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Review

Collected marine litter — A growing waste challenge

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ABSTRACT

Marine litter, in particular plastic debris, poses a serious threat to marine life, human health and the economy. In order to reduce its impact, marine litter collections such as beach clean-ups are frequently conducted. This paper presents a systematic review of temporal developments, geographical distribution, quantities and waste treatment pathways of collected marine litter. Results from over 130 studies and projects highlight the worldwide increase in collection efforts. Many of these are in wealthy countries that do not primarily contribute to the problem. Over 250 thousand tonnes, have already been removed, but there is little or no information available regarding how this waste is treated or used post collection. This paper highlights the need for a whole-system quantitative assessment for the collection and waste treatment of marine litter, and identifies the challenges associated with utilising this waste in the future.

1. Introduction

Possibly the biggest landfill of our planet is the ocean. It accumulates various types of waste, called marine litter. This includes metals, glass, ceramics, textiles, paper and timber. Yet, the largest and probably most harmful fraction of marine litter is plastic debris. It is estimated that every year between 4.8 and 12.7 million tonnes of plastic waste enter the ocean from land-based sources alone (Jambeck et al., 2015). The high input is linked to plastics durability and lightweight which allows it unlike other types of marine litter to be easily transported via wind, waste water and rivers when it has been littered or inadequately disposed (Li et al., 2016). This is not only true for macroplastics but also for microplastics from e.g. car tire wear, clothes washing (Browne et al., 2011) and cosmetic products (Napper et al., 2015; Sherrington et al., 2016). Marine litter also originates from sea-based activities for example when fishing gear or cargo is lost, abandoned or discarded despite international legislation that prohibits the dumping of waste at sea (MARPOL (International Convention for the Prevention of Pollution from Ships), 1988; Jones, 1995).

Inside the ocean, marine litter is found in all seven ocean compartments: biota, coastlines, at the sea surface and the seafloor as well as in sediments, sea ice and the water column (Law, 2017; Fig. 1). The contact with biota has been reported in 44 thousand reported cases of entanglement and ingestion affecting up to 1400 marine species worldwide (Gall and Thompson, 2015; Tekman et al., 2017a). Marine litter can also lead to a decline in tourism when washed ashore on beaches (McIlgorm et al., 2011; Keswani et al., 2016), destroy corals at the seafloor (Kühn et al., 2015), spread invasive species (Kiessling et al., 2015) and cause accidents with ships (Cho, 2005). The plastic fraction of marine litter can be particularly harmful because it is able to travel over long time and distances before breaking down into smaller fragments (Andrady, 2011). Microplastics can then adsorb and release chemicals (Li et al., 2016), which become bioavailable after ingestion. This is also a risk for humans because these substances can accumulate along the biological food chain (Li et al., 2016).

On a political level, the United Nations Development Goals demand that the majority of countries worldwide “prevent and significantly reduce marine pollution” by 2025 (United Nations General Assembly, 2015). This may be achieved by implementing the increasingly popular framework of a closed-loop and resource efficient Circular Economy, as alternative to the established linear take-make dispose economy (Lieder and Rashid, 2016). The European Union has set this in motion in their “Action plan for the Circular Economy” implementing a waste hierarchy in which prevention, reuse, recycling and energy recovery are favoured over landfill in this respective order (European Commission, 2015). While this may help to reduce the input of waste in the long run, in the meantime the collection of marine litter is essential to reduce its stock and impact in the ocean.

Reviews of marine litter collections are frequently undertaken (Li et al., 2016; Keswani et al., 2016; Iñiguez et al., 2016; Browne et al., 2015; Barnes and Milner, 2004; Derraik, 2002) but there is no published quantitative overview describing the output of the various collection efforts (Law, 2017). Also, such reviews traditionally adopt an upstream perspective that focuses on input reduction and the impact of

