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Handling the growing problem of offshore food waste

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ABSTRACT

The international debate on food waste prevention and handling often oversees one critical modality, whose importance should not be overlooked: offshore food waste. The amount of offshore food waste produced is not a commonly reported or tracked statistic. However, offshore food waste is a global issue. It can result from various sources, such as cruise ships, fishing vessels, and offshore platforms. This Commentary describes the scope of the problems posed by offshore food waste and outlines some of the measures which are needed to address it.

1. Offshore food waste

Most of the human-produced waste is produced on land. This includes household waste as well as waste from municipal sewers and treatment plants [13]. However, the discharge of waste and sewage into the sea from ships, oil rigs, and other offshore activities, also contributes to marine pollution [16].

Offshore food waste is food that is not used by consumers when offshore, i.e., when traveling in rivers or high seas. It can include food that is spoiled, expired, or over-prepared. It can also include food that has been discarded by restaurants on board of ships or oil rigs, as part of catering operations. Because the offshore disposal of garbage is prohibited in many countries, many types of offshore food waste need to be transferred to shore for disposal. This includes contaminated or adulterated food or expired or improperly stored food, which - according to current rules - should be processed on board prior to disposal.

Regulations for the prevention of pollution by waste from ships are described in Annex V of the MARPOL Convention [22]. Annex V seeks to eliminate and reduce the amount of waste being discharged into the sea from ships. Unless expressly provided otherwise, Annex V applies to all ships, which means all ships of any type whatsoever operating in the marine environment, from merchant ships to fixed or floating platforms to non-commercial ships like pleasure crafts and yachts. These are also subject to the specific requirements valid in various countries. This regulation states that the discharge of all waste into the sea, except as provided otherwise in regulations 4, 5, and 6 of the Annex, which are related to food waste, cargo residues, cleaning agents and additives, and animal carcasses [22]. Exceptions with respect to the safety of a ship and those on board and accidental loss are contained in regulation 7 of Annex V. Thus, under MARPOL Annex V, waste includes all kinds of food, domestic and operational waste, all plastics, cargo residues, incinerator ashes, cooking oil, fishing gear, and animal carcasses generated during the normal operation of the ship and liable to be disposed of continuously or periodically. Waste does not include fresh fish and parts thereof generated as a result of fishing activities undertaken during the voyage, or as a result of aquaculture activities.

Vaneeckhaute and Fazli [19] contend that precise quantification of offshore food waste remains elusive. Although reliable statistical data

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concerning the quantities of food waste deposited in marine ecosystems are lacking, Annex V of the MARPOL Convention (International Convention for the Prevention of Pollution from Ships) clearly discourages such practices [8,22].

The scope of the problem means there have been various studies trying to measure its occurrence (eg., [1]) and to address it (eg., [10, 21]). Nevertheless, the theme is complex since it involves a set of measures whose implementation may be costly, and national regulations do not always provide a due emphasis to the problems associated with on-board food waste. Thus, apart from describing the scope of the problem originating from offshore food waste, this Commentary presents some of the current trends and outlines the urgent need for measures to address it.

2. Current trends

One of the main challenges with marine food waste disposal is that it often occurs in the high seas, i.e. in international waters where no single country has a jurisdiction. This loophole is often used. Therefore, the only possible means of regulation is via MARPOL, which has been endorsed by 156 countries, responsible for 99% of the worlds̓ shipping tonnage.

In special environments such as in sea vessels, the need to optimise processes and reduce food waste is particularly acute. However, offshore food waste is increasing, partly because the cruise ships that tend to offer "all-inclusive" services to customers and are sometimes unable to keep full control of the amounts of food cooked.

The effective handling of offshore food waste poses a significant worry for managers overseeing ships and oil rigs, given the potential hazards of biological contamination and unpleasant odours [15]. This concern arises from the fact that wet waste can foster microbial activity and trigger enzyme activation, thereby hastening the spoiling process [19].

