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## Challenges on Marine Litter Issues in the Adriatic

### Abstract

Marine litter places significant burden on beaches, marine surface, marine bottom and biota of the Adriatic Sea. It results mainly from inappropriate waste management on land. The paper analyses quantities and composition of marine litter and its sources, the threat of plastics, the approach to circular economy and waste management in Croatia and presents proposals for circular flow of materials with minimum leakage into the ecosystems and novel approach to marine litter issue. The solution of marine litter problem is in waste management involving source separation, numerous local sorting facilities, home composting, municipal composting and biogas production, with minimum resources left for disposal as well as implementing the policies to reduce and modify packaging, the materials used therefor and to avoid one-use and disposable plastic materials, that implying a change of habits, intervention in supply chain and increasing domestic supply.

**Keywords:** marine litter, Adriatic, environment, waste management

### 1. Introduction

Marine litter is for its most part the result of inappropriate waste management on the land. Marine litter on Croatian coast is therefore a sign of alarm that measures must finally be implemented in Croatia and all countries whose shores are washed by the Adriatic Sea to handle the waste in a way which does not make the sea its final destination, thus avoiding the damage to marine ecosystems, public health, standard of living and tourism.

The paper analyses the obstacles in resolving marine litter issue in the Adriatic Sea, the quantities and composition of marine litter, its sources, emphasizing the threat of plastics, it elaborates the approach to circular economy and waste management in Croatia and presents proposals for circular flow of discarded materials/resources with minimum leakage into the ecosystems as well as novel approach to marine litter.

## 2. The concept of marine litter

Marine litter is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. Marine litter thus consists of items that have been made or used by people and deliberately discarded or unintentionally lost into the sea or coastline including such materials transported into the marine environment from land by rivers, drainage or sewage systems or wind [1]. It appears on beaches, on the sea surface, below the surface in water column, on the seafloor and in biota.

The marine litter issue has been identified as one of major threats to marine ecosystems in the Mediterranean due to its environmental, economic, safety, health and cultural impacts. Regional Plan for the Marine Litter Management in the Mediterranean [2] was adopted in 2013. The Republic of Croatia has for decades been a member of MARPOL Convention, London and Barcelona Conventions and as a member has international obligation of their implementation. Protocol on Integrated Coastal Zone Management in the Mediterranean [3], one of the accompanying protocols of Barcelona Convention (Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean adopted in 1995) introduces an obligation of integrated coastal area management, taking into account physical planning, environment and nature protection, protection of cultural heritage, sustainable agriculture, fisheries, tourism and other economic activities in coastal area. The protocol also addresses marine litter.

Marine litter related information in the Adriatic as well as in the Mediterranean remains limited, inconsistent and fragmented, although it is widely considered that the Mediterranean is one of the most affected seas by marine litter worldwide. Effective measures to tackle marine litter in the region are thus seriously hampered by the lack of reliable scientific data [4].

Regional approach to abatement of such pollution is indispensable for any successful solution as the problems of marine litter go beyond national borders. However there is no adequate approach to assessment and monitoring of this kind of waste and implementation of current waste management legislation is poor. Insufficient knowledge of oceanographic and climate processes which affect its distribution and persistence in marine environment prevails [5].

Another difficulty lies in the fact that public policies relative to waste are often separated from that relative to the water pollution. The marine litter is situated at the cross of these two sectorial policies [1].

## 3. Quantities and composition of marine litter

According to the findings of recent project entitled Derelict Fishing Gear Management System in the Adriatic Region (DeFishGear) [4], aggregated results on

national level showing the abundance of beach litter reveal that the beaches most affected are those surveyed in Croatia. The highest average litter densities were recorded in Zaglav (Vis Island), while the highest average abundances were recorded in the coastal waters of Hvar Aquatorium. Seafloor of the Adriatic and Sea is impacted by marine litter, with amounts of litter being 2-5 times higher than those reported for some other seas, whereby one of the most affected countries is Croatia.

When it comes to the material composition of litter found in all marine compartments of the Adriatic, the majority of litter items were artificial polymer materials. The most abundant items for beaches included: 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. The most abundant floating litter items were: plastic bags, plastic pieces, sheets, fish polystyrene boxes, cover/packaging, and other plastic items. Results obtained from the bottom trawl surveys showed that sheets, industrial packaging, plastic sheeting are the most abundant types 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. When it comes to the biota, nine marine litter categories were found in the guts of the examined – filaments, films, sheets, industrial packaging and plastic sheeting.

The quantity and presence of plastic waste at the bottom of the Adriatic Sea is among the highest in Europe, after North-east part of the Mediterranean and Celtic Seas. The waste from about four million people living along its coasts ends up there, and the number is multiplied almost six-fold during tourist season.

