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Prevention through policy: Urban macroplastic leakages to the marine environment during extreme rainfall events

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ABSTRACT

The leakage of large plastic litter (macroplastics) into the ocean is a major environmental problem. A significant fraction of this leakage originates from coastal cities, particularly during extreme rainfall events. As coastal cities continue to grow, finding ways to reduce this macroplastic leakage is extremely pertinent. Here, we explore why and how coastal cities can reduce macroplastic leakages during extreme rainfall events. Using nine global cities as a basis, we establish that while cities actively create policies that reduce plastic leakages, more needs to be done. Nonetheless, these policies are economically, socially and environmentally cobeneficial to the city environment. While the lack of political engagement and economic concerns limit these policies, lacking social motivation and engagement is the largest limitation towards implementing policy. We recommend cities to incentivize citizen and municipal engagement with responsible usage of plastics, cleaning the environment and preparing for future extreme rainfall events.

1. Introduction

Plastic is increasingly prevalent in the world's oceans. An exact estimate for the amount of plastic in the ocean is unknown, but the amount floating at the surface of the ocean is at least 93 thousand tons (van Sebille et al., 2015). However, estimates for the amount of plastic waste entering the ocean are significantly higher. Jambeck et al. (2015) estimate that coastal countries produce 275 million tons of plastic waste annually, releasing 4.8–12.7 million tons into the ocean, while the Ellen Macarthur Foundation (2016) estimates that of the 78 million tons of plastic packaging produced, 32% leaks into the environment, (roughly 25 million tons) some of which ends in the ocean. A significant fraction of this plastic could be on coastlines. In 2015, the International Coastal Cleanup programme collected nearly 8.2 thousand metric tons of trash on over 40,000 km of coastline globally (ICC, 2016).

This ocean plastic is harmful to marine life, through deformation, maiming, suffocation and death (e.g. Derraik, 2002; Gregory, 2009; Rochman et al., 2015). Furthermore, plastic can help spread invasive species and release toxic chemicals into the environment (Thompson et al., 2009; Kwon et al., 2015; Zettler et al., 2013;). Because biological diversity and species abundance tends to be highest near coastlines, plastic does most harm there (Wilcox et al., 2015; Schuyler et al., 2016; Sherman and van Sebille, 2016), often close to where the plastic enters the ocean.

Marine plastic not only harms marine life, but also impacts our ability to interact with the coast. Potential decreases in marine biota would directly affect the fisheries economy. The tourism industry is also influenced by the presence of coastal plastic on beaches. Ballance et al. (2000) estimate that a loss in the standards of cleanliness on the beaches in Cape Town would result in a 97% loss in the value of those beaches. In Geoje Island, Korea, following an extreme rainfall event in 2011 marine debris cost the island US$29–37 million in tourism losses (Jang et al., 2014). Marine macro-plastics are unsightly and detract from the inherent value of the world's coastlines.

The shoreline does not act as an unlimited plastic sink. Plastic may degrade on the beaches due to chemical and physical erosion and be washed back into the oceans (Cooper and Corcoran, 2010; Corcoran et al., 2009). Plastic found on the shore is seasonal in its input. During rainier seasons, more plastic debris is flushed from land to the sea (Silva-Cavalcanti et al., 2009; de Araujo and Costa, 2006). While the rainy season is more prevalent in the tropics, extreme rainfall events occur across the globe.

Human behavior and policies on land affect the amount of plastic in the oceans. Littering and poor waste management, stormwater discharge, and extreme events such as floods and landslides are large terrestrial sources of marine debris (NOAA, 2016). From inland, the

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Table 1
A selection of international and regional policy agreements targeting marine debris and plastics. Source: UNEP, 2005; Allsopp et al., 2006; Gold et al., 2013; Carroll, 2014.

Date	Policy/Legislation	Purpose
1973/78	International Convention for the Prevention of Pollution from Ships (MARPOL)	Annex V species to prevent the dumping of plastic while at sea and for ports to have adequate facilities to handle waste
1972	London dumping convention	Targets the dumping of land-based waste deliberately at sea
1976	Barcelona convention	Targets the dumping of plastics in the Mediterranean from land and marine sources
1982	UN Convention of the Laws of the Sea (UNCLOS)	Targets the prevention, reduction and control of pollutants in the oceans from land and marine sources
1983	Cartega convention	Targets the dumping of pollutants in the Caribbean from land and marine sources
1992	Helsinki convention	Targets pollution from all land and marine sources
1992	OSPAR	Targets pollution into the North East Atlantic from land and marine sources
1995	FAO code of conduct for responsible fisheries	Targets the management of fishing gear
1995	UNEP global programme of action for the protection of the marine environment from land based activities	Targets pollution from rivers, estuaries and storm drains
2000	EU port reception facilities for ship-generated waste and cargo residues directive	Targets pollution from waste at ports
2005	UN resolution S/60/L.22	Targets the integration of marine debris into national waste management
2008	UN resolution A/60/L.3	Targets the creation of new strategies to tackle lost or abandoned fishing gear
2008	EU marine strategy framework directive	Targets litter in all EU seas based on source and type
2009	UNEP global initiative on marine litter	Creation of twelve regional seas to target marine litter at a regional level. Ties in with the UNEP Regional Seas Programme
2011	Honolulu strategy	Targets the management and monitoring of marine debris. Framework for application
2012	Rio + 20	Targets a reduction in marine debris by 2025
2012	Manila declaration	Targets the reduction of pollution from land-based activities
2012	Global partnership on marine litter	Targets the reduction of land and marine sources as well as reduce impacts on habitats

