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A Canadian policy framework to mitigate plastic marine pollution

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ABSTRACT

Marine pollution from plastic debris is a global problem causing negative impacts in the marine environment. Plastic marine debris as a contaminant is increasing, especially in Canada. While the impacts of macroplastics are well known in the literature, there are relatively few policy studies related to mitigating microplastic toxicity in the environment. Despite overwhelming evidence of the threat of plastic in the marine environment, there remains inadequate or limited policies to address their mitigation, particularly microplastic debris. Existing policies for waste management, marine debris monitoring and awareness campaigns were evaluated from other jurisdictions. Policies and recommendations were developed for the Canadian context. Recommendations include improved practices for: (1) law and waste management strategies; (2) education, outreach and awareness; (3) source identification; and (4) increased monitoring and further research.

1. Introduction

Plastic marine debris pollution is a global problem causing negative impacts in the marine environment. Marine impacts include entanglement or entrapment of seals, turtles and seabirds, ingestion, habitat destruction, transport and bioaccumulation of contaminants [1–4]. Coastal economies may also be impacted with declines in tourism or increased cleanup costs. Fishing, aquaculture, and seafood industries may suffer from poor catches that require increased fishing effort [5]. Additionally, marine plastic pollution may decrease the esthetic appeal of coastal areas [3,6,7].

While societal benefits of plastics are unquestionable, they are highly durable, degrade slowly and create widespread environmental and waste disposal problems [8]. Macroplastics (>5 mm) enter the marine environment via rivers, poor waste management or by being simply dumped into the ocean [2,9]. Degradation of macroplastics into microplastics (<5 mm) has received increased attention recently [10]. Microplastics are the most abundant plastic in the ocean and exist in two forms, primary and secondary [4]. Primary microplastics are tiny plastic granules (e.g., scrubbers in cosmetics), while secondary microplastics are derived from degradation of macroplastics [8]. Marine microplastics are pervasive and ubiquitous with the potential to cause harm to biota [10–13].

1.1. Contaminants associated with plastic

Persistent organic pollutants (POPs) associated microplastics include polychlorinated biphenyls, polycyclic aromatic hydrocarbons, petroleum hydrocarbons, organochlorine pesticides, and bisphenol A [10,12]. POPs at low concentrations in the marine environment are sorbed onto microplastic litter and can accumulate at concentrations several orders of magnitude higher than in seawater [10]. Contaminants are subsequently transferred to marine biota most commonly through ingestion. When ingested by marine species, contaminated plastics present a pathway for POPs to enter the marine food web that can eventually be consumed by humans [12]. Although ingestion of contaminated microplastics by marine biota poses potential ecological risks through bioaccumulation, implications are still poorly understood, because few models exist to predict total pollutant loads introduced by microplastic debris into the marine environment [10]. Overall, the lack of scientific knowledge hinders management strategies or monitoring programs to mitigate marine plastic debris, and microplastics specifically [8,10–12].

The problem of plastic pollution in the oceans is undoubtedly a marine problem that has a land-based solution. Despite being an internationally recognized pollutant, supported by legislation to restrict macroplastic debris entering the marine environment, an estimated 10% (of global plastics), will enter the ocean [8]. However, there are currently no formal management strategies or policies that govern microplastic contamination [4,9].

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1.2. Methodology and approach

In recent decades there have been a proliferation of monitoring studies related to marine debris, most of which comprise >70% plastic items [1,2,14]. A keyword search for "*marine debris*" in international journals such as, '*Marine Pollution Bulletin*' and '*Marine Policy*' yielded 1446 and 90 studies, respectively. While the impacts of macroplastics are well known in the literature, there are relatively few policy studies related to mitigating microplastic toxicity the environment.

Based on the apparent lack of policy studies aimed at mitigating plastic debris accumulating in the marine environment (particularly in Canada), this study was designed to assess current international and national management practices and policies, to better understand macro- and microplastic contamination in the Canadian marine environment. Recommendations for management strategies and policies concerning marine plastic contamination in the Canadian context were explored.

A literature review was conducted to assess current management frameworks and policies. Potential limitations and issues associated with marine plastic (both macro- and microplastic) contamination were highlighted using monitoring studies from across Canada. Based on this preliminary assessment, recommendations were made to support current and future policy on national and regional plastic management strategies. Recommendations to mitigate plastic marine pollution include improved practices for: (1) law and waste management strategies; (2) education, outreach and awareness; (3) source identification; and (4) increased monitoring and further research.

