Canadian Science Symposium on Plastics Report

November 16, 2018

A Report prepared for:
Environment and Climate Change Canada
Ottawa, ON

This is a "what we heard" report from the workshop facilitator. It is not a comprehensive report and does not reflect the official position of the Government of Canada.

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EXECUTIVE SUMMARY

On November 16, 2018, **Environment and Climate Change Canada (ECCC)** brought together federal government representatives and domestic and international academic experts, including participants of the November 15, 2018, Best Brains Exchange on microplastics[1], to inform the development of a domestic science agenda for plastics, in a one-day Canadian Science Symposium on Plastics.

The Canadian Science Symposium on Plastics offered a unique opportunity to identify science priorities regarding plastics waste and its impacts in order to inform a Canada-wide approach to eliminate plastic waste and reduce plastic pollution.

The objectives of the symposium were the identification of:

1. **Science Gaps and Needs:** Participants were asked to identify and prioritize key science gaps based on the state of science within the four themes outlined below, and what science is needed to advance policy solutions.
2. **Proposed Activities for Moving Forward:** Discussions supported the development of proposals on how to address the aforementioned gaps and needs along the lifecycle of plastics.

The symposium focused on four themes:

1. Monitoring and Detection of Plastics in the Physical Environment;
2. Impacts of Plastic Pollution on Wildlife;
3. Product Design; and,
4. Waste management, Recovery and Conversion.

The day's activities were structured to maximize participation and development of ideas to meet the objectives:

- a scene-setting presentation,
- panel discussion with experts in the four theme areas,
- two break-out sessions, and
- sharing of outputs in plenary.

There was general agreement that a large economic opportunity exists in innovations that keep plastics in the value chain. Participants supported the idea that we cannot wait for our knowledge base to be complete before taking action. In addition, there were recurring mentions of the need for funding to advance research and monitoring in all four thematic areas, as participants underscored the need for investment in science due to many outstanding knowledge gaps.

[1] Canadian Institutes of Health Research Best Brains Exchange (BBE): Ecological and Human Health Fate and Effects of Microplastic Pollution

Standardized methods and monitoring programs were two of the key proposed activities for moving forward in advancing our understanding of plastics impacts in the environment and for human health. In terms of design, it was seen as important to keep in mind the full life cycle, particularly the end of life, for reparability, recyclability, compostability, and energy conversion.

Participants also discussed the global nature of the plastics pollution issue and the importance of learning from and collaborating with the international community.

The symposium was deemed a success by ECCC. Ideas gathered at the Symposium, and from future communications and collaboration, will be used to move forward on a comprehensive Canadian research agenda for plastics pollution.

The table below provides participants' key outputs from the break-out sessions, by theme:

	Break-Out #1: Science Gaps and Needs **Key outputs**	**Break-Out #2: Proposed Activities for Moving Forward** **Key outputs**
Theme 1: Monitoring and Detection of Plastics in the Physical	• Standardized methodologies • Improved access to data and collaborative opportunities	• Greater collaboration and opportunities to advance research and monitoring in a coordinated fashion. • Networks for standardized monitoring
Theme 2: Impacts of Plastic Pollution on Wildlife	• Understanding impacts on the entire food web • Monitoring and quantification of exposure	• Research and monitoring programs at all government levels, and in which stakeholders will take part • Vulnerability assessments
Theme 3: Product Design	• Robust policy and regulatory agenda to focus the research agenda and incentivize innovation • Product designed informed by lifecycle analysis	• Undertake targeted research and innovation on plastic alternatives. • Create networks of researchers from all parts of the lifecycle, and between research and industry
Theme 4: Waste management, Recovery and Conversion	• Research to improve recyclability, conversion and lifecycle analysis • Investigate, communicate and implement strategies to influence consumer and business behaviors	• Create consortia (could be industry-led) to lead on analyses, handling and conversion • Smart policy design to support innovation

INTRODUCTION

On November 16, 2018, **Environment and Climate Change Canada (ECCC)** brought together domestic and international experts from academia and the federal government, and participants from the November 15, 2018 Best Brains Exchange on microplastics, in a one-day Canadian Science Symposium on Plastics.

CONTEXT

Addressing issues surrounding plastic waste is becoming a global priority, and the Government of Canada is actively working to help achieve Canada's G7 commitments for a future with zero plastic waste. Domestically, the Government of Canada is collaborating with provinces and territories, through the Canadian Council of Ministers of the Environment (CCME), to move toward a circular and low carbon economy approach that will keep plastics in our economy and out of the environment.

