A full picture of the origin and nature of ocean litter

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Credit: Andres Cozar, Marine Litter Lab

A new study published in *Nature Sustainability* provides the first complete diagnosis of the origin and nature of the litter dumped into the ocean. The collaboration between research institutions such as Wageningen University and Research and NGOs from 10 countries has allowed the identification of the most polluting products for the main aquatic ecosystems on a global scale. This is a much-needed information

for prevention policies. The study presents a new paradigm for understanding how the ocean deals with litter accumulation through a selective delivery to coastal ecosystems and the open ocean.

The new study puts numbers to the composition of the human-made litter in the global ocean. On average, 80% of the litter items are made of plastic. This is by far the dominant material found in the environment, followed by metal, glass, fabrics, paper, and processed wood. The largest share of plastic is found in surface waters (95%), followed by shorelines (83%), while riverbeds show the lowest proportion of plastic (49%).

Litter related to household and industrial activities is prominent on river bottoms and riverbanks, while tobacco-related litter (cigarette packages, plastic pouches, and lighters) is especially abundant on beaches. Although the study only used data prior to the COVID pandemic, items with a medical and/or hygienic origin are particularly common in nearshore seafloors, and mainly attributed to toilet flushing. But what is most striking is that, of the 112 litter categories used in the analysis, only 10 plastic products accounted for threequarters of all litter items found worldwide. Waste from take-out consumption of convenience food and beverage largely dominates global litter. Single-use bags, bottles, food containers and wrappers are the four most widespread litter items, accounting for almost half of the human-made objects.

The irresponsible production of throwaway plastic goods, the careless behavior by some end-users, and the flaws in recovery systems, lead to a continuous leakage of plastic into nature. This input, together with the persistence of plastic materials, explain the overwhelming prevalence of plastic in the ocean. Action plans against plastic have already been drawn up for the EU and UK; however, market-restrictions of these plans are limited to single-use items that are superfluous or easily replaceable. "Here we show that restrictions on the use of plastic items, such as straws, cotton buds and drink stirrers, while sound, do not yet address the

core problem," says Andrés Cózar, professor at the University of Cádiz, Spain, and coordinator of the study.

Suggestions for management action

Considering that waste avoidance is the most effective way to minimize litter pollution, the authors advocate regulatory bans on avoidable take-out plastic products as the preferred management action. For those take-out products deemed indispensable, the study suggests a particular enforcement of the so-called "extended producer responsibility" (EPR), coupled with a deposit-refund levy to the take-out consumers, both justified by the extra risk of leakage of these products to the environment. Likewise, replacing top polluting plastic items by others made of more easily degradable materials should account for all life-cycle impacts of the alternative products, including production, transportation, and disposal. "We found that paper and cardboard products, for example, show a very low occurrence in nature [1% on average], but their production also requires a sustainable raw material sourcing," says Carmen Morales, researcher at the University of Cádiz and first author of the study.

"Our initial idea was simple: to create a ranking of the top items littering the ocean as a reference for preventive policies" explains Carmen. "We soon realized that it was not such a simple task; we were lucky enough to have the support from researchers and NGOs worldwide, but the existing information is based on disparate sampling methods and classification criteria," she adds. The poor comparability of data hindered a comprehensive picture. The research team applied a systematic workflow of harmonization to integrate each of the great databases available worldwide. This process, with more than 12 million data standardized, later allowed the researchers to connect and compare patterns across ecosystems and world regions.

A new paradigm: A selective delivery of large and small plastics to shores and open ocean

Plastics derived from land-based consumption are by far the most frequent items in marine litter on a global scale. However, the proportion of litter related to sea-based activities (fishing, shipping, aquaculture) increases in sparsely inhabited areas, becoming the predominant litter-type in open ocean waters as well as at high latitudes (> 50°). Interestingly, the composition of debris on the ocean surface shifts from take-out consumer items nearshore to a dominance of fishing-related items offshore. The explanation shown by the study has to do with the effect of wind and waves, which recurrently sweep large floating objects to the coasts. Once there, the items either accumulate on the nearby seafloor or undergo an accelerated process of weathering and breakage on the shore until they are transformed into tiny fragments, so-called microplastics. It is then, in the form of microplastics, that they can more easily overcome the waves, be released into the open ocean, and enter the transport circuits of ocean currents.

In 2014, Andrés Cózar and his team presented the first global map of plastic waste in the ocean. They revealed the existence of five great accumulation zones of floating plastic debris, one in the center of each of the ocean basins. However, 99% of the plastic collected across the ocean gyres during that study were fragments smaller than 2 cm. "A burning question left unanswered was where were the bottles, bags, and all those large objects that enter the ocean?", Andrés says. This time, the team was looking for the largesized litter, the so-called macrolitter (> 2 cm), and found it mainly associated to coastal environments.

"The concentrations of macro-litter on shores and nearshore seafloors are of the order of 10,000 times higher than the concentrations on deep seafloors, and 100,000 times higher than in surface waters," Andrés

concludes. "Shores emerge as key areas to intercept litter before it becomes microplastic and spreads out of control across the global ocean," Carmen adds.

The contribution of sea-based activities

The study also places the contribution of sea-based activities to ocean litter at 22%, on average across ecosystems, with the caveat that this figure should be regarded as a lower limit. The estimate only includes items clearly related to sea-based activities (mainly fishing gear), although "throwaway" plastics or any other type of item might have been dumped into the ocean from vessels of all types. Litter from sea-based sources, due to its diversity, requires a more complex recipe of actions, among which the authors suggest a global fixed fee for waste landing, irrespective of quantity. "Waste landing in any port should not imply a cost dependent on the quantity landed," Cózar says.

The accumulation of litter in the oceans is one of the great challenges of the present century. Scientific and social concern has triggered a wave of initiatives aimed at mitigating this problem. However, the knowledge needed to guide and coordinate action plans remains limited. Although abundant, the information needed to assess the origin and nature of litter is dispersed and fragmented. Increasingly urgent decisions often have to be based on data presenting only a partial view of the problem. In this study, the most polluting products have been identified for each of the seven world socio-economic regions. Although there is no silver bullet for litter pollution, studies like this one do provide a consistent basis on which to design and coordinate more effective action plans.

More information: An inshore-offshore sorting system revealed from global classification of ocean litter. *Nature Sustainability*, doi.org/10.1038/s41893-021-00720-8

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