

Marine Litter and the Circular Economy*

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Abstract: Marine litter has been identified as one of major threats to marine ecosystems due to its environmental, economic, safety, health, and cultural impacts. The paper analyses the sources of marine litter and the obstacles to resolving the issue of pollution by marine litter. It addresses the quality of the national waste management concept as well as the efficiency of its implementation in the Republic of Croatia where the Adriatic Sea is subject to substantial pressure from littering. Resolving the problem of marine litter means adopting appropriate policy regarding waste generated at sea, marinas, cruising and fishing, and at land in line with circular economy principles. Findings of the study show that the country should be proactive in adopting policies to reduce and modify packaging and link the bioeconomy to the circular economy in achieving environmental and economic benefits in terms of materials and energy efficiency. Further research concerning all Mediterranean countries should integrate, in a holistic manner, municipal waste management, food packaging and food waste, marine litter, tourism, local agriculture, and local economies.

Keywords: Marine litter, Circular economy, Waste management plan, Adriatic Sea, Croatia.

1. Introduction

While litter is a key marine environment and biodiversity challenge, its generation and prevention are linked to a variety of human activities and policy areas, such as waste and wastewater management, product design, shipping, fisheries policies, consumption, and behavioural patterns.

The purpose of this paper is presenting the waste management model that is compliant with circular economy principles, international

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recommendations, and requirements, and which at the same time systematically addresses the problem of marine litter. Given holistic focus of the topic, the authors applied qualitative research based on direct observations, authors' previous research and experiences, official documents, and literature surveys.

The authors focus on the major source of marine litter, which is land. Policies related to litter and the protection of the oceans from land-based pollution are reviewed. The Croatian case is analysed regarding its national policies and approach to waste management and marine litter, also highlighting the deficiencies in implementation and proposing solutions.

2. Marine litter and its sources

Marine litter is any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in marine and coastal environment. Marine litter contains items that have been made or used by people and deliberately discarded or unintentionally enter the marine or coastal environment including materials that enter the marine environment from land by rivers, drainage or sewage systems or the wind [1]. Marine litter appears on beaches, on the sea surface, below the surface in water column, on the seafloor and in biota. Marine litter mirrors inappropriate waste management on the land and inefficient resource economy [2, 3].

Most of marine litter (about 80 %) originates from the land [4]. Smaller portion is generated at sea and includes waste that falls from ships of all types and purposes, floating ropes, nets, floats and other debris from fisheries, shipping, aquaculture, and nautical tourism. The waste produced on the beaches and on board the increasing number of passenger ships and yachts that visit the coasts of the Adriatic Sea, aggravates the problem. In this context, plastic materials pose a particular threat to the marine environment. Major sources of plastic waste are packaging, agriculture, fisheries and aquaculture, natural disasters, relief operations, refugee camps, and various discards related to protection from COVID-19 and its treatment [5].

Apart from the microplastics intentionally used in products and that incurred by weathering of macroplastics in marine environment, the microplastics in the seas also originate from abrasion of tyres against road surfaces, the release of fibres from synthetic textiles during wear and tear, laundering, cleaning, and from fibreglass boats, fisheries, and aquaculture activities [5].

Most litter items found in the Adriatic are composed of artificial polymer materials. The items found on beaches include, among others, plastic pieces, polystyrene pieces, cotton bud sticks, plastic caps/lids from drinks, cigarette butts and filters, plastic caps/lids unidentified, mussel & oyster nets, crisp packets/sweet wrappers, etc. Floating litter items are mostly plastic bags, plastic pieces, sheets, fish polystyrene boxes, cover/packaging, and other plastic items. Bottom trawl surveys showed that sheets, industrial packaging, and plastic sheeting are the most abundant type of litter, followed by bags and food containers, including fast food containers. In the visual seafloor surveys with scuba/snorkelling, the most common items found were glass bottles or pieces thereof, followed by plastic bottles and metal cans. Regarding biota, nine marine litter categories were found in the guts of the examined – filaments, films, sheets, industrial packaging, and plastic sheeting [6].