Science can support decision makers by providing relevant, timely and credible evidence alongside social, economic and political considerations. Scientific research activities are underway by governments, academia, and NGOs in Canada to better understand the movement of plastics in the physical environment, and its impacts on wildlife. In addition, innovative research activities are also taking place across the entire lifecycle of plastics, from product design to end-of-life management, with the aim of reducing plastics waste and the associated impacts.

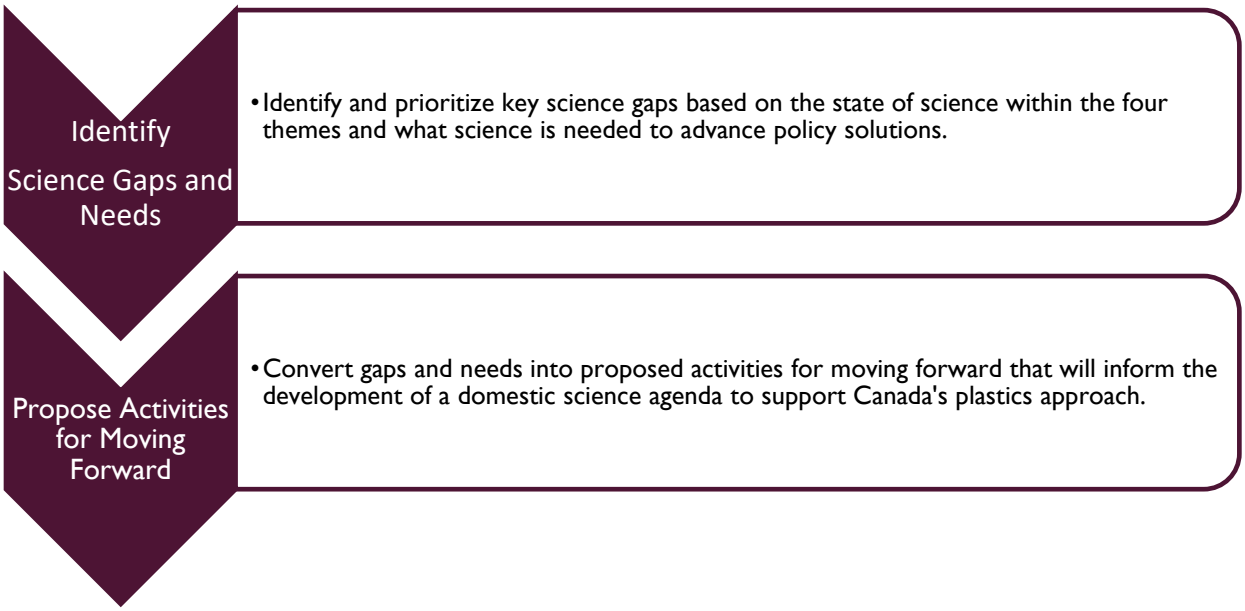
The Canadian Science Symposium on Plastics offered a *unique opportunity to identify science priorities regarding plastics waste and impacts* in order to ensure that Canada has the knowledge to support a circular economy and Canada's Strategy on Zero-Plastic Waste.

PURPOSE

The purpose of the Canadian Science Symposium on Plastics was to share information and take stock of current areas of scientific research to inform the development of a domestic science agenda for plastics that supports the implementation of a Canada-wide approach to eliminate plastic waste and reduce plastic pollution.

OBJECTIVES

The objectives for the day were to fulfil these tasks:



The symposium focused on **four themes**:

1. **Monitoring and Detection of Plastics in the Physical Environment**
2. **Impacts of Plastic Pollution on Wildlife**
3. **Product Design**
4. **Waste management, Recovery and Conversion**

The prioritized gaps and needs will inform the development of a domestic science agenda for plastics that supports the implementation of a Canada-wide approach to eliminate plastic waste and reduce plastic pollution.

BENEFITS OF THE SYMPOSIUM

The symposium was designed to produce multiple outcomes:

1. Building networks and partnerships: The symposium brought together Canadian scientists from a broad range of interest areas and will help foster collaborative opportunities to deliver on priority science needs and increase efficiency in addressing plastics science.
2. Informed decision-making: Key takeaways and recommendations from the symposium will help inform decision making on potential policy options and direct concerted science activities and resource allocations.
3. Support Canada's domestic and international commitments: Discussions from the symposium will help inform Canada's position on plastics science needs to support a national approach and support international initiatives, such as the February 2019 meeting with the European Union on science cooperation to address microplastics.