2. Current international policy frameworks for macro- and microplastic contamination

Environmental impacts of macroplastics are well known, with established programs designed to remove macroplastics from beaches, waterfronts, and oceans [1,3,6,15]. However, there are major gaps of scientific knowledge, hindering the development of management strategies for microplastics due to the limited number of studies [8,10–12]. While management strategies for macro- and microplastics are lacking in Canada [4,9], a few global initiatives do exist that further knowledge on plastic contamination, disposal, and pollution prevention. However, because plastics are globally persistent, development of both international and regional management strategies are required to address the issue.

2.1. Prevention of pollution from ships

Although legislation aimed at preventing disposal of waste at sea is limited, the International Convention for the Prevention of Pollution of Ships (MARPOL) Annex V prevents pollution of plastic waste by ships through international agreements and domestic legislation [13]. Some countries have their own domestic legislation (e.g., *US Marine Plastic Pollution Research and Control Act*), requiring all waste to be disposed of or recycled properly on shore, according to local waste management plans [16]. Many ports across North America have also adopted the *Green Marine* environmental program, requiring participants to provide adequate reception facilities at ports for ship generated waste [17]. In addition, shipowners are encouraged to adopt best management practices and implement effective solutions to reduce, reuse and recycle ship generated garbage. Walker et al. [6] found that ~70% of marine debris found in Halifax Harbor was derived from land-based sources, rather than ship-based sources.

2.2. United Nations Environment Programme and National Oceanic and Atmospheric Administration

The United Nations Environment Programme (UNEP) governs the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities, which provides a mechanism for development and implementation of initiatives to address transboundary issues [9,18]. Microplastic and other marine debris issues are addressed by this program. Additionally, UNEP collaborates with the International Oceanographic Commission of the United Nations Educational, Scientific, and Cultural Organization to develop guidelines to monitor marine litter [9].

The National Oceanic and Atmospheric Administration (NOAA) and UNEP developed the UNEP Honolulu Strategy after the Fifth International Marine Debris Conference in March 2011 [3]. The Honolulu Strategy is a global tool with two purposes: (1) to describe and catalyze the multi-pronged and holistic response required to solve the problem of marine debris; and (2) to guide monitoring and evaluation of global progress on specific strategies at different levels of implementation-including local, national, regional, and international efforts and achievements. The strategy has three main goals to reduce pollution from marine debris:

- Reduce amount and impact of land-based litter and solid waste introduced into the marine environment;
- Reduce amount and impact of sea-based sources of marine debris including solid waste; lost cargo; abandoned, lost, or otherwise; discarded fishing gear; and abandoned vessels introduced into the sea; and
- Reduce amount and impact of accumulated marine debris on shorelines, in benthic habitats, and in pelagic waters [3].

The Honolulu Strategy is a framework that can be adapted and implemented worldwide to develop different programs and region specific measures [3]. Examples of region-specific programs developed from this framework include United States Environmental Protection Agency (USEPA) Marine Debris Strategy, and the Global Partnership on Marine Litter (GPML). The USEPA Marine Debris Strategy focuses on three main objectives: land-based prevention, ocean assessment and cleanup, and land-based reduction of marine debris [19]. GPML is a "voluntary open-ended partnership" and outlines seven objectives guided by the Honolulu Strategy with the goal of reducing and managing marine debris [18]. An online Marine Litter Network, demonstration projects, and public-private partnerships have been initiated to implement GPML.

2.3. Non-governmental organizations (NGOs)

Some NGOs also monitor marine debris and promote waste management education practices. The 5 Gyres institution focuses on impacts of plastic marine pollution in five subtropical ocean gyres where plastic accumulates to investigate distribution of microplastics and associated POPs [9]. Through scientific research and community engagement, the institution's goal is to raise awareness and develop solutions through a variety of social media [20].

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) is an organization that "advise[s] the UN's system on the scientific aspects of marine environmental protection" [21]. GESAMP has developed ecological quality standards and outlined standards that vary between countries. Clean Seas Coalition targets Californian seas and beaches, including the North Pacific Gyre. This gyre is the biggest ocean garbage patch in the world. The coalition includes a variety

of stakeholders including environmentalists, scientists, lawmakers, students and community leaders. It attempts to raise awareness of marine pollution and its impacts, and provide recommendations for the state Ocean Protection Council [22].

