology. 2021 Mar 5;55(6):3807-18.

Zhang, Z., Weichenthal, S., Kwong, J.C., Burnett, R.T., Hatzopoulou, M., Jerrett, M., Donkelaar, A.V., Bai, L., Martin, R.V., Copes, R., Lu, H. 2021. *Long-term exposure to iron and copper in fine particulate air pollution and their combined impact on reactive oxygen species concentration in lung fluid: a population-based cohort study of cardiovascular disease incidence and mortality in Toronto, Canada*. International Journal of Epidemiology. 2021 Apr;50(2):589-601.

Gao, D., Ripley, S., Weichenthal, S., Pollitt, K.J. 2020. *Ambient particulate matter oxidative potential: Chemical determinants, associated health effects, and strategies for risk management.* Free Radical Biology and Medicine. 2020 May 1;151:7-25.

Smargiassi, A., Sidi, E.A.L., Robert, L.-E., Plante, C., Haddad, M. Gamache, P., Burnett, R., Goudreau, S., Liu, L., Fournier, M., Pelletier, E., Yankoty. I., 2020. *Exposure to ambient air pollutants and the onset of dementia in Québec, Canada.* Environ. Res. 2020. 190:109870. DOI: 10.1016/j.envres.2020.109870.

Methods Development for Modelling Concentration-Response Function

Focus of research: New evidence is emerging that relationships between outdoor concentrations of air pollutants and health may not all be best characterized by linear risk models. This project will develop mathematical methods to combine results from several studies with non-linear associations between air pollution exposure and health.

Results: This study investigates the association between ambient air pollution concentration levels and emergency department visits for personality disorders, acute reaction to stress, and disturbance of conduct using a non-linear modeling technique. The study suggested an impact of urban air pollution, mainly fine particulate matter, on human behaviour.

Publications: Szyszkowicz, M. 2020. *Application of quantile regression in environmental epidemiology.* Polish J Pubic Health. 129(3):72-74. DOI: 10.2478/pjph-2019-0017.

Szyszkowicz, M., Zemek, R., Colman, I., Gardner, W., Kousha, T., Smith-Doiron, M. 2020. *Air Pollution and Emergency Department Visits for Mental Disorders among Youth.* Int J Environ Res Public Health. 17(12):4190. DOI: 10.3390/ijerph17124190.

Air Pollution and COVID-19

Focus of research: Studies from the United States and Europe suggested that both short and long-term exposure to air pollution may increase the incidence of and mortality from COVID-19. This study examined whether the number of cases of COVID-19 infection is related to air pollution levels among 111 Canadian health regions, as well as 140 Toronto neighbourhoods, adjusting for other factors such as race, income, weather, population density and time since the peak number of cases.

Results: The national study found that there was a positive association between COVID-19 incidence and long-term exposure to fine particulate matter ($PM_{2.5}$) in Canadian health regions. The association was larger in magnitude and stronger in health regions with higher rates of COVID-19, and in those health regions where estimated exposure to $PM_{2.5}$ is expected to be more accurate. The Toronto study found that there was a positive association between COVID-19 incidence and long-term exposure to reactive oxygen species in $PM_{2.5}$. The results require further examination using studies based on individual-level rather than area-level data.

Publications: Stieb, D.M., Evans, G.J., To, T.M., Brook, J.R., Burnett, R.T. 2020. *An ecological analysis of long-term exposure to $PM_{2.5}$ and incidence of COVID-19 in Canadian health regions*. Environ Res. 2020 Dec;191:110052. DOI: 10.1016/j.envres.2020.110052.

Stieb, D.M., Evans, G.J., To, T.M., Lakey, P.S.J., Shiraiwa, M., Hatzopoulou, M., Minet, L., Brook, J.R., Burnett, R.T., Weichenthal, S.A. 2021. *Within-city Variation in Reactive Oxygen Species from Fine Particle Air Pollution and COVID-19.* Am J Respir Crit Care Med. 2021 Apr 2. DOI: 10.1164/rccm.202011-4142OC.

7.3 Water quality

ECCC continued water quality research activities during 2020-2021.

7.3.1 ECCC research

Nonylphenol, octylphenol, and nonylphenol ethoxylates dissemination in the Canadian freshwater environment

Focus of research: Nonylphenol, octylphenol, and nonylphenol ethoxylates are manmade compounds that are only discharged in the environment due to anthropogenic activities. The objectives of this study were to determine the current concentrations of these substances in the Canadian freshwater environment and to determine if past regulatory actions were beneficial to the environment.

Results: All compounds in the study were detected more frequently in urban and municipal wastewater treatment plant-associated sites than at other locations. Additionally, there is a statistically significant ($p < 0.05$) downward temporal trend in 4-nonylphenols concentrations in Canadian surface waters from 2014 to 2019. There were no exceedances of the Canadian Water Quality Guideline of 1000 ng/L.