4. Inform and influence intramural and extramural science activities: A comprehensive internal report of the Symposium will be prepared and made available to federal Departments. A public summary will also be posted on the web and circulated to external participants.

SYMPOSIUM STRUCTURE

The Science Symposium was structured to focus on the objectives of supporting participants in identifying science gaps and needs and proposing activities for moving forward. In particular, the day was made up primarily of opportunities for participants to discuss plastics issues, in small groups and in plenary.

The morning began with scene-setting presentations, followed by a panel discussion on the four themes, then a question and answer period. The rest of the day was comprised of two break-out sessions, sharing of break-out outputs in plenary, and concluding remarks.

During the two break-out sessions, participants worked in small groups. They were asked to note individually their ideas, then to discuss and find commonalities among their group. They then put their outputs to paper, and chose the most important. Participants' top ideas were presented and discussed in plenary.

The panel and break-out session discussions and the written outputs from the small group work form the basis for this high-level report. The written results of the facilitated group work have also been used in this report. Participants are not identified in this report, nor are their comments attributed.

This report includes the following sections:

- A panel discussion with experts under the four themes to help stimulate discussion
- A summary of the outputs from the break-out sessions
- Final comments and next steps
- Key findings

Note: Plenary discussions #1 and #2 took different formats, which is reflected in this report. In the first plenary, the top two outputs of break-out #1 by theme were presented, followed by a discussion. For the second plenary, the outputs of break-out #2 for each group by theme were presented. The outputs from break-out #1 are found in the appendix.

SETTING THE SCENE

The symposium began with a presentation by Helen Ryan, Associate Assistant Deputy Minister, Environmental Protection Branch, ECCC, providing an overview of the drivers of the Government of Canada's approach on plastics, giving context to the day's discussions.

The presentation highlighted the important role Canada has played internationally in plastics, including on science. A key message delivered is that we cannot wait for our knowledge base to be complete before taking action. The need was also emphasized for a multidisciplinary approach, encompassing material and social sciences.

It was communicated that a key area of focus for the Government of Canada is plastics. In particular, there is a drive to decrease marine litter, and that drive can be used as an opportunity to reduce all plastic waste, especially given the large about of terrestrial plastic waste that eventually makes it to the ocean. A key message delivered was that as a nation, we are working toward a circular economy. Increasing awareness and research innovation and shoreline cleanups, all embed in the circular economy we are striving for. We are moving to more sustainable products: reparable, reusable, recyclable.

The Government of Canada has committed by 2030 to a 75% reduction of plastics use by the government. The momentum of interest on plastic pollution is ever increasing: the challenge is to rise to that.

A key point from the Best Brains Exchange from the previous day was re-iterated: that cross-cutting conversations are critical. Also reinforced at the symposium was this sentiment: We can take a precautionary approach, we need to move forward and take action while continuing to pursue science to fill important knowledge gaps.

The need is to keep the value in our economy and out of our environment. Canada was said to be pursuing solutions for plastics all along the value chain, and those solutions will provide a platform for action on the ground.

PANEL DISCUSSION ON THEMES

The panel discussion provided a concise summary of the state of research in specific fields, with a focus on the state of knowledge in each of the four symposium theme areas, and set the stage for the break-out sessions.

PRESENTATIONS BY PANELISTS

The panel discussion focused on several key questions around emerging opportunities and current key findings, science needs, and what areas of science should be prioritized to inform action. Participants also posed a few questions to the panel. Key messages and themes covered by the panel helped to set the tone for much of the conversation to follow. These were:

- Action on plastic waste needs to **consider the entire life-cycle of plastics** and integrate a conversation across design, human behavior, end-of-life, as well as economic and ecological impacts. This could be enabled by tracking plastic as it moves through the economy.
- **Microplastic is found everywhere in the ecosystem**.
- Plastic manufacturing needs to consider entire **lifecycle** and **smart design**, aiming to create products that have the smallest environmental footprint over the entire lifecycle. **Industry needs to be supported with the right conditions** so that they invest in new technology to enable the circular economy.
- There are great **opportunities for citizen science engagement**, and recruiting partners, to get the message out about the challenge we face with plastic in the environment.
- Encouraged the **inclusion of microplastic in water quality monitoring across the country** to see changes through time and policy measures effectiveness.
- More public policy research is needed to find ways to address the plastic pollution problem while **limiting adverse cost effects across the whole system**.
- Designing studies that are **more biologically and ecologically relevant** and looking at experimentation.