3. Policies concerning marine environment and waste management

Various policies concerning marine environment protection against waste pollution have been launched at international fora, including, the 1973/78 MARPOL Convention - Annex V [7], which deals with garbage that can become marine litter, the 1972 London Convention [8] and the 1996 London Protocol [9], which are legal instruments regulating activities that can become litter in the sea, and regional seas initiatives, such as the 1976 Barcelona Convention [10] and the 1980 Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources [11].

Basel Convention [12] is a legally binding instrument to address plastic waste and in 2019 Conference of Parties (COP) decided to enhance control of plastic waste by amending Annexes II, VIII and IX to the Convention (plastic waste amendments) [13], it now being the only globally binding instrument to specifically address plastic waste. In addition, the categories of plastic waste have been further clarified [5].

The European Marine Strategy Framework Directive (MSFD) [14] sets the framework for Member States to achieve Good Environmental Status (GES) for their marine waters by 2020, considering 11 descriptors, whereby Descriptor 10 focuses on marine litter and states that GES is achieved only when properties and quantities of marine litter do not cause harm to the coastal and marine environment.

Other important European Union directives directly related to marine litter are the 2019 Single-use Plastic Directive [15] that addresses 10 most commonly found single-use plastic items on European beaches which,

alongside fish gear, represent 70% of all marine litter in the European Union, and the 2019 Directive on Port Reception Facilities [16] which aligns EU legislation with amended International Convention for the Prevention of Pollution from Ships (MARPOL) and is a part of the circular economy policy and plastics strategy of the European Union.

4. The Croatian case

Croatia, with its long coast, is particularly affected by the problem of marine litter and it also contributes to its generation. The quantity and presence of plastic waste on the bottom of the Adriatic Sea is among the highest in Europe [17]. Croatian coastal counties populated by abt. 1.3 million inhabitants [18] recorded in 2022 abt. 15.6 tourist arrivals [19], meaning that significant quantities of waste end up in the area. Marine litter presents one of the major threats to marine ecosystems due to its environmental, economic, safety, health, and cultural impacts. Coastal and nautical tourism which contributes to generation of marine litter is at the same time affected by its presence.

The 2017-2022 Waste Management Plan [20] acknowledged that the system for marine litter management had not yet been implemented and that there was no official data or adequate assessment of the quantity of marine litter in the Republic of Croatia. The 2023-2028 Waste Management Plan [21] currently in force points out that it is not possible to propose quantitative targets regarding marine litter.

The quantity of mixed municipal waste landfilled annually in the Republic of Croatia is still far from the targets and obligations set in the Landfill Directive [22], the Waste Framework Directive (WFD) [23], the Accession Treaty [24], and the national Act on Sustainable Waste Management [25]. Regarding biodegradable municipal waste landfilled, Figure 1 shows that its quantities are still far above the value for year 2020 prescribed by the law. It is necessary to increase separate collection and capacities for separating waste – sorting plants (for dry fractions and mixed waste, where appropriate) and the capacities for treating biodegradable waste (composting plants, biogas plants). As a newcomer, Croatia has had the opportunity to serve as a model for other countries in the efficient transition from landfilling to the circular economy and to avoid mistakes that may have been made by those who abandoned landfilling long ago in search of alternatives.