The International Coastal Cleanup (ICC) is a movement guided by Ocean Conservancy that unites volunteers around the world to clean up aquatic and marine environments. The goal is to strengthen science, engage people in solutions and promote sound policies [23]. The Ocean Conservancy is also a current founding member of the Trash Free Seas Alliance, which "provides a constructive forum focused on identifying opportunities for cross-sector solutions that drive action and foster innovation" [23]. The World Wildlife Fund (WWF) in partnership with the Vancouver Aquarium also holds an annual Great Canadian Shoreline Cleanup (GCSC). The aim of the event is to "promote understanding and education about shoreline litter issues by encouraging Canadians to rehabilitate shoreline areas through cleanups" [24]. All of these NGOs have common approaches, including: increasing awareness, research and monitoring, as well as mitigating plastic pollution in the oceans through improved waste management policies.

3. Current policy frameworks for mitigating plastic pollution in Canada

3.1. Proposed addition of microbeads to Canadian Environmental Protection Act (CEPA) 1999

The Canadian government admits that there are uncertainties about the behavior and fate of microplastics in the environment and researchers have been unable to find a causal relationship between adverse effects in organisms and microbeads [25]. Despite the uncertainty, concentrations of microplastics in the environment are expected to increase through overuse and poor waste management practices [7]. Microplastics account for 94% of global plastic debris items [25]. While microplastics are poorly understood, adverse effects do have short-term and long-term implications. Since microbeads are ubiquitous and have long residence times in the environment, it is likely the continuous release of these substances will result in long-term effects on biological diversity and ecosystem health [25]. Uncertainty surrounding microbeads prompted a declaration to classify them as a toxin under the *Canadian Environmental Protection Act* (CEPA), 1999 on August 1st, 2015 [26]. Declaring microbeads as a toxin under CEPA can establish and enforce preventative measures to mitigate their release into the environment. The order was accompanied by a notice of intent to develop microbead regulations to prohibit the manufacture, import and sale of certain exfoliating personal care products. However, solely focussing on regulations for exfoliation and cleansing products will limit management practices for other products containing similar contaminants (e.g., cleaning products, printer toners and abrasive media) [26].

3.2. Solid waste management strategies in Canada

The majority of law and management regarding marine plastic pollution applies to macroplastics [27]. Managing waste is an ongoing goal across Canada, where citizens are encouraged to sort and recycle waste [28]. Throughout Canada, a four-bin garbage system is used to separate waste. Halifax, Nova Scotia is a leader in waste disposal using this system [29]. Waste reduction, recovery of valuable resources, development of new technologies, and actions to ensure a sustainable future are among the many challenges identified in Nova Scotia's Solid Waste-Resource Management Strategy, which promotes increased recycling of plastics, enforces bans against plastic disposal in landfills, littering, and aggressive waste diversion goals [30]. In 2014, Nova Scotians were required to dispose of waste in a limited number of plastic bags, forcing people to be conscious of waste generation and promoting recycling [29,31].

Halifax also focusses heavily on including waste management in their waterfront development. The four-bin system along the Halifax Waterfront uses solar powered compactors on each bin to reduce costs, frequency and time in collecting the waste, and to free up more space in the bins [32]. These management practices transfers responsibility to consumers and aids in reducing plastic pollution, but enforcement is lacking [29]. Without enforcement, consumers will likely refrain from sorting, reusing and recycling waste.

While there has been some management practices to control macroplastic waste in Canada, microplastic waste management has received little attention. Although, enforcement of macroplastic disposal management is growing, enforcement, knowledge or law around microplastics is lacking. Since microplastic pollution is an emerging topic, many people are unaware of the impacts, making it difficult to force change. The manufacture and sale of products containing microplastics is currently proposed to be banned in Canada, however it only includes microplastics in certain personal care products. The federal government has reportedly admitted that microbeads may also be used in cleaning products, printer toners, industrial products such as abrasive media (e.g., plastic blasting, textile printing and automotive molding), other plastic products (e.g., anti-slip, anti-blocking applications) and medical applications [26]. While primary microplastics may be mitigated through implementation of prohibitions to their use, secondary microplastics can still accumulate in the environment through the degradation of macroplastics [8].

3.3. Education, outreach and awareness

Globally, over 240 million tonnes of plastic are produced annually [12]. Approximately 50% (mostly packaging material) are disposed after a single use. Of particular concern, are plastics that enter the marine environment through indiscriminate disposal. Once in the marine environment, plastics can be detrimental to marine life through entrapment (macroplastic) or potential toxicity (microplastic) [8].