#### **4. Sources of marine litter**

The bulk of marine litter originates from land (almost 80%), and only a lesser part is generated at the sea itself. Land sources of waste are uncontrolled or poorly managed communal landfills or waste sites along sea coasts, as evidenced in [6] or river banks, illegal dumping and mishandled waste on land, drainage and sewerage, river discharges, rain washouts and blowout from coasts during storms, as well as tourist activities. Marine litter is waste which falls from ships of all types and designated purposes – floating ropes, nets, floats and other debris, from fisheries, merchant shipping, cruise ships and also from aquaculture, oil and gas rigs and tourist activities. The cause of marine litter is therefore human activity – on the land and in the seas whereby all sectors and individuals contribute to this pollution. Waste delivered from the increasing number of passenger ships and yachts visiting Croatian coasts additionally aggravates the problem.

The composition and distribution of floating litter suggests that everyday public and tourist activities are mostly responsible for this kind of pollution in the Adriatic waters. The region suffers from both recent (based on the presence of paper) and past

(based on the presence of fragments) littering activities. Fisheries is the only specific economic sector that has an apparent share in floating litter. Of course, other economic sectors (e.g. shipping) may also pollute but via general purpose waste and hence their share cannot be quantified [4].

## 5. The threat of plastics

Plastics have only been mass-produced for around 60 years and therefore it is impossible to know with certainty how long they last in the marine environment. Most types of plastic are not biodegradable. In fact, they are extremely durable. Majority of polymers manufactured today will persist for decades and probably for centuries. So-called degradable plastics may persist for a long time because their degradation depends on physical factors, such as exposure to light, oxygen and temperature. For the large majority of plastic items, even if they disintegrate by breaking down into smaller plastic debris under the influence of weathering, the polymer itself may not necessarily fully degrade into natural chemical compounds or chemical elements under marine conditions [7].

Larger „macroplastics“ harm marine life when animals and fish become entangled or eat them, leaving also socioeconomic consequences for fisheries, shipping and tourism. Microplastics measure less than 5 mm in diameter and are either manufactured for industrial or domestic purposes (e.g. microbeads in toothpaste) or are a result of weathering and fragmentation of larger material secondary microplastics which is assisted by exposure to UV radiation and oxygen at or close to the water surface. At lower levels the lack of light slows this process so that it takes a long time for even biodegradable plastics to break down [7].

There is a major gap in our knowledge about the actual quantities of plastic debris and microplastics and the proportion coming from different sources. A further challenge is that we cannot see a large part of the litter because it lies below the surface. We don't know whether it is affecting the trophic chain, the potential for bioaccumulation in certain species, what chemicals are released into the marine environment when plastic waste degrades, the impact on food safety or the potential connections to climate change [7]. There is increasing concern that ingested plastics may transport potentially harmful chemicals to organisms [1].

A particular problem is posed by single-use, throw-away plastic products whose production has increased exponentially since the 1950s. Plastics are designed to be durable and it is precisely this characteristic combined with an unwillingness or inability to manage waste effectively, that has created a global issue [7]. A large fraction of the top 20 items found in the Adriatic were short-lived single-use plastic items such as plastic cups/lids from drinks, crisp packets and sweet wrappers, food wrappers and fast food containers, straws and stirrers, cups and cup lids, shopping bags, drink bottles, etc. Marine litter is thus not merely a waste management issue as one of the

root causes of waste accumulation on land and at sea is the linear use of resources from their production, to a short-lived, single use, to final disposal. Therefore, management measures should focus on the one hand on awareness raising of consumers and citizens and on the other on full implementing circular economy schemes (promoting eco-design) and/or policies that will drastically reduce the use of such items (e.g. banning or putting a levy on single use plastic bags) [4].

## 6. The approach to circular economy and waste management in Croatia

Besides being an environmental problem, the waste is a serious economic loss and burden for the society. The EU Country Report for Croatia [8] identifies various issues and opportunities. It states that given the low resource productivity and low recycling rates in Croatia, promoting a circular economy and improving resource efficiency could stimulate investment. Resource productivity in Croatia (how efficiently the economy uses material resources to produce wealth) is still much below the EU average with 1.1 EUR/kg (EU average is 2.0 EUR/kg) in 2015. Also for the year 2015 Croatia is ranked low among the EU-28 countries in terms of eco-innovation performance, having achieved an index 33% lower than the EU average and placing Croatia fifth from the bottom in the EU-28 ranking of eco-innovation, which is the same ranking Croatia held in 2013. Recycling of municipal waste (including composting) remains quite low (17% in 2014 compared to the EU average of 44% in 2014), so that significant efforts will be needed to meet the EU recycling target by 2020. In 2013, 115% of biodegradable municipal waste was landfilled compared to the reference year 1997. Also illegal landfilling remains an important problem in Croatia. The identified underlying causes for the current distance to EU waste targets are suboptimal planning of waste management, insufficient incentives to manage waste according to the waste hierarchy, insufficient door-to-door separate collection of waste, lack of clear allocation of tasks, lack of co-ordination between the different administrative levels, and insufficient enforcement capacity, see also [9, 10]. Although Croatia has invested in improvements to its waste management services, to date most of the investment has been focused on residual waste treatment. As regards marine protection, the report points out that unique biodiversity of the Mediterranean Sea Region is also threatened by pollution from land-based sources, such as marine litter and that with regards to waters in Croatia there are weaknesses in identifying „good environmental status“.