As highlighted by IMO [9] and Wilewska-Bien et al. [21], in a study assessing the nutrient load caused by food waste generated onboard ships, it is a fact that the high volume of maritime traffic exposes the marine environment to anthropogenic effects, such as the generated food waste onboard ships comprising tonnes of nitrogen and phosphorous being legally discarded into the marine environment at a specific distance, i.e., at more than 12 nautical miles, a common practice, if not comminuted or ground, from the nearest land. Nutrient contamination is acknowledged as a serious environmental hazard in terms of aquatic ecosystems, with phosphorus being a limiting factor for primary production in freshwater, and nitrogen a limiting factor in seawater [11].

Nevertheless, adopting a more sustainable strategy, vessels have the capability to shred and store food waste generated onboard, with the intention of transporting it to port receiving facilities for subsequent collection and valorisation [6,17]. An instance of such integration between vessels and ports is evident within the European Union (EU). Through Directive (EU) 2019/883, the EU aims to protect the marine environment from the detrimental effects of waste discharges from ships operating in EU ports. This directive not only aligns with the MARPOL Annex V resolution but also strives to improve the accessibility and utilisation of appropriate port reception facilities, along with ensuring the efficient delivery of waste to these facilities [3]. A solid working partnership between ships and ports is absolutely essential for the successful accomplishment of any sustainable waste management valorisation plan [18] and marine pollution prevention onboard [21].

Onboard food waste storage is challenging because of limited storage space, favouring disease and pest, putrefaction and odours, being necessary to perform treatment when possible and available, e.g., screening, aerobic digestion, chlorine disinfection, in order to have a treated effluent to discharge the wastewater in the sea only after previous treatment, which may not always be the case [12,17,19]. Several other more advanced treatments are possible, e.g., suspended solids, biochemical oxygen demand (BOD), or pathogens, aiming to remove nutrients, i.e., nitrogen and phosphorus, according to different implemented regulations [17], guided by environmental aspects [21]. Thus, according to Wilewska-Bien et al. [20], the contribution of nutrients from onboard food waste will be significant in the future, when compared to sewage. Ship-generated nutrient-rich food waste contributes to marine ecosystem eutrophication and deoxygenation, resulting in oxygen depletion and causing severe environmental impacts to the aquatic ecosystem [17]. Food waste is the basis of some specific environmental impacts, namely exacerbating the climate change effects, and consequently human health, detailed in Fig. 1, either if directly discharged at the aquatic environment or treated, e.g., composting or anaerobic digestion, or disposed of in landfills. Among several other environmental effects, it is known that the gaseous emissions resulting from food waste treatment are significant contributors to eutrophication, acidification, and photochemical oxidation. In any case, treatment options must always be considered positive, despite polluters being emitted, since they assist in counterbalancing the negative points through environmental benefits such as fossil fuel replacement or using compost to replace inorganic fertilisers [2]. Fig. 1 illustrates some of the most common environmental impacts triggered by offshore food waste

Fig. 2 shows the two alternatives for the final disposal of food waste available under the IMO MARPOL Convention. The first option involves releasing these waste materials into the sea, while the second entails temporarily storing the waste on board for subsequent disposal at ports. The direct disposal of organic food waste into the sea can occur when the vessel is located 12 nautical miles away from the nearest land, without the need for waste processing. Alternatively, the food waste can be comminuted (ground or crushed) and then discharged into the sea, located 3 nautical miles away from the nearest land (or 12 nautical miles in special areas). Another option is to store the food waste separately on board for later disposal at a Port Reception Facility (PRF) if sea disposal is prohibited by regulations [7]. The guidelines also emphasise the importance of taking precautions to prevent the discharge of plastics contaminated with food waste (such as plastic food wrappers) and other waste into the sea along with the food waste.