Education, outreach, and awareness are effective ways to promote change to limit indiscriminate disposal [33]. With Canada's large coastline and population, many Canadians have strong ties to the ocean [34]. Promoting and including oceans education and awareness in schools would be a valuable tool to mitigate plastic pollution. By targeting youth habits, practices can be fostered that may indirectly involve ocean protection (e.g., choosing alternatives or practicing efficient waste disposal). Currently, each Canadian province has jurisdiction over their curriculum. Nova Scotia thrives on the ocean for tourism, fishing, and science, all of which heavily impact the standard of living and economy of the province, but ocean education is lacking [34]. High schools have recently introduced an Oceans 11 course, but unfortunately, this is overlooked by academics as it is not considered a prerequisite for post-secondary institutions [34].

A growing number of NGOs in Canada focus primarily on ocean education and awareness. The Oceans Nova Scotia (Oceans NS) organization aims to promote oceans education and awareness in youth. They offer workshops and projects for students to learn more about oceans and associated issues. They also educate youth on how to protect oceans, get involved, and pursue marine related careers. Oceans NS also works with the International Ocean Institute (IOI)-Canada, Department of Labor and Advanced Education, Dalhousie University, Education and Early Childhood Development, and Ocean Technology Council of Nova Scotia [35]. Other organizations in Canada focus on the general population, like the IOI-Canada. IOI-

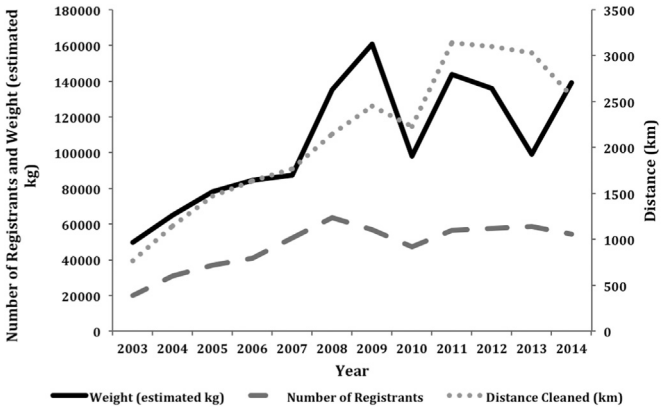

Fig. 1. Overall total distance (km) cleaned, estimated weight of waste collected, and number of registrants for the Canadian Shoreline Cleanup from 2003 to 2014 (adapted from [24]).

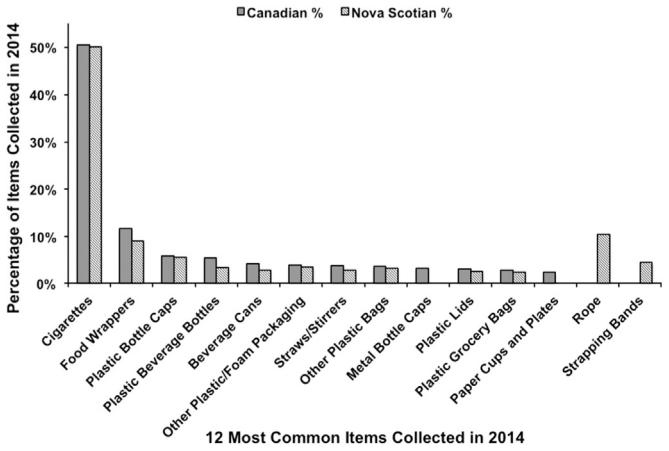

Fig. 2. Percentage of top 12 items collected during 2014 Canadian Shoreline Cleanup for Canada and Nova Scotia (adapted from [24]).

Canada works to "promote responsible ocean governance and the stewardship and sustainable use of coastal and ocean resources in Canada and around the world" [36]. World Wildlife Fund-Canada (WWF-Canada) is currently focusing on improving and enforcing ocean management [37]. In partnership with the Vancouver Aquarium, WWF holds an annual Canada-wide event, the GCSC. The aim of the event is to "promote understanding and education about shoreline litter issues by encouraging Canadians to rehabilitate shoreline areas through cleanups" [24].