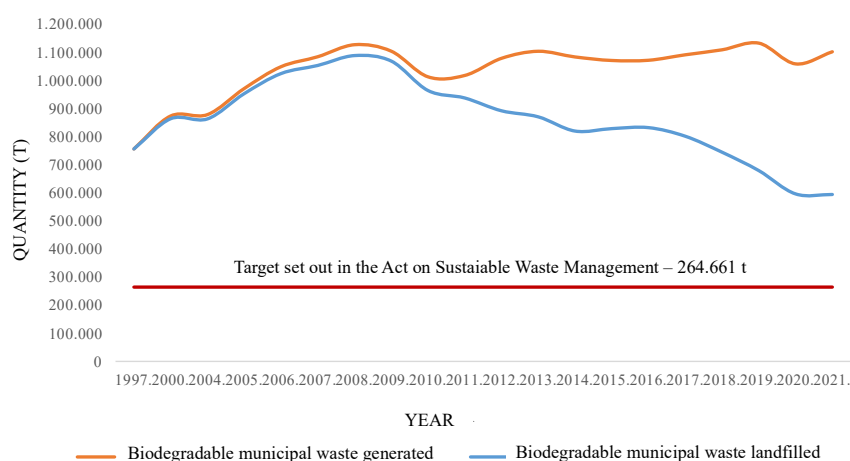


Fig. 1 – *Generated and landfilled biodegradable municipal waste for the period 1997-2021 in relation to the statutory target [26].*

The deficiency in Croatia is that substantial public money has been invested in an inefficient waste management system, despite its obligation to comply with the EU legal framework. The waste management centres in operation in Croatia are not the best available technology and represent a major financial burden on taxpayers, service users, and municipalities, in terms of investment, operation and maintenance. Namely, two major problems prevail. One is the fact that all the waste delivered to the now-completed waste management centres is actually landfilled (Figure 2), including the refuse derived fuel (RDF), which cannot be marketed because it is of very low quality and therefore mostly remains on landfills. Certain smaller quantities of it are delivered to entities that charge significant amounts to receive it. It is expected that other centres will face the same problem since they will apply similar technology.

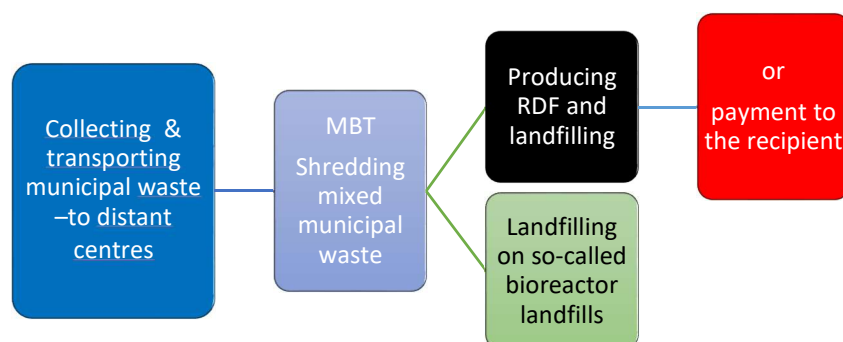


Fig. 2 – Waste flow in waste management centres in the Republic of Croatia.

Another problem related to the concept of waste management centres is their capacity. The total designed capacity of the 11 centres that are either completed or planned is 885.000 t (see Table 1). This differs significantly from national targets to be reached regarding municipal solid waste landfilling quantities.

Table 1 – Designed capacity (t) of waste management centres (WMC) Croatia [27].

Item no.	WMC	Capacity, t
1.	Mariščina	100.000
2.	Kaštijun	90.000
3.	Bikarac	40.000
4.	Biljane Donje	70.000
5.	Piškovnica	110.000
6.	Babina Gora	30.000
7.	Lečevica	110.000
8.	Lučino Razdolje	40.000
9.	Orlovnjak	60.000
10.	Šagulje	55.000
11.	City of Zagreb	180.000
	Total	885.000

Specifically, Waste Management Plan amended at the end of 2021 [27], states that quantities of waste to be landfilled by 2022 should not exceed 25% of the quantity of municipal waste generated in 2015 (1.653.919 t), i.e. no more than 413.480 t should be landfilled by then. At the same time, the quantity of 1.029.608 t landfilled in 2021 according to official data [26] included 328.847 t of biodegradable waste that should never have ended up in the landfill. As mentioned previously, the actual quantity that remain in

the landfills is closer to the total quantity of municipal waste collected, i.e. about 1.3 million t. In addition, the 2018 Amendment of the Landfill Directive requires Member States to take the necessary measures to ensure that the amount of municipal waste landfilled is reduced to 10 % or less of the total amount of municipal waste generated (by weight) by 2035 [28], which means that the limits are becoming more stringent.