PLENARY SESSION ON BREAK-OUT DISCUSSION #1 (PRIORITIZATION EXERCISE)

The plenary session to discuss outputs from break-out session #1 began with presenting the top two science gaps and needs by theme, followed by a discussion and ended with a summary of participants' comments.

For a detailed summary of outputs from this break-out discussion, see the appendix to this report.

TOP SCIENCE GAPS AND NEEDS

To begin the plenary discussion session, the items below were presented, in response to, *Identify and prioritize current and important science gaps and needs in the four themes*:

THEME #1: MONITORING AND DETECTION OF PLASTICS IN THE PHYSICAL ENVIRONMENT

- Standardized methodologies
- Improved access to data and collaborative opportunities

THEME #2: IMPACTS OF PLASTIC POLLUTION ON WILDLIFE

- Understanding impacts on the entire food web
- Monitoring and quantification of exposure

THEME #3: PRODUCT DESIGN

- Robust policy and regulatory agenda to focus the research agenda and incentivize innovation
- Product design informed by lifecycle analysis

THEME #4: WASTE MANAGEMENT, RECOVERY AND CONVERSION

- Research to improve recyclability, conversion and lifecycle analysis
- Investigate, communicate and implement strategies to influence consumer and business behaviors

DISCUSSION AND SUMMARY

Participants discussion branched into several areas, including better scientific coordination in Canada across all environmental components. Comments also highlighted the benefits of focusing on international collaboration for developing standard methods and shared databases, as well as a "Made in Canada" solution because of our unique national challenges of geography and diverse communities. Within the Canadian context, participants felt we need to remember to include indigenous and other small communities where there may not even be recycling programs, yet others pointed out that if we

can make changes in places where the economics are more feasible – our big cities – we will have made a big dent in the problem.

A summary of the discussion was presented:

- We all have a role to play. With the prediction of doubling plastic production in the next 15-20 years, to even just maintain the status quo in terms of the environmental pollution of plastics, we need to half our leakage.
- A gap is an opportunity: for innovation, for success, for research and development, and for Canada to lead in economic terms.
- Moving forward in partnership with industry will be an important factor in success in tackling the problem of plastic waste.

Lastly, a summary of gaps and needs identified during the morning's work, and from the previous day's Best Brains Exchange on microplastics, was presented:

- There is a need for better, stronger analytical tools and standard operating procedures.
- There is a need for improved resources and sharing, to create or support a Canadian community of researchers and knowledge-keepers that would support the sharing of databases, inter-laboratory exchanges, standard QA/QC protocols, etc.
- There is a need for standardized methodologies for monitoring.
- There is a need for monitoring to protect the environment and human health. That means finding key sentinel species.
- Innovation and opportunity: take the crisis and create positive momentum. Make it an opportunity. Harness people's interest and enthusiasm, youth in particular.
- Science and policy experts need to keep talking with one another.
- Plastic research needs to continue, but isn't viewed as a reason for industry and government to wait for cause and effect relationships, or a concrete understanding of harm to humans or the environment.
- Advances should be made in lock step across science and policy: We will do better science, we can proceed with excellent policy, we can take a precautionary approach, we can integrate humans and ecology as we move forward on the policy pathway.
- Keep in mind life cycle analyses, recyclability, the closed loop economy.
- Canada is not alone and yet we have a capacity and interest to create a Canadian spotlight on this issue to focus our efforts and to connect with the international community.

PLENARY SESSION ON BREAK-OUT DISCUSSION #2 (PROPOSED ACTIVITIES)

During the plenary on break-out discussion #2, groups presented their ideas. A "what we heard" summary is bellow organized by theme. Ideas are grouped together, in some cases in categories set by the groups during plenary, and in others formulated to organize this report..

Below are the proposed activities, as reported during the session, grouped by theme, and then into categories.

