



Reducing marine pollution from single-use plastics (SUPs): A review

Riley E.J. Schnurr, Vanessa Alboiu, Meenakshi Chaudhary, Roan A. Corbett, Meaghan E. Quanz, Karthikeshwar Sankar, Harveer S. Srain, Venukasan Thavarajah, Dirk Xanthos, Tony R. Walker*

School for Resource and Environmental Studies, Dalhousie University, Halifax, NS, Canada



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ABSTRACT

Single-use plastics, or SUPs (plastic bags, microbeads, cutlery, straws and polystyrene) are substantial sources of plastic marine pollution, yet preventable via legislative and non-legislative interventions. Various international legislative strategies have been reported to address plastic marine pollution from plastic bags and microbeads, but these have since been accompanied by recent increasing public awareness triggered by international agencies and organizations. The Sixth International Marine Debris Conference highlighted increasing intervention strategies to mitigate SUP pollution. This study presents new multi-jurisdictional legislative interventions to reduce SUPs since 2017 and incorporates emergence of new non-legislative interventions to mitigate other types of SUPs at individual and private-sector levels that complement or influence legislative interventions. Further, effectiveness of SUP bag interventions (e.g., bans vs. levies) to help reduce SUP marine pollution are presented and range between 33 and 96% reduction in bag use.

1. Introduction

The marine environment has become sinks for vast quantities of anthropogenic marine debris (Kershaw et al., 2011). The most abundant and widespread source of marine debris is plastics, accounting for 60–95% of marine litter (Walker et al., 1997, 2006; Derraik, 2002). Jambeck et al. (2015) estimated 8 million metric tonnes (Mt) of mismanaged plastic waste entered the oceans in 2010. Over 300 million Mt. are produced annually, but 50% are discarded after a single-use (Geyer et al., 2017). Single-use plastics (SUPs) can include plastic bags, microbeads, cutlery, straws and polystyrene (including cups and food containers) which are substantial sources of marine pollution (Xanthos and Walker, 2017). Plastic is highly durable, potentially taking centuries to degrade, and is considered hazardous due to release and sorption of contaminants (e.g., endocrine disruptors and persistent organic pollutants) (Teuten et al., 2007; Rochman et al., 2013; Napper et al., 2015; Wang et al., 2016). Although plastic marine pollution was reported decades ago, it has only recently been recognized as a pervasive global issue (Andrady, 2011; Eriksen et al., 2013, 2014; Jambeck et al., 2015; Walker, 2018a).

Plastic marine pollution comprises both macro- (> 5 mm) and microplastics (0.1 µm to < 5 mm) (Thompson et al., 2004). Macroplastics enter marine environments via rivers, dumping or poor waste management, harming wildlife from entanglement, ingestion or habitat destruction (Barnes et al., 2009; Vegter et al., 2014). Microplastics

include primary microplastics (e.g., microbeads) and secondary microplastics (e.g., small plastic fragments derived from degraded macroplastics, such as plastic bottles) (Pettipas et al., 2016). Although microbeads were first created by Dr. John Ugelstad in the 1960s, they were not widely used in as exfoliants in personal care products and in cosmetics until the 1990s (Environment Canada, 2015). Microbeads are also used in cleaning products, printer toners, industrial products such as abrasive media (e.g., plastic blasting, textile printing and automotive molding) and medical applications (Pettipas et al., 2016). Microplastics are the most abundant plastic in the ocean and approximately 8 trillion microbeads are released into wastewater daily, making them difficult to remove from aquatic environments (Cole et al., 2011; Rochman et al., 2015a, 2015b). Microplastics accumulate in ocean gyres and have been found in remote aquatic and marine environments (Baldwin et al., 2016; Hurley et al., 2018). Rochman et al. (2015a) suggested microplastics pose a greater threat than macroplastics due to their ingestion by marine organisms, such as filter-feeding bivalves (Mathalon and Hill, 2014).

Microplastics could also cause human health impacts due to consumption of microplastic contaminated foods, with potential effects mainly associated with toxicity of chemicals that are sorbed from the environment or additives that are used in the plastic materials themselves (UNEP, 2015; GESAMP, 2016; Karbalaei et al., 2018). Marine plastic pollution has justifiably become an important global issue for citizens, governments, academics, and non-governmental organizations

* Corresponding author.

E-mail address: trwalker@dal.ca (T.R. Walker).

(NGOs) (Seltenrich, 2015). Economic and aesthetic impacts of marine plastic debris are vast and the global estimate of damage to marine ecosystems caused by plastic amounts to at least USD \$13 billion annually from lost tourism revenues due to adverse impacts on recreational activities and navigation (Raynaud, 2014; Borrelle et al., 2017). In the Asia-Pacific region alone plastic debris costs tourism, fishing and shipping industries roughly USD \$1.3 billion annually and in Europe, removal of plastic debris from coastlines costs approximately €630 million each year (UNEP, 2018a).

In 2011, the Fifth International Marine Debris Conference (5IMDC), developed the *Honolulu Strategy*, an international framework to reduce marine plastic pollution (UNEP and NOAA, 2015; Pettipas et al., 2016; Walker, 2018a). Strategies from the *Honolulu Strategy* include market-based instruments (e.g., levies on plastic bags) for waste minimization or implementing policies, regulations, and legislation to reduce marine debris (e.g., imposing outright bans on various SUPs) (Xanthos and Walker, 2017). Since the *Honolulu Strategy*, UNEP (with support from 42 governments), declared a fight against plastics, announcing their global CleanSeas campaign on February 23, 2017 to eliminate major sources of marine debris by 2022 (UNEP, 2017a, 2017b). On January 16, 2018 the European Commission (EC) adopted the first-ever Europe-wide strategy on plastics, transitioning towards a more circular economy (EC, 2018a, 2018b; Liu et al., 2018). All plastic packaging in the European Union (EU) must be reusable or recyclable by 2030, and use of SUPs including straws, cutlery and microplastics will be restricted (EC, 2018a, 2018b).