To compensate for all the resource inefficiencies described above, the Waste Management plan for the period 2023-2028 [21], is entirely focused on incineration, which is contrary to the principles of the circular economy. As increasing volumes of sludge from inefficient, energy and water consuming centralized wastewater plants pose an additional problem for existing waste management facilities, this material stream serves as an additional argument in support of such concept of energy recovery, which certainly poses a serious threat to the environment and public health.

In 2016, the Draft Waste Management Plan [29] had been proposed, but was never adopted, which was based on the quantity of 1.300.000 t of mixed municipal waste per year. It reflected a holistic and sustainable approach to waste and capital flows, as well as to the environment and society in general, applying the circular economy and zero waste concepts. Its features are presented in Figure 3 which shows that after proper processing of the recyclables and composting/digesting or biowaste, less than 25% remains as mixed municipal waste which may then end up in waste management centres or on landfills.

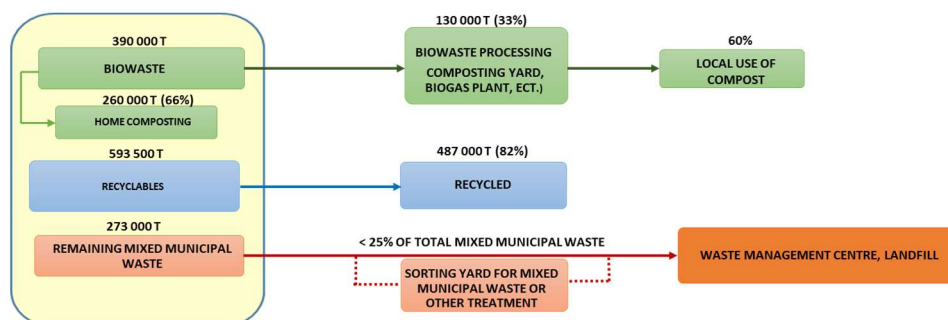


Fig. 3 – Targeted waste flows [29].

Croatia is not proactive regarding sustainable packaging and is mainly concerned with end-of-pipe solutions, which are inefficient. Prevention, the top priority measure in waste hierarchy, is not tackled at all.

Looking at circular economy indicators for the year 2021 [30], Croatia produced less municipal waste per capita than the EU average. The recycling

rate of municipal waste was low (29.5%) compared to the EU average of 48.6%. Recycling of biowaste per capita was exceptionally low (21 kg) compared to the EU average (93 kg).

Relevant legislation addressing marine litter in the Republic of Croatia involves the umbrella law in waste management, the 2013 Act on Sustainable Waste Management, as amended [25], the EU Marine Strategy Framework Directive (MSFD) that has been transposed into Croatian legislation [31], the European Commission (EC) Decision on good status of marine environment [32], the Protocol to Barcelona Convention [33], the 2011 Regulation establishing the framework for action of the Republic of Croatia in marine environment protection [34], and the 2017 Programme of measures for the protection and management of marine environment and coastal area [35], prescribing measure 3.3.1 Drafting the national marine litter management plan.

The strategic objectives laid down in the Marine Litter Management Plan [36] involve the establishment of a marine litter management system that focuses mainly on collection, the waste management information system, educational activities, and international cooperation. The implementation includes, among others, the prevention and reduction of marine litter from land input, strengthening of land-based waste management system in the Republic of Croatia, transition to the circular economy, and activities in sectors important for coastal areas (tourism, leisure).

It is to be noted that at national level the administration of waste management and of marine litter is not integrated within, and exercised by, a single body, but by two different bodies within the same ministry, each in charge of a respective portfolio, one being within the Directorate for Waste Management and Environmental Impact Assessment, and another within the Directorate for Waters.