PROPOSED ACTIVITIES FOR MOVING FORWARD

To begin the plenary discussion session, groups presented their outputs in response to: *Convert gaps and needs into proposed activities for moving forward that will inform development of a domestic science agenda to support Canada's plastics approach*:

THEME #1: MONITORING AND DETECTION OF PLASTICS IN THE PHYSICAL ENVIRONMENT

Convert gaps and needs into proposed activities for moving forward that will inform development of a domestic science agenda to support Canada's plastics approach, in the area of monitoring and detection of plastics in the physical environment:

Opportunities for research and monitoring
• Greater open access to information, data, and international best practices • Increase interdisciplinary and cross-sector collaboration (academia, industry, government) • Use government challenges to try to create R&D momentum within industry • Some funding streams from tri-council, as well as the Northern Contaminants Program. • Opportunity to build on the model of NCP to have a muti-stakeholder forum to help manage the research agenda • Targeted funding, within all sectors, can enable high impact research specific to plastics (versus being opportunistic) (e.g., investments to characterize microplastics). • National monitoring could build on existing networks, focus on centralized data availability, scope an appropriate role for community-led science with standardized methods
Standardized Methods
• ISO and OECD to expand the development of standards for microplastics • A federal initiative focused on developing a standard approach • Adopt an effects-based approach • Clear definitions of what microplastics are • Collect data and documentation on "no effect" • Develop / standardize extraction methods for microplastics

Science Policy initiatives

- Create an overarching body to help coordinate plastics science agenda, coordination internationally through OECD
- Capacity building: put Canada front and centre on the world stage
- Communicate data openly

Coordinate research and share data

- Information exchange: create a community of practice, policy forums or convener task force, to help push things forward faster
    - Open access to data
    - International consensus
    - Incorporate industry
- Create a repository of information
- Establish a research forum through OECD: a global advisory forum.
- Start up a scientific journal on plastics: government-based, but needs some independence
    - Interdisciplinary journal, and lay summaries that would better communicate science to the public to raise the profile of the issue
- Prioritize research needs and move research forward
- Consolidate current knowledge
- Get cross-cutting areas on board

Set up standardized monitoring programs

- Already monitoring air quality across the country – modify to include plastics
- Coordinate a citizen science program, but this needs to be appropriate to certain types of plastics (i.e. microplastic samples can be easily contaminated)
- Enable community engagement with low tech monitoring methods
- Establish standardized monitoring networks
- Develop an approach through other monitoring organizations
- When, what, where, to monitor?
- Develop a life cycle approach to monitoring
- Create a national monitoring program
- Develop field monitoring
- Piggy-backing off programs already in place

THEME #2: IMPACTS OF PLASTIC POLLUTION ON WILDLIFE

Convert gaps and needs into proposed activities for moving forward that will inform development of a domestic science agenda to support Canada's plastics approach, in the area of impacts of plastic pollution on wildlife:

Short-term activities
• Vulnerability assessment: identify areas, species, and populations that are most vulnerable to determine what needs to be monitored and what needs to be researched • Regulations: Prohibition on sources that could affect wildlife • Funding for monitoring: commit and start now   ○ Canada has sentinel species that have been monitored opportunistically on all three coasts – they need to be done in one program
Medium term activities
• Develop an implementation plan, including identifying sentinel species that would be more heavily researched and monitored
Long-term activities
• Research and monitoring programs at all government levels, and in which stakeholders will take part
Leadership
• Federal leadership to implement networks and monitoring • Clarification on jurisdiction • Set up policy framework with checks in place for when monitoring starts
Other
• Map all solutions onto the product life cycle • Citizen scientists: where can they meaningfully contribute?   ○ Microplastics is not a good area for citizen science

THEME #3: PRODUCT DESIGN

Convert gaps and needs into proposed activities for moving forward that will inform development of a domestic science agenda to support Canada's plastics approach, in the area of product design:

Smart plastics
• Targeted research on plastics alternatives, smart design, and products that degrade more efficiently, or degrade into a different material (including full lifecycle analysis, especially end-of-use considerations) • Prize-based challenges to create incentives for plastics alternatives, at multiple levels (governments, industry)
Networks
• Multi-disciplinary research networks: bringing together designers, recycling experts, etc. to the table, to bring the entire community together to discuss opportunities in a positive way • Facilitate more collaboration, internationally and industry-academic. Can help create an international body for standards, particularly in terminology
Policy tools to support innovation
• Regulation can be a tangible driver for moving industry towards smarter design, and investing in needed R&D • Regulations can allow industry to be more open about their processes • Need outcome-based regulation, leaving space for innovation and space and time for industry to get there
Behaviour
• Communications and human behaviour: Driving consumer want for sustainable products