Wilewska-Bien et al. [21], Vaneeckhaute and Darveau [18], and Argüello [3] international regulations define a set of rules related to the handling of food waste. Among the recommendations, it is storing the waste in separate and tightly covered containers, double bagging, and quarantine arrangements. Additionally, ships or platforms can be equipped with refrigerated chambers to preserve food waste and prevent putrefaction. In some cases, dehydration of the waste is promoted to reduce volume, and incineration is occasionally reported as a method of improving food waste management on vessels and offshore oil rigs. In respect of incineration as a possible solution, it should be noted that this has environmental implications. Also, this method may be deemed as adequate for ships producing large amounts of food waste. For

OFFSHORE FOOD WASTE	
Eutrophication	Nutrient-induced deoxygenation caused by nutritional excess
Climate change exacerbation and ozone depletion	Food waste contributes to the climate change crisis with significant greenhouse gas (GHG) footprint. Handling of food generates carbon dioxide (CO_2) emissions and methane (CH_4) when ending up in landfills
Particulate matter emission	Generated when food waste is combusted, contributing to air pollution and threatening human health and the global environment
Photochemical oxidation	Gaseous emissions from the composting and anaerobic digestion
Acidification	Gaseous emissions from the composting and anaerobic digestion
Human toxicity	Gaseous emissions from the composting and anaerobic digestion
Marine biota health and toxicity	Affected by increased turbidity and high nutrient load

Fig. 1. Environmental risks caused by incorrect treatment of food waste.

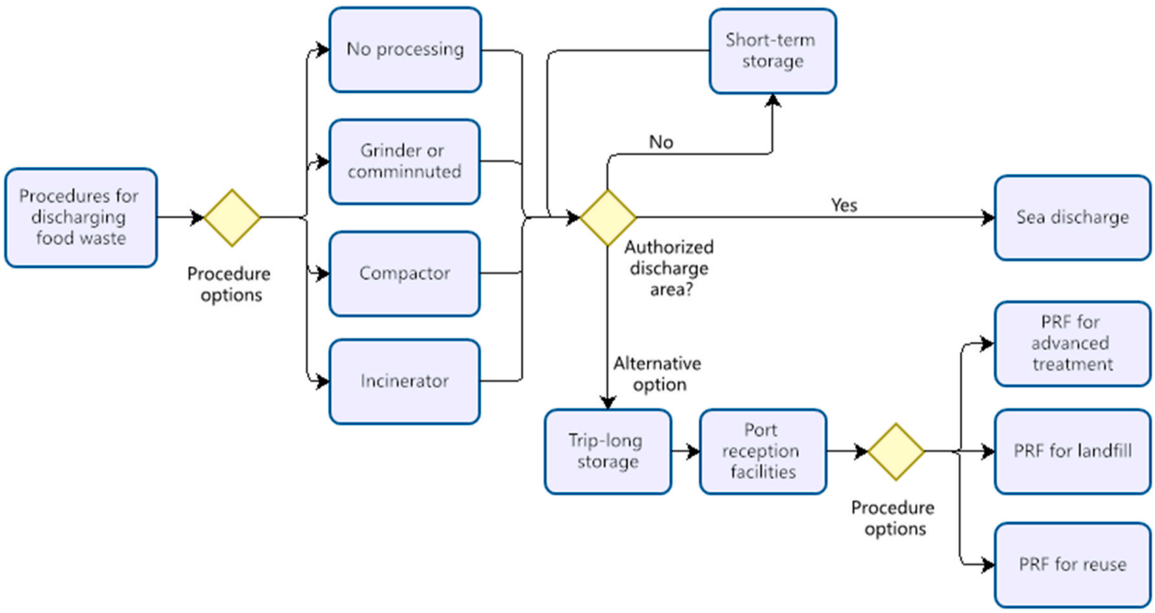

Fig. 2. Overview of options for handling and discharging offshore food waste. Source: adapted from EMSA [7], Vaneeckhaute & Fazli [19], and Argüello [3].

medium-sized and smaller boats, an appropriate solution may be to bring the waste to shore for proper disposal or reuse, and sustainable valorisation such as thermal energy [4,14].

Despite international legislation allowing the disposal of waste at sea, Butt [5] acknowledges the importance of encouraging the adoption of more sustainable approaches to waste management, rather than using the sea as a convenient dumping ground. Therefore, there should be an integrated effort among ships, oil platforms, ports, and multilateral regulatory bodies to develop technologies that enable the implementation of more sustainable integrated management strategies for offshore food waste.