debris travels to the oceans via wind and water, while human activity on the coast creates direct inputs of marine debris. In 2002, 58% of the debris collected in the International Coastal Cleanup was attributed to shore-line and recreational activities (Allsopp et al., 2006).

In cities, street litter is not only unsightly but also expensive to cleanup. England spends £1 billion annually to clean up the 30 million tons of litter generated (Keep Britain Tidy, 2013) and the USA spends upwards of $11 billion annually to clean up litter (NC DPS, 2016). Yet, litter persists; upwards of four trillion cigarette butts, which are frequently made of the plastic cellulose acetate, are improperly disposed of globally every year (ASH, 2015).

Globally, better waste management is a focal point in reducing plastic in the environment. However, there are instances when day-to-day waste management will not suffice in stopping plastic leaking into the ocean. For example, in the immediate aftermath of a tropical storm, resource management is focused on human health, toxic spills and air quality (Institute of Medicine, 2007) as opposed to waste management. Yet, debris including plastic flushes into the ocean during these extreme rainfall events. There is a gap in our understanding of debris and plastics management in the coast and ocean immediately following disaster and extreme rainfall events.

As urban environments grow, stormwater management will become more important. In addition, it is projected that extreme rainfall events will increase due to climate change (PIK, 2015; IPCC, 2013; U.S. Climate Change Science Program, 2008). An increase in extreme rainfall events is likely to stress our current stormwater management systems and thus there is an increased potential for plastic to spill into the ocean. Extreme rainfall events only represent a portion of plastic that leaks into the marine environment, however, their growing frequency offers an opportunity to make infrastructure and economic investments to prepare for these events. In addition to removing plastic from the ocean, reducing urban plastics can be co-beneficial for the overall urban environment. Therefore, this study asks the following question: "*Why and how could coastal cities reduce urban plastic leakages due to extreme rainfall events?*"

This study aims to establish how coastal cities reduce plastic leakages and why these initiatives are beneficial to the city system using the following nine case cities as a basis for discussion: Vancouver, New York City, Miami Beach, Sydney, Singapore, Hong Kong, Rio de Janeiro, Copenhagen and Mumbai. It attempts the following four objectives:

- To evaluate the current policy towards urban plastic management across the globe
- To establish the co-benefits of reducing urban plastic in extreme rainfall events
- To evaluate the limitations towards implementing these policies
- To make recommendations for cities experiencing a projected increase in extreme rainfall events

In Section 2, we discuss the legislation regarding plastics and the ocean from the international, national and local levels. In Section 3 we examine the initiatives coastal cities can undertake to combat plastic leakages to the ocean before moving on to the research method in Section 4. In Section 5 we discuss the results found in our case cities. In Section 6, we discuss the co-benefits of implementing these policies before examining the limitations to these policies in Section 7. Finally, in Section 8 we list recommendations for policy makers to minimize plastic leakages to the ocean.

2. International agreements and policy

2.1. Global agreements

Since the late 20th century there have been international efforts to curb the amount of marine debris in the world's oceans. These agreements underline crucial global issues and efforts and often lead to the creation and enforcement of policy at the national and local levels. In the 2015 G7 summits, the health of the ocean was one of the three key issues of global importance (G7 Germany, 2015). Table 1 lists a selected few international and regional policies from the 1970s-2012. Some of the largest and most impactful agreements have been MARPOL Annex V (shipping waste) and UNCLOS (marine pollution). Both of these conventions are over 30 years old and are limited in their scope. As monitoring is difficult throughout the ocean, in addition to the complicated legalities of international waters, MARPOL is often ignored (Allsopp et al., 2006) and countries create exemptions to the regulations, as the USA has done for their naval vessels (Gold et al., 2013). Furthermore, these conventions are not always practical. MARPOL has denoted special seas where no dumping can occur but regions such as the Caribbean, without appropriate port facilities, can't adhere to these rules (Allsopp et al., 2006).

If signatories of MARPOL Annex V suspect foreign ships of breaking