THEME #4: WASTE MANAGEMENT, RECOVERY AND CONVERSION

Collaboration/Consortia
• Collaboration across all areas is important
Waste handling
• Opportunities to advance work on handling, converstion (e.g., energy/thermal recovery, chemical feedstock), and value recovery • Need to understand more the social and behavioural factors   o End of life management criteria to enable waste recovery
Science-policy interface
• Policies that include producer responsibilities. Policy action can be designed to generate revenue to feed back into science and innovation. • Innovation and rules to shift to closed loop industrial processes (i.e., waste becomes input stream).   o Evidence-based regulation of sources that re-introduce microplastic to environment from the waste-stream (e.g., Biosolids from wastewater treatment plants: certified before they can be put on farmer's fields)
Design and lifecycle analysis
• Socio-techno-economic lifecycle analysis covering the first three themes, and include analysis of how people behave, definitions and standards for characterizing and cataloguing materials or plastics • Everybody should be at the table for life cycle assessment policy creation • A label on products showing fraction of recovered plastics, etc. to stimulate public awareness • Look at products – properties and tradeoffs for design parameters

CLOSING REMARKS AND NEXT STEPS

Nancy Hamzawi, Assistant Deputy Minister, Science and Technology Branch, ECCC thanked participants for the energy – creative and innovative – that they put into the day, and stated that participants' ideas and future communications and collaboration will be used to move forward on a comprehensive Canadian research agenda for plastics pollution.

KEY FINDINGS

Canadian Science Symposium on Plastics was well attended by **academics from multiple regions across Canada and internationally, and by federal government representatives**. A diverse range of perspectives was represented, covering the full life cycle of plastics; from design to presence of plastics in the environment, and from ecological impacts to recycling and diversion. Participants came together to **work deliberately across disciplines and sectors** to move science forward in response to commitments made under Canada's G7 Presidency. A key direction provided to participants was **to think big and think outside the box**.

An ECCC representative gave a **Scene-Setting Presentation** that outlined the broad policy context to provide framing for the day's discussions. The presentation highlighted the **important role Canada has played internationally**, including on science. A key message delivered, that was echoed later in the panel discussion is that **we cannot wait for our knowledge base to be complete before taking action**. The need was also emphasized for **a multidisciplinary approach, encompassing material and social sciences**.

Key messages from the day:

- Action on plastic waste needs to **consider the entire life cycle of plastics** and integrate a conversation across design, human behaviour, end-of-life, as well as economic and ecological impacts.
- Research is needed to determine how to consider life cycle and end of life issues **at the product design stage.**
- It is important to consider **leakages through the life cycle**, particularly with respect to waste management, recovery and conversion.
- **Microplastics are found everywhere in the ecosystem** and research needs to consider all environmental compartments (land, freshwater, marine, human health) in an integrated way.
- More public policy research is needed to find ways to address the plastic pollution problem while **limiting adverse cost effects across the whole system**.
- Many participant comments focused on the need for **standardized methods** and the **sharing of data, tools and approaches** to benefit the research community.
- **Funding to support research,** including on informed substitutions for plastics.

- **Clear policy and regulatory direction** to support research and incentivize innovation. It is important to set outcome-based regulations that are not prescriptive but allow industries to come up with innovative solutions to meet established goals.
- Plastic pollution is a global issue and we can learn a lot from **international collaboration** and can benefit from **best practices from across the global.**
- There are opportunities to create **multi-disciplinary, cross-jurisdictional research networks** to foster collaboration internationally and across industry and academia.
- Science communication and public education are crucial to **influencing public behaviour**, and thereby reduce plastic use and to adopt a life-cycle mindset to plastic use.

APPENDIX: OUTPUTS FROM BREAK-OUT DISCUSSION #1

Below are the outputs from break-out discussion #1, in response to:

> *Identify and prioritize key science gaps based on the state of science within the four themes outlined below, and what science is needed to advance policy solutions.*

Outputs were taken from written notes of participants and facilitators. Responses are organized by theme, and have been grouped into categories and duplications omitted.

