Plastic marine litter- Stop the leakage now!

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Marine litter damages ecosystems, and marine-based economic sectors such as tourism and fisheries. It also impacts upon other aquatic environments that are vital for human societies, such as rivers. The extent of marine litter is now global, with plastic particles having been detected in all of the world's oceans - even the most remote and untouched environments – and it has entered the food chain.

It is estimated that between 4.8 and 12.7 million tonnes of waste plastic was released into the marine environment from costal populations in 2010 (Jambeck *et al*, 2015). A further 1.2 to 2.4 million tonnes of plastic is estimated to reach the oceans from inland sources via rivers (Lebreton *et al*, 2017) To put this in perspective, approximately 380 million tonnes of plastic resins and fibres were produced in 2015 of which about 275 million tonnes is thought to have become waste (Jambeck *et al*, 2015) suggesting that, at the very least, 2% of total plastics production is 'leaking' into the environment each year.

Due to the poor quality of underlying data and the necessity to make a number of simplifying assumptions, these figures can only be considered to be order-of-magnitude estimates. Overall, the scientific community has an incomplete understanding of the sources and flows of waste plastics into the environment and, in particular, implications of material properties, consumption patterns and littering behaviours on solid waste generation.

Key land-based sources of plastic marine litter are numerous and include plastics leaking into the environment as a result of: uncontrolled dumping of waste from municipal sources (organised and unorganised dumping, fly tipping) – a significant problem in the Global South, with direct dumpling into rivers or at/by the sea; littering by members of the public (e.g. through tourism, major public events, or in busy areas of cities). And even some limited escape of plastics from existing waste management activities during transport, handling, treatment or disposal.

Four key systemic failures, related directly to the waste and resources management sector, are considered as major contributors to the plastic marine litter problem: the continuous growth in use of thousands of different forms of plastics in each and every aspect of our daily lives; poor or absent solid waste management services and infrastructure (mainly in the Global South), and insufficient monitoring & law enforcement (mainly in the Global North); problematic and vulnerable markets for secondary plastics, resulting in poor and very fragile incentives for material recovery; and, lack of a systemic and in-depth understanding of the technical and economic challenges related to plastics, the effects of social consumption patterns and littering behaviours on solid waste generation, the impacts of unplanned tourist developments and of the fishing industry.

Under this framework this paper does not seek to reiterate the case for action on marine litter. That case has been made effectively and at length by many researchers, practioners, policy makers and activists. Instead, this paper provides a review of the current level of understanding of the issue and explores how the waste and resource management sector can tackle marine plastics. The sector has a key role to play in making a step-change from the current situation, where the vast majority of plastics are used once - with much of this material escaping the system - to a system based on the principles of circularity, where the use of plastics is minimised and those that are used are collected and cycled back into the system as valuable raw materials. In addition, the paper presents an overview of our current understanding of marine litter issues in terms of its sources, pathways, transformations and fate.

In order to prevent plastic marine litter a number of immediate, mid-term and long-term actions that need to be prioritised, designed and implement on local, national and global level are introduced. More specific according to the authors investing in effective waste management in the Global South is likely to represent the most cost-effective and immediately practicable solution to reducing marine litter in the short term. Furthermore, there is a need to significantly reduce the 'leakage' of plastics into the environment by intervening at the source that requires to close dumpsites and provide appropriate waste treatment and disposal facilities for all communities. It is estimated that over 3 billion people globally still do not have access to appropriate disposal facilities; preventing uncontrolled dumping by providing collection services for all (D-Waste, 2012). Dumping of wastes causes significant environmental, social and economic impacts, particularly for low income communities. It is estimated that over 2 billion people globally still do not have access to adequate waste collection services (UNEP, 2015). These needs to be provided as a matter of urgency. Preventing littering is also a major action. Waste items dropped by people 'on the go' or at major events/ gatherings are a key source of plastics that escape into the marine environment. Reducing littering will require proactive engagement with communities, public awareness-raising, and an enhanced understanding people's needs and behaviours. Furthermore, working with the maritime sector to establish effective take-back systems for recovering waste and recyclable materials from the fishing, shipping and touristic activities shall be a priority.

Mid-term actions includes capturing and enhancing the value of waste plastics through effective collection systems that maximise and stabilise the value of secondary plastics, considering the social and market particularities of each and every municipality and region.

Furthermore, there is a need to address issues associated with global supply chains and social and environmental justice, and reverse the often unfair competition with primary raw materials, so that littering/dumping and therefore wasting used plastics becomes unthinkable. Better data and information sharing on waste and recycled materials at all stages of their use and end-of-life cycle can enable properly functioning, stable markets for secondary plastics.

In the long-term a step-change from the linear use of plastics to a sustainable and proven circular and cascading system is needed. More specific, it is essential to move from the current situation, where the majority of plastics are used once - with much of this material escaping the system - to a system based on the principles of sustainable and effective circularity and cascading, and clean material cycles, where the use of plastics is minimised and those that are used are collected and cycled back into the system as valuable raw materials and energy. This will require action on many fronts. The generic case has been widely made, but a more detailed and operationalised approach needs to be developed to being about the step change that is needed.

Since it is crucial to address the issue at the very beginning, priority actions shall include reducing (i.e. rationalising) single-use items and, developing materials and designing products for recyclability and value retention after the use phase. This requires a new innovation model that goes beyond cost-effectiveness, functionality during useful life time, and narrowly defined utility needs to one that incorporates complex value. This will require a radical shift from today's practices, based on a cross-sector and intra-disciplinary scientific collaboration.

Finally, to prioritise, design and implement effective solutions, it is essential to act on multiple levels and apply customised interventions. Nevertheless, such actions require a detailed understanding on many key aspects associated with plastics marine litter which currently are lacking. The flows of plastics in the environment are complex. Yet, current estimates of quantities and sources are based on simplified assumptions and poor-quality base data of very low spatial resolution. Proper sets of indicators are not well established and they are not available for policy and decision-making support. Many factors influence the release, movement, and transformation of plastics.

The paper concludes that there is an urgent need for a better and more precise understanding of marine litter, based more on science and systemic descriptions, rather than simplified and potentially misleading empirical approaches, to understand the most effective interventions to make and stop the leakage of plastics into the marine environment.