Following China's ban on importing recycled film plastics, interventions have intensified across developed countries (Walker, 2018b). Many countries and jurisdictions have already successfully implemented bans of SUP bags (Xanthos and Walker, 2017). Some recent studies on the efficacy of bans or levies of SUP bags have been encouraging. For example, the 2002 levy (€0.15) in Ireland resulted in an immediate reduction (~90%) in SUP bag use. Similarly, in Wales, SUP bag consumption declined by 71% between 2011 and 2014 (when a five pence levy was introduced in October 2011), which was corroborated in 2012 by the Welsh Government, who suggested that SUP carrier bag use in Wales had reduced 96% since the levy was introduced (Welsh Government, 2016). However, few countries have data available related to the effectiveness of bans, mainly because many have been implemented only recently. According to UNEP (2018a), in countries that do have data, about 30% have reported dramatic reductions in SUP bag use within the first year. Bans, partial bans, and fees have been implemented across local jurisdictions (e.g., North America), but national approaches have also been undertaken (e.g., across Europe). Some national bans on microbeads have been implemented. For example, the Canadian government classified microbeads as a toxin under the *Canadian Environmental Protection Act* and banned single-use toiletries and cosmetics containing microbeads from stores in July 2018 (Walker and Xanthos, 2018).

National interventions to ban other SUPs (e.g., plastic straws, cutlery, bottles and polystyrene) are gaining momentum, and are being led by Costa Rica, Taiwan, Belize and India (Surfrider Foundation, 2016; Independent, 2017a; World Economic Forum, 2017; Lonely Planet, 2018; Taiwan News, 2018; Waste Dive, 2018; UNEP, 2018a). However, most plastic straw and cutlery bans are being implemented across local jurisdictions, with US states such as California and Florida leading jurisdictional legislative initiatives. Non-legislative efforts also raise awareness about marine pollution and help persuade governments to take legislative action. International and national marine debris monitoring by The International Coastal Cleanup (ICC, 2018), NOAA Marine Debris Program (NOAA, 2018), and the Great Canadian Shoreline cleanup (GCSC, 2018), categorize debris items to help inform policy related to SUP interventions (Pettipas et al., 2016). Campaigns such as “Straw Wars”, which started in Soho, London in 2012, was one of the first anti-straw initiatives comprising a growing coalition of voluntary commitments to ban or reduce straws at food and beverage outlets (The

Guardian, 2012). For example, the most common items collected during international coastal cleanups comprise of SUPs and include, cigarette butts, plastic beverage bottles, plastic bottle caps, food wrappers, plastic grocery bags, plastic lids, straws and stirrers, and foam take-away containers (ICC, 2017). These international SUP debris categories are consistent with those from individual countries, such as Canada (Pettipas et al., 2016).

To date, few studies have examined global interventions related to reducing SUPs in the marine environment. A review by Xanthos and Walker (2017) documented international policies to reduce plastic bags and microbeads, but other international interventions have increased dramatically along with emergence of non-legislative interventions to mitigate other SUPs.

There are multiple strategies to reduce SUP entering our terrestrial, aquatic and marine environments. These will all need to work in combination together to achieve positive impact and will have to be modified depending on demographics and location (see UNEP, 2018a). For the purposes of this study it is assumed that all SUP strategies, either directly or indirectly, will help reduce marine pollution. The Sixth International Marine Debris Conference (6IMDC) in San Diego, California, in cooperation with NOAA and the United Nations Environment Programme (UNEP), provided a forum to discuss current research to reduce marine plastic pollution, including emergence of legislative and non-legislative interventions to mitigate SUPs (Walker, 2018a). This study: (i) highlights new legislative and non-legislative interventions since 2017; (ii) describes other SUP interventions (e.g., straws, plastic cutlery, polystyrene and cups); and (iii) describes effectiveness of legal frameworks to help reduce marine pollution.

2. Methods

Current international market-based interventions for banning, adding taxes, fees or levies on SUPs, not previously described in the academic literature, were reviewed. A systematic literature review of peer-reviewed journals, news articles, government, and NGO websites was conducted using ProQuest, ScienceDirect, Web of Science and Google Scholar. Information was also gathered from 6IMDC delegates, to assess current policies. Search terms included: “microbeads”, “plastic bags”, “single-use plastic(s)”, “plastic straws”, “national policies”, “legislation”, “bans” or “taxes”, among others. Searches were also conducted using social media by following 5 Gyres (<https://www.5gyres.org/>), UN Environment Clean Seas (<http://www.cleanseas.org/>), Surfrider Foundation (<https://www.surfrider.org/>), Ocean Wise (<https://ocean.org/>), and other media. Legislative or non-legislative interventions were cross referenced and corroborated using more than one primary source (e.g., online news articles), and referenced herein.

Methods used by Xanthos and Walker (2017) for plastic bag legislation at multi-jurisdictional levels were followed. New and updated interventions for plastic bags and microbeads since the first review (to March 31, 2018), along with other new SUP interventions are presented. These include some limited non-legislative interventions, to highlight efforts made by stakeholders (e.g., NGOs and private sector) which are described in this study to help reduce marine plastic pollution. Effectiveness of plastic bag interventions were assessed and recommendations to support policies on global SUP reduction and areas for future research were identified. Although this study did not document interventions after March 31, 2018, it is recognized there has been a proliferation of new announcements, many of which can be found in UNEP (2018a).

3. Results and discussion

3.1. Government bans of SUP items

3.1.1. Plastic bag interventions

Interventions began in the 1990s but have since evolved and

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