THEME #1: MONITORING AND DETECTION OF PLASTICS IN THE PHYSICAL ENVIRONMENT

Identify and prioritize key science gaps based on the state of science and what science is needed to advance policy solutions, in the area of monitoring and detection of plastics in the physical environment:

Standardized methodologies

- Methodologies
    - QA/QC, standardized comparable methods (including internationally)
    - Automated/efficient: technologies for ID and characterizing microplastics (source and polymer type)
    - Principles for methods in monitoring/detecting
- Standardization and development of sampling and handling methods (cookbook, compilation of standardized operation procedures)
- Standard reference materials:
    - Standard methods for sampling and analysis
    - Indicator samples
    - Complex lab requirements – clean room, etc.
- Guidelines and Standard Analytical methods for quantification and characterization
    - Characterization of MP (size and shape)
    - Standardization/guideline methods for detection of MP
    - Harmonization of reporting
    - High quality analyses
- Consistent/standardized methodology (How)
    - Detection in complex matrices
    - Linking environmental mixtures to effects
    - Regulatory definitions
- New/updated standardization methods and meta-data access/sharing
    - Method development and advanced technologies for nanoplastic detection and quantification
    - Understanding where monitoring activities should be directed
    - Consistent methods (QA/QC) that are accepted international (i.e. ISO, OECD)
    - Develop technology allowing the detection/identification of the full range of nano and microplastics.
    - Effects at environmentally relevant concentrations.
    - Improve/standardize extraction techniques (biota) or find more efficient ones.
    - Determine what level of polymer ID is needed for monitoring plastics.
    - Data management and consistent methods to allow for data sharing/meta data
    - Need: international networking and partnering to avoid re-inventing the wheel.
    - Use long-term (26 year) GCSC data to determine temporal changes in "leakage." Maintain monitoring locations to detect positive impacts of interventions.
- Toxicology drivers; size, type, etc.; lack of regulation and quality guidelines
- Better tools to characterize environmental microplastics
    - Higher throughput methodologies
    - Lack of capacity in methodology
- Need: funding for method development

Improved access to data and collaborative opportunities

- Open, accessible, National/International reporting system (coordination feeds into this)
    - Databases of spectra/plastic types; sources and product types
    - Establish data sharing and reporting structure
    - Structure data to support policy and management.
- Need for a database of collected information, using a tiered approach (start somewhere)
- Better tools to bring researchers together
    - Data/information sharing
    - Inter-lab exchanges
    - Shared, annotated FTIR spectral library
    - Lack of partnerships
    - Dialogue/exchange on approaches to distinguish on background contamination of samples in the field and lab
- Network: need to engage polymer, spectroscopy, material experts
- Need: facilitated international monitoring research collaboration

Tracking pathways in the environment/ecosystems

- Source tracking and pathways into the environment
    - Devise a classification system based on the types of plastics
    - Relate types/shapes and abundance to specific sources; not broad categories; relate strongly to guidance of management.
- Holistic/ecosystem approach
- Fate/transport processes
    - Major pathways
    - Modeling
    - Accumulation rates based on sediment core data
    - Find main sinks and relate to animals who live in those ecosystems

Monitoring programs

- Coordination/sustained monitoring programs
    - Establish monitoring programs and combine with high throughput analytical protocols, at macro, micro and nano scales; including Arctic monitoring and community-based monitoring.
    - Linkages between plastics pollution and other contaminants, e.g., persistent organic pollutants
- Identify where to monitor to address science gaps and public health/ecological protection
- When/what/where to monitor
- Need for a monitoring program (provincial/national)
- Focus themes for monitoring – value focus
    - Foods
    - Sentinel species
    - Species at risk
    - Children, youth, family engagement in monitoring
    - Drinking water
    - Initiate monitoring of plastics in ecologically and commercially important fish species (finfish and shellfish), both wild and cultured.
    - Monitoring microplastics in the air

Other identified gaps and needs

- Assessment/Policy Development
- Investments in equipment to ensure appropriate instruments are used.
    - More data on freshwater/terrestrial/marine/air:
    - Loads, fate, and effects of nanoplastics in terrestrial environments
- Fate and fluxes in the freshwater environment (rivers)
- Citizen involvement/engagement – is there a role for citizen science?
- Knowledge gap: Micro and nanoplastic behaviours specific to the Canadian climate and environment.

THEME #2: IMPACTS OF PLASTIC POLLUTION ON WILDLIFE

Identify and prioritize key science gaps based on the state of science and what science is needed to advance policy solutions, in the area of impacts of plastic pollution on wildlife:

Understanding impacts on the entire food web

• Fate in the food web: chemical and physical fate
• Ingestion/chemical:
  ○ Cumulative effects of plastics
  ○ Effects in sediments on aquatic food web
  ○ Plastics mixtures vs single chemical effects
  ○ Identifying other environmental contaminants versus plastics
  ○ Understanding acute versus chronic, and potential population level impacts
• Ecological effects
• Quantify exposure
• Indigenous peoples and wildlife interactions
• Ghost fishing gear – risk factors for entanglement, prominence in Canadian waters, awareness and removal