3.4. Source identification

Canada has the world's longest coastline (243,797 km), increasing the potential risk for land-based plastic waste to enter the ocean [38]. Through initiatives such at the GCSC, led by the WWF and the Vancouver Aquarium, volunteers across Canada come together to clean up marine debris from shorelines. The types of debris removed from shorelines can then be quantified. WWF further categorizes their data according to province which varies between regions. Since 2003, the amount of waste, distance cleaned, and the number of volunteers has increased overall (Fig. 1; Table 1). Recent data from 2014, indicates that 2563 km of coastline was cleaned, representing only a fraction of the total Canadian coastline (~1%) [24].

After each GCSC, the WWF assesses the collected waste and composes a list of the 12 most common items collected. In 2014, 40% of waste collected from all provinces and territories comprised of plastic (Fig. 2). This is in stark contrast to plastic composition found in other studies (>70%) (e.g., [2,6]). In Nova Scotia, 37% comprised of plastic, including food wrappers, bottle caps, strapping bands, packaging, beverage bottles and plastic grocery bags ([24]; Fig. 2).

While the WWF's GCSC only focuses on macroplastics and covers only a small fraction of the overall Canadian coastline, it provides valuable data to help promote behavioral changes. Ocean Conservancy has a similar yearly event with similar goals to the GCSC, the International Coastal Cleanup (ICC) [23]. Unlike the GCSC, the ICC event is global. In 2014, over 1/2 million volunteers (mostly from developed countries), collected 7,357,616 kg of waste along over 21,376 km of coastline. Common debris items found globally compared favorably to the 2014 GCSC results (e.g., cigarette butts, food wrappers, plastic bottle caps, straws/stirrers, and plastic beverage bottles) [23].

Source identification of these specific items is necessary to mitigate and reduce plastic pollution. Initiatives like the GCSC and the ICC get individuals involved and provides an understanding of adverse effects of poor waste management practices. These initiatives provide information where further management efforts are required by determining types of waste in the marine environment. By using this data, mitigation measures can be implemented to target and reduce specific waste items.

4. Future considerations for macro- and microplastic contamination

4.1. Solid waste management strategies

Globally, successful management of marine debris will require development and implementation of effective policies and

Table 1
Great Canadian Shoreline Cleanup data by province or territory (2014) (adapted from [24,38]).

Province	Total provincial population	Total number of registrants	Total number of sites	Total coastline (km)	Total distance cleaned (km)	Percent cleaned (%)	Total weight of litter removed (kg)	Total number of items removed
BC	4,638,400	22,462	790	25,725	1136	4.4	42,279	469,672
AB	4,120,900	2560	91	–	130.1	–	6670	60,334
SK	1,122,300	807	33	–	39.4	–	942	22,072
MB	1,280,200	1145	25	917	40.8	4.4	1956	11,955
ON	13,677,700	19,205	677	1210	806.4	66	29,617	355,990
QC	8,214,900	3463	117	13,773	168.1	1.2	46,507	75,415
NB	754,600	964	34	2269	64.9	2.8	1835	13,303
PEI	146,200	294	15	1260	35.2	2.8	729	2690
NS	942,400	1303	62	7579	75.6	1	3087	20,826
NL	529,100	660	18	28,956	29	0.1	523	6863
NU	36,100	1140	10	–	23.5	–	4052	11,579
NT	44,000	121	4	161,760	7.5	0.00005	40	5623
YU	37,000	39	4	343	6.5	1.8	1025	1956

measures, supported by international conventions. Decision-makers must give marine debris a higher priority in national and international environmental protection regulations [9]. Designing biodegradable plastics would help ameliorate accumulation of plastic in the marine environment [4]. While MARPOL requires the complete ban of plastic disposal at sea, there remains a lack of enforcement [13]. The Canadian Coast Guard is responsible for monitoring plastic disposal from ships, but when violators are identified, enforcement actions are rarely taken [39]. Furthermore, international conventions only apply to signatories that incorporate the conventions into their own legislation [40]. In Canada, regulations governing the disposal of garbage from ships (including plastic) can be found in the Regulations Respecting the Prevention of the Pollution from Ships and for Dangerous Chemicals. These regulations incorporate content from MARPOL [40]. Despite incorporating international regulations in Canada, enforcement of these regulations are still lacking. Education of enforcement officers would help identify violators and support findings so that violators can be penalized.