In order to lessen the risks caused by offshore food waste, some initiatives have been carried out, but most of them are obviously connected with the development of technologies that can be used by the main pollutants (ferries, cruises boats, fish and seafood processing boats, oil platforms, etc.). One example of these technological solutions is the food waste shredders. This solution has been used by MS Fram, a cruise vessel owned by Norway-based Hurtigruten ASA. The ship operates in some of the world's most sensitive waters (Baltic Sea). Onboard this ship, it is possible to use a food waste system macerator that grinds raw food waste to particles less than 25 mm and transports it by vacuum to a special holding tank for disposal.

Regarding the particular case of cruises, some of the food waste practices adopted in the hospitality sector could be of relevance to shipping, but in some cases, they are of difficult application due to the specific conditions of shipping. In the Baltic Sea, this industry voluntarily committed to be more restrictive in terms of discharging sewage and grey water; however, nothing was stated regarding the discharge of food waste. Thus, Wilewska-Bien et al. [21], analysing this specific problem, reported that a minority of the cruise operators informed about food waste management practices. The examples given by the companies interviewed by the authors evidence multiple approaches to reduce food waste generation, mostly in buffet-type restaurants, however legal aspects (e.g., reusing of food) were mentioned as a barrier.

3. Future prospects

As this *Commentary* evidenced, offshore food waste is a serious problem, which requires attention. Some reasons why offshore food waste needs to be managed effectively can be pointed out. Firstly, food waste can lead to harm to marine wildlife, and to the ecosystem. Secondly, if food waste is dumped in the ocean, it can contribute to the growth of harmful algal blooms, which can deplete oxygen levels in the water and harm aquatic life. Thirdly, food waste can release greenhouse gases when it decomposes, contributing to climate change.

To address these issues, concerted action is needed at different levels. For instance, governments should establish and enforce regulations to prevent the dumping of food waste into the ocean and encourage the use of onboard waste management systems to reduce waste generation. The shipping and offshore industries should implement best practices for waste management. This should not only include proper incineration procedures, but also the implementation of measures to reduce waste generation, the segregation of food waste, and the use of environmentally friendly disposal methods such as composting. In addition, public awareness campaigns should be conducted to educate individuals about the impact of food waste on the environment and encourage them to reduce waste generation by practicing sustainable consumption habits.

The scope of the problems caused by offshore food waste means that urgent action is needed to address it. In line with this concern, MARPOL has set up some special areas under Annex V [22].

These are sea areas where, for recognised technical reasons related to their oceanographic and ecological characteristics and the particular nature of the traffic, such as heavy shipping traffic, low water exchange, extreme ice conditions, or vulnerable marine species, the application of specific mandatory methods to prevent marine litter pollution is required. This does not mean that food waste is not a problem in the other seas. But in the areas listed under Annex 5, which refer to semi-enclosed seas, the environmental sensibility is higher, and the dispersal of organic waste is more difficult than in open seas such as the North Sea, or the South China Sea.

Overall, addressing offshore food waste requires a multi-faceted approach involving government, industry, and individuals. As the number of passengers in cruising ships and the amount of food consumed increases, it is important that all relevant agents work together towards addressing the problem, hence alleviating the pressure on oceans and marine ecosystems.

The policy implications of the paper and threefold. First, the paper outlines the need for more coherent and specific policies on food waste. Secondly, it demonstrates the need for consistency among policies aimed at reducing the environmental impacts of ships operation. Finally, the paper outlines some areas where action is urgently needed to address a growing problem, associated with the expansion of sea cruises.

In terms of guidelines for policymakers, there is a need to take matters related to food waste pollution from ships more seriously as part of national environmental regulations. Ship operators need to make better provisions for handling on-board food waste, especially in the prevention of such waste. Passenger too need to be made aware about the problems associated with their consumption of food and be encouraged to be more careful when choosing their menus, and calculating the portions of food they need.

CRediT authorship contribution statement

Maria Alzira Pimenta Dinis: Investigation, Writing – original draft. **Arminda Paço:** Investigation, Writing – original draft. **Claudio Ruy Portela de Vasconcelos:** Investigation, Writing – original draft. **Walter Leal Filho:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data was used for the research described in the article.

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