Monitoring and quantification of exposure
• Identifying vulnerable ecosystems, species and populations (what should we focus on) • Sentinel/monitoring species (How? Policy check) • Clear scientific direction and leadership (who?) • Technological barrier: analytical tools for quantifying plastic-derived contaminants in wildlife

THEME #3: PRODUCT DESIGN

Identify and prioritize key science gaps based on the state of science and what science is needed to advance policy solutions, in the area of product design:

Clear vision and leadership on policy direction
• Civil society, industry, government • Product design – need for matchmaking between academic product design experts and companies • Corporate responsibility taken into account • Need for innovative training programs at college/university dedicated to designing products for circular economy • Support key industries relevant to Canada (packaging, auto, ag) • Design with end of life in mind • Select major areas of impact as priority for action • Influence product design toward sustainable choices • regulatory and incentives • consumer education and behaviour • Need for incentives and regulation
Application of life cycle end design principles
• Need bioplastics in product design – supported by socio/economic research on utilization of Canadian feedstocks • Design of packing material from food waste with good barriers/mechanical properties • Ensure product quality, safety, integrity, compostability/recyclability • Consider recyclability of complex mixtures
Innovations in materials
• Plastics that are compostable, distinguishable, and accepted in municipal waste systems with supporting policy research to help achieve this goal • Material science gap – understanding materials and alternatives for plastic products • New technology, lower cost: AI for design and sorting, replacement options, recycling strategies for composite materials • High cost to design new materials/technologies • Research into alternatives • Informed substitution • Impact of factors on use: Safety, duration of use, etc.
Standardized methodologies
• Need identification and quantification of attributes that bring value to customer and environment

- Gap in standard for characterization of plastics and impacts on ecosystems

THEME #4: WASTE MANAGEMENT, RECOVERY AND CONVERSION

Identify and prioritize key science gaps based on the state of science and what science is needed to advance policy solutions, in the area of waste management, recover and conversion:

Policy and communication

- Providing related data to researchers to develop optimization models for minimizing impacts of the recovery process, monitoring costs of recycling
- Regulations to collect waste products separately: paper, plastics, glasses
- Technological economic analysis of plastics for energy conversion for waste material and life cycle analysis
- Policy gap/need: standardization of the practice of waste audits
- Communications: programs are available
- Industrial composting facilities for biodegradable plastics
- Managing non-point source waste
- Standardized municipal collection and recycling processes. Facilities for recycling in Canada
- Public Consultation and Engagement
    - Communications
    - Policy coherence
    - Resources and national strategy

Application of life cycle end design principles

- Circular economy: time lag for handling
- Ability to recycle or manage composite waste (e.g., fibreglass)
- Compound/combined plastics: no means to separate and put back in the supply chain
- Addressing microplastics in organic waste management: brown bins, municipal sludge
- Life extension of industrial plastics, and how to manage the product lifecycle
- Single use items made out of biodegradable plastics and composted.
- Durable items, designed to last many years.

Waste prevention and minimization

- Many initiatives: bags, forks, straws, etc.
- Public awareness increase of amount of plastics being used
- Education gap: increase liaison initiatives to educate consumer/communities

- Changing consumer habits
- Public perception

Avoid plastic waste in the environment

- Collection: Implement stewardship plans, like the ones related to electronics, batteries, and beverage containers
- Recycle: Streamline and standardize municipal recycling programs; improved recycling technology; enhance recyclability
- Recovery: develop industrial composting facilities for biodegradable plastics; build plastics recycling facilities in Canada; Feedstock characterization and standardization; advanced conversion processes to treat plastics in sludge; Standardization of bulk properties for refuse derived fuels; Development of plastic materials that have a high value for energy conversion
- Increase collaboration between waste management practices and those developing conversion processes

Producer and user responsibility

- Waste to be handled at home, not exported
- Waste management can only be well managed from the design/selection of materials in which waste management is one critical criterion
- Divert large-scale waste to be re-used – manage waste in Canada or another well-regulated environment

Lower Environmental Impact

- Climate impact for all solutions
- How to ensure alternatives will have lower impact considering design and end life use
- Will circular economy concept work with plastic waste without greater harm to the environment
- There is potential for chemical recovery using thermal processing
- Energy used to drive circular economy – close the circle

Measuring and monitoring

- Resource traceability
- International trade
- Environmental crimes
- Heterogeneity of waste