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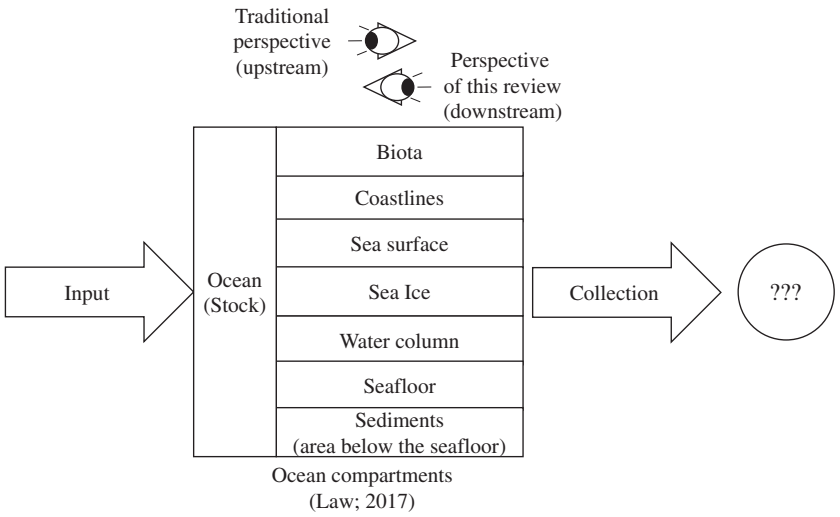

Fig. 1. Marine litter flow and perspective of this review.

marine litter in the ocean rather than downstream activities for the collected litter (Fig. 1; but see Iñiguez et al., 2016). Yet, the investigation of collection and further downstream pathways is crucial to understand the full environmental impact of marine litter which is a necessary input to policy-making in this area.

This study reviews current literature relating to the collection of marine litter, and uses the findings to support a case for greater systems thinking and a fuller life cycle perspective towards collection and downstream treatment activities. This would enable both collection and treatment approaches to meet the Circular Economy and Sustainable Development Goals. It identifies where current gaps lie which currently prevent us from developing a full systems approach, and specifies what further data would be needed to progress this.

2. Materials and methods

2.1. Literature search

Based on the mode of collection the literature has been divided into two groups: scientific and non-scientific collections. Scientific collections are studies that describe the typically very structured collection process in detail so that studies can be repeated and compared. For example, Alshawafi et al. (2017) marks several transects on a beach before starting the collection. Non-scientific collections on the other hand are result focused clean-up projects that do not commonly describe the collection process in detail.

2.2. Scientific collections

The literature search for scientific collections was based on peer-reviewed publications from the database Scopus using the title keywords “ocean”, “sea” or “marine” in conjunction with “plastic” or “debris”. After removing duplicates, 254 accessible articles published between January 2013 and April 2017 were evaluated in order to identify publications in which marine litter had been removed from the marine environment. Errata and reviews were excluded as were other publications when their methods section did not describe the marine litter collection protocol. This resulted in 103 publications.

2.3. Non-scientific collections

The search for non-scientific collections was based on references from the reviewed literature described above, the Global Ghost Gear Initiative (http://www.ghostgear.org/) and MARELITT (http://www.marelitt.eu/). The scientific publications and the Global Ghost Gear Initiative linked to individual removal projects worldwide whereas MARELITT had a focus on Europe specifically. In total 58 projects were identified for which a more detailed internet search was performed. For credibility, information was only taken from published documents and not from websites directly which gave 29 results.

2.4. Data extraction

From the 103 scientific and 29 non-scientific collection projects data about the (1) removal period, (2) location, (3) ocean compartment, (4) removed quantity, (5) collection method and (6) waste treatment was extracted. Subsequently, this data was sorted in a descending order based on the quantity collected (Appendices 1 and 2). When projects described multiple collections, data about the removed quantity and collection method were taken separately for each represented ocean compartment. This leads to 114 and 32 rows of data entries for the scientific and non-scientific collection projects respectively (Appendices 1 and 2).

2.5. Assumptions and limitations

Where a publication focused on derelict fishing gear and did not state otherwise it was assumed that the collection took place from the seafloor. Some publications give information in multiple formats, for example, by weight and by volume. To avoid double counting in these situations only one unit was extracted, giving priority in the order of: (1) weight, (2) item counts and (3) volume. For scientific collections from the coastline it was assumed that the collection was conducted manually if not otherwise specified.

This review is clearly limited to the approach and databases taken for the literature search. The approach focuses on marine litter collection but not on waste treatment pathways. Therefore such literature was excluded. The database Scopus has an emphasis on scientific studies but it has to be noted that the majority of marine litter is not reported in academic journals. Therefore other references, including the Global Ghost Gear Initiative and MARELITT were included, but this only provides a snapshot of the marine litter collections worldwide.

3. Results

3.1. Historic development

The starting date of the scientific and non-scientific collection projects indicate an increase of removal efforts over the last decade (Fig. 2). This is possibly a response to the overall rise of awareness