Publication: Lalonde, B., Garron, C. 2021. *Nonylphenol, Octylphenol, and Nonylphenol Ethoxylates Dissemination in the Canadian Freshwater Environment*. Arch Environ Contam Toxicol 80, 319-330. DOI: 10.1007/s00244-020-00807-x.

Aquatic toxicology of silver nanoparticles

Focus of research: Silver nanoparticles (nAg) represent one of the most popular nanomaterials owing to their antibacterial properties. The increased use of nAg has raised concerns on potential impacts to aquatic ecosystems. The influence of surface coatings, size and the form of silver nanoparticles on the bioavailability and toxicity in freshwater mussels were examined.

Results: Different geometries of nanosilver initiated biophysical stress in the soft tissues of mussels, leading to the formation of liquid crystals, and protein damage. Moreover, the toxicity of nanometals were influenced by the properties of surface waters (for example, conductivity and organic content) and had different toxicity than did dissolved metals.

Publications: Auclair, J., Peyrot C., Wilkinson K.J., Gagne F. 2020. *The geometry of silver nanoparticles toxicity in freshwater mussels.* Comp Biochem Physiol 239, 108841

Auclair, J., Turcotte, P., Gagnon, C., Gagné, F. 2021. *The influence of surface waters on the bioavailability and toxicity of copper oxide nanoparticles to freshwater mussels.* Invertebrate Survival Journal, 2021, 18(1), pp. 33-45.

Auclair, J., Turcotte, P., Gagnon, C., Peyrot, C., Wilkinson, K.J., Gagné, F. 2020. *Toxicological effects of inorganic nanoparticle mixtures in freshwater mussels.* Environments – MDPI, 7(12), pp. 1-18.

Auclair J., Turcotte P., Gagnon C., Peyrot C., Wilkinson K.J., and F., Gagné 2020. *Comparative toxicity of copper oxide nanoparticles and dissolved copper to freshwater mussels*. Intern. J. Zool. Invest. 6: 135-147. DOI: 10.33745/ijzi.2020.v06i01.011.

Auclair, J., Turcotte, P., Gagnon, C., Gagné, F. 2020. *Toxicity of copper oxide nanoparticles to rainbow trout juveniles.* Current Topics in Toxicology 16, pp. 1-11.

André, C., Lachance, B., Turcotte, P., Gagnon, C., Emond, C. 2020. *Size-dependent toxicity of CdTe quantum dot aggregates in trout and human hepatocytes.* Current Topics in Toxicology 16, 215-225.

Gagné F. 2020. *Mini-review: Ecotoxicology of altered fractal organization in cells*. Am J Biomed Sci Res 8, 498-492.

Availability and biophysical effects of polystyrene nanoparticles

Focus of research: The presence of nanoplastics in various products and from the weathering of released plastic materials are of concern for the environment's safety. The purpose of this study was to examine the biophysical effects of polystyrene nanoparticles on cnidarian and freshwater mussels.

Results: Polystyrene nanoplastics in intercellular spaces were found to influence lactate dehydrogenase activities in *Hydra attenuate*. They disrupted the internal organization of cells in a way that interfered with the normal association of enzymes involved in energy metabolism in freshwater mussels, potentially increasing oxidative stress in affected organisms.

Publications: Auclair, J., Gagné, F. 2020. *Crowding Effects of Polystyrene Nanoparticles on Lactate Dehydrogenase Activity in Hydra attenuata*. J Xenobiotics 10, 2-9.

Auclair J., Peyrot C., Wilkinson K.J., Gagné, F. 2020. *Biophysical effects of polystyrene nanoparticles on Elliptio complanata mussels.* Environ Sci Poll Res. DOI: 10.1007/s11356-020-08920-z.

Auclair, J., Gagné, F. 2020. *Change in the spatial organization of mussel mitochondria exposed to polystyrene nanoplastics*. Current Topics in Toxicology,16, 127-140.

Auclair, J., Gagné, F. 2020. *The influence of polystyrene nanoparticles on enzyme clusters of fumarate, malate dehydrogenase and citrate synthase: a fractal analysis study*. Letters in Applied NanoBioScience 9, 981-987.

Auclair J, Quinn B and F., Gagné 2020. *Bioavailability and Effects of Polystyrene Nanoparticles in Hydra circumcincta.* Emerging Technologies and Research for Eco-friendly Aquaculture Chapter 2-14.

Auclair, J., Gagné, F. 2020. *The influence of polystyrene nanoparticles on the fractal kinetics of lactate dehydrogenase.* Biochemistry and Biophysics Reports 23, 100793.