5. The solution for the problem of marine litter

Sound approach to the problem of marine litter should imply the combination of different solutions. Above all, it is necessary to significantly reduce or halt the inputs of litter into the marine environment, and this reduction should mainly concern plastics consumption or the unnecessary and problematic use of plastics. It is also indispensable to create sustainable circular markets and improve waste collection from households. An increase in plastic waste collection of 1 t in the formal and informal sector can result in an average decrease of 0.1 t of plastic pollution in the aquatic environment [37].

Recycling of plastics, while important, is not sufficient in the current crisis. Therefore, materials and products need to be designed with circularity in mind, which implies innovativeness. Single-use items should be eliminated. Changing consumer behaviour is also important and has an impact on plastic leakage. Regarding water for drinking purposes, the access to tap water should be promoted to reduce the need for packaging of bottled water. The development of high-frequency, small-scale transactions (neighbourhood groceries) would certainly lead to less packaging and the use of reusable packaging.

As for the use of biodegradable plastics and bioplastics, currently the most popular ones are polylactic acid (PLA), polyhydroxalkanoate (PHA), and the starch-based polymer polybutylene succinate (PBS) which usually substitute PP, PET and PS. The sources for their manufacture are sugarcane, soy, maize, and potatoes [5]. Bioplastics are used for packaging, textiles, automotive applications, and the agriculture. The term bioplastic refers to either its plant origin or biodegradability, whether it is plant-based or fossil-based. The environment in which bioplastics are used or disposed of, be it the soil or the marine environment, plays a crucial role in their degradation. Some of the same problems exist with bio-based plastics made from renewable raw materials as with conventional plastics. They can contain toxic additives and contaminants and, although they are manufactured from plant-based polymers, they are not necessarily biodegradable, so they can fragment into microplastics and persist in the environment for long periods. In addition, bioplastics can contaminate the recycling process if not separated from conventional plastics, which is usually due to a problem of differentiating them visually (PET and PLA). In terms of industrial compostability, it requires 12 weeks at 60 °C, but in composting facilities it is often removed after only four weeks. Last but not least, people do not feel the same sense of responsibility to properly dispose of “biodegradable” plastic when they assume it will degrade in the environment [5].

National goals should therefore go beyond the development of effective management processes, and it is necessary to incentivize eco-design, eliminate from domestic market the products that are harmful to human health and environment, introduce product taxes to reduce per capita consumption, and promote design for repair. Furthermore, financial mechanisms should be considered. For example, taxes on tourism, hospitality and leisure could contribute to managing significant volumes of waste generated in the tourism sector. Public procurement rules should be used to increase demand for recycled materials, and the impact of oil price fluctuations on the use of recyclable plastics should be offset. Other benefits

of lower plastic production should also be kept in mind, namely lower CO₂ emissions and less virtual water consumed in production.

6. Conclusion

Resolving the problem of marine litter means adopting appropriate policy regarding waste generated at sea, marinas, cruising, fishing, and at land in line with circular economy principles.

Cleaning up the oceans is not a solution. It is energy consuming and generates other environmental impacts, for example on biodiversity. The solution is to tackle the problem at its source. Marine litter mirrors waste management problem on the land and is a problem for all countries washed by the Adriatic Sea.

Croatia is an example of a country where substantial public money has been invested in an inefficient waste management system, despite having to comply with the EU legal framework. Croatia should initiate and accelerate the transition to a circular economy which is beneficial for the environment and the economy, material and energy efficiency, and for maintaining the value of resources in the economy as long as possible.

The country should be proactive in adopting policies to reduce and modify packaging and link the bioeconomy to the circular economy. Further research concerning Croatia and other Mediterranean countries should integrate in a holistic manner municipal waste management, food packaging and food waste, marine litter, tourism, local agriculture, and local economies.

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