Although Nova Scotia Environment has banned disposal of plastics in landfills and littering through the Solid Waste-Resource Management Strategy, there is little enforcement, particularly for microplastics [28]. Household plastic disposal cannot be easily regulated because of inadequate resources for auditing. It is also difficult to determine waste origins in larger multi-industry buildings and apartments. Comprehensive programs to improve waste management need to be implemented [9]. Programs could include improved design and application of single-use plastics, increased consumer awareness and behavioral changes through environmental education, improved recycling and reuse, and the introduction of economic incentives to reduce littering and promote secondary uses of plastic debris as well as enforcement [41]. Additionally, secondary microplastics may be managed by manufacturing more sustainable plastics. The next generation of plastics could be designed to be more biodegradable to decrease their half-life; therefore, decreasing their potential to accumulate in the marine environment and biota [4].

4.2. Education, outreach, and awareness

Education and outreach programs to encourage industry sectors and the general public to modify behavior and assume greater personal responsibility for their actions should be widely adopted [9]. Incorporating ocean education, pollution, and waste management into schools through curriculum changes and events, could be extremely valuable. Targeting youth is an effective way to promote positive change (e.g., choosing alternatives, reuse or proper disposal) [34,35]. Schools can directly incorporate ocean and pollution education into lesson plans, enforce proper waste management, and help increase awareness, like Oceans Day. Whilst some of these national and regional strategies may appear overly optimistic, raising awareness can effect change (albeit incrementally) for this major international and national issue.

All Canadian stakeholders (e.g., citizens, governments, industry and NGOs) must continue to encourage and enforce innovative plastic management practices. Financial budgets and partnerships with organizations could be adjusted to host events, such as shoreline cleanups. These events would raise more awareness, educate, and encourage change. The use of social media can also achieve similar goals using advertisements, photos, stories, and videos to deliver messages quickly to many users [42].

4.3. Source identification

Source identification is invaluable to control and mitigate marine plastic pollution effectively. Identifying common items at sea and along shorelines can help establish specific targets and goals. Further action can then be taken to eliminate these items and/or provide a basis for future research into alternatives. Targets and goals will likely be more specific and will require behavioral change, although most will apply to macroplastics, rather than microplastics.

To understand the most common materials and their extent in the ocean, it would be worthwhile to host more clean up events. While data will be limited to macroplastics, it can provide a representation of the pollution specific to each region. These events will also offer opportunities for public education and involvement. The GCSC and the ICC events will hopefully continue to expand throughout Canada, and the world, covering coastline through increased participation. The GCSC 'Dirty Dozen' list will hopefully inspire people to choose alternatives and be more aware of proper disposal practices.

4.4. Monitoring and future research

Further research concerning sources, distribution, estimated quantities, fate, and potential impacts of plastics in the marine environment, especially microplastics, is imperative [1,2,7,9,43–45]. There is inadequate knowledge of the potential physical and chemical effects on marine biota from microplastics [8,10–12]. Nearly 700 species are reported to have encountered marine debris, and 10% of those had ingested microcoplastics [45]. Research should be focused at local, regional, and global scales because sources, circumstances, capabilities, and mitigation strategies will vary at each level [9]. Further knowledge of plastic composition (through widespread monitoring programs) will help develop concrete policies involving a broad spectrum of plastic contamination and its impacts. Banning microplastics (currently proposed in Canada) will help eliminate them from the ocean. However, it will not be feasible to completely abolish microplastics as there are currently no alternatives for those used in medical applications. Additionally, banning microplastics will not help mitigate secondary microplastic contamination in the ocean because they arise from the degradation of larger plastic pieces. Understanding the composition of plastics found in the marine environment through research will help develop policies that need to be implemented across Canada.

5. Conclusions

Despite existence of numerous international conventions, plastic marine debris is a global problem. This persistent issue demonstrates the lack of effective global, national, and regional strategies to address sources of plastic waste. Additionally, it suggests deficiencies in the implementation and enforcement of existing regulations and standards, some of which may lack financial support. Canada has taken measures through legislation, and enforcement of regional and international agreements to mitigate plastic pollution; however, these initiatives appear to be ineffective.

In order to promote change, implementation of waste management strategies must become a priority. Many management strategies stem from organizations focusing their recommendations and solutions on changes in behavior, such as recycling, and plastic consumption rates. Moreover, the greatest focus tends to be on macroplastics. The use of microplastics continue to be a pressing issue, however, their consequences are largely ignored. To mitigate plastic contamination, law and management strategies must be enforced and improved, the supply and demand of macro- and microplastics needs to be controlled, and it is imperative that proper education and awareness is promoted. Overall, the global

marine plastic pollution issue is ultimately a land-based problem, wherein the solutions will lie.

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