Fate, transformation and bioavailability of metal-based nanoparticles in the aquatic environment

Focus of research: To evaluate the environmental transformation and fate of metal-based nanomaterials in natural waters. The fate of nanomaterials such as cerium, copper and zinc oxides and silver nanoparticles (NPs) released from municipal wastewaters and their toxicity in exposed fish and bivalves were assessed.

Results: Analytical issues related to interferences from naturally occurring colloidal zirconium were attenuated by the use of the 109 isotope in detecting silver, limiting false positives and improving the reliability of silver nanoparticle measurements in natural waters. Moreover, the cytotoxicity of monomeric and aggregated cadmium telluride quantum dots (CdTe QD) in human hepatoma (HepG2) were compared to rainbow trout hepatocytes (RTH). CdTe QDs were cytotoxic to both cell types with toxicity decreasing as QD aggregate size increased.

Publications: André, C., Lachance, B., Turcotte, P., Gagné, F., Gagnon, C., Emond, C. 2020. *Size-dependent toxicity of CdTe quantum dot aggregates in trout and human hepatocytes.* Current Topics Toxicol. 16: 215-225.

Turcotte P., Gagnon C. 2020. *Zirconium interferences on the detection of silver nanoparticles by single particle ICP-MS: implications on natural water analysis*. J Nanomed Nanotech. 11:550. DOI: 10.35248/2157-7439.20.11.550.

Accumulation, trophic transfer and biological effects of priority perfluoroalkyl substances (PFAS) in aquatic environments

Focus of Research: This research project aims to better understand the environmental distribution of emerging perfluoroalkyl substances in aquatic environments and their biological effects in aquatic organisms. Perfluoroalkyl substances (PFAS) are a group of man-made chemicals that have been used since the 1950s in a wide range of consumer products and in firefighting foams.

Results: A review article summarizes discussions concerning the ecotoxicology and ecological risks of PFAS. It includes information relevant to problem formulation/ prioritization, exposure, and hazard/effects of PFAS in the context of regulatory and ecological risk assessment activities from around the world. In a separate study, the temporal trends of legacy and unregulated PFASs in liver of the endangered beluga whale population from the St. Lawrence Estuary in Canada collected from 2000 to 2017 were examined. A suite of 54 PFASs were tentatively identified, and were grouped into nine structurally distinct classes. Single-hydrogenated perfluoro carboxylic acids (H-PFCAs), single-hydrogenated sulfonamides (H-Sulfonamides), as well as other select sulfonamides were detected for the first time in wildlife. Greater concentrations of the majority of PFASs were determined in newborns and juveniles than in adults, suggesting effective placental and lactational transfer of PFASs.

Publications: Ankley, G.T., Cureton, P., Hoke, R.A., Houde, M., Kumar, A., Kurias, J., Lanno, R., McCarthy, C., Newsted, J., Salice, C.J., Sample, B.E., Sepulveda, M.A., Steevens, J., Valsecchi, S. 2020. *Assessing the ecological risks of per- and polyfluoroalkyl substances: Current state-of-the science and a proposed path forward*. Environmental Toxicology and Chemistry. 40: 564-605. Critical review. Open Access. DOI: 10.1002/etc.4869.

Barrett. H., Dua, X., Houde, M., Lair, S., Verreault, J., Peng, H. 2021. *Suspect and nontarget screening revealed class-specific temporal trends (2000-2017) of poly- and perfluoroalkyl substances in beluga whales (Delphinapterus leucas). Environmental Science and Technology* 55: 1659-1671. DOI: 10.1021/acs.est.0c05957.

Giraudo, M., Colson, T.-L.L., De Silva, A.O., Lu, Z., Gagnon, P., Brown, L., Houde, M. 2020. *Food-borne exposure of juvenile rainbow trout (Oncorhynchus mykiss) to benzotriazole UV stabilizers alone and in mixture induces specific transcriptional changes*. Environmental Toxicology and Chemistry 39: 852-862. DOI: 10.1002/etc.4676.

8. Additional information

Further information on CEPA and related activities can be found online.

- CEPA Environmental Registry
- Environment and Climate Change Canada
- Health Canada
- CMP chemical substances section of the Canada.ca

For more information contact the Environment and Climate Change Canada's Inquiry Centre.

Environment and Climate Change Canada
Public Inquiries Centre
7th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 819-938-3860
Toll Free: 1-800-668-6767 (in Canada only)
Email: enviroinfo@ec.gc.ca

The following media relations contacts are also available to provide information.

Environment and Climate Change Canada
Toll-free within Canada: 1-888-908-8008
Outside Canada: 1-819-934-8008
Email: media@ec.gc.ca

Health Canada
Telephone: 613-957-2983