In author's opinion the sea, being an invaluable resource of the Republic of Croatia, deserves that much more appropriate cognizance, approach and treatment be reflected in official policies dealing with all aspects of the sea and its protection.

The years-old concept of municipal waste management in Croatia based on collection and processing of mixed waste in about a dozen big MBO centres with bioreactor landfills and RDF production, which never completely materialized and became outdated in technological and regulatory sense, was formalized by 2005

Waste Management Strategy of the Republic of Croatia [11] and Waste Management Plan of the Republic of Croatia for 2007-2013 period [12]. On the other hand, in the process of accession of the Republic of Croatia to the EU, Croatia assumed certain obligations to comply with the provisions from accession documents [13], the 1999 Landfill Directive [14], and the 2008 Waste Framework Directive [15]. The time limits are imposed concerning the achievement of targets, that is permissible quantities to be landfilled on substandard landfills, limits concerning permissible quantities for disposal of biodegradable municipal waste, providing for the operation of separate waste collection system and providing for appropriate processing. National legislation scheduled for adoption, besides the 2013 Sustainable Waste Management Act [16] was a new six-year waste management plan (hereinafter WMP) by 2014, waste prevention programme (hereinafter WPP) by 2013, and the implementing regulation on municipal waste management by 2014. The procedure of drafting and adopting mentioned documents got into substantial delay. A 2015 Draft WMP [17] with regard to achieving EU targets resulted in excess capacity of waste management centres and the increase in unit cost of waste processing [18].

It is only in the beginning of 2016 that the Republic of Croatia for the first time expressed its official support to EU Circular Economy Package proposal and started to produce new or review existing draft legislation compliant with circular economy concept and the EU documents in force.

Waste Management Plan 2017-2023 and Waste Prevention Programme were finally adopted in January 2017 [19] and also the Regulation on Municipal Waste Management [20] in May 2017, with entry in force in November 2017. The WMP was shortly following its adoption also followed by Government Decision [21] which partly modified the WMP. Mentioned planning documents in fact attempt to preserve previous policies based on mixed waste treatment with RDF production and landfilling of „treated“ waste.

With regard to marine litter, valid 2017-2022 WMP also states that the system of marine litter management has not been established and that currently there are neither official data nor appropriate assessment regarding the quantity of marine waste in the Republic of Croatia. It is to be pointed out however that Marine Strategy Framework Directive [22] which among other things defines important descriptors on pressures on marine environment, marine litter being one of them, lays down obligation on the Member State to adopt a marine strategy. The Republic of Croatia has never adopted the Strategy on Marine Environment and Coastal Area Management, although one has been drafted in 2015.

## **7. Proposal of advanced sustainable waste management approach**

In 2016 the author personally actively participated in drafting a holistic variant of planning documents which would have lead the way to embarking upon true circular

economy and consequently the reduction or elimination of marine litter from domestic sources. The basic concept of draft WMP and WPP [23] is presented below.

Principal measures were set for achieving set targets, starting with the limits concerning permissible quantities to be landfilled on all substandard landfills and permissible quantities of disposal concerning biodegradable waste, both presented in Table 1. The measures ensuring the operation of separate waste collection system are listed in table 2. The measures required for ensuring appropriate processing are presented in table 3.

The quantity of mixed municipal waste produced annually in the Republic of Croatia was estimated to be 1.300.000 t. The recycling target for municipal waste is at least one half of said quantity, with the potential for recycling of materials contained in that quantity being estimated to be even higher than 50%. In order to achieve recycling targets, it is necessary to collect separately a significant part of plastics, paper, metal, glass and also textile and biodegradable waste, which presently constitute municipal waste. In other words, dry fraction such as paper and cardboard, metal, plastics, glass and textile or all waste packaging and similar materials should be collected separately from biodegradable waste and mixed municipal waste. It is also necessary to increase the capacities for separating waste – sorting plants (for dry fraction and where appropriate mixed waste) and the capacities for treating biodegradable waste (composting plants, biogas plants).

*Table 1. Measures as stipulated in [23] for achieving national targets, with regard to landfill compliance and biodegradable waste.*

	NATIONAL TARGET	MEASURES
LANDFILLING	<p>a. Landfilling no more than 1.010.000 tons of waste on substandard landfills in 2016</p> <p>b. Landfilling no more than 800.000 tons of waste per annum on substandard landfills in 2017 and 2018 – presently we are at ~ 1.300.000 t</p> <p>c. To discontinue landfilling of waste on substandard landfills on 31 December 2018</p>	<ol style="list-style-type: none"> <li>1. Adopting the criteria concerning compliant landfills</li> <li>2. Defining the compliance status for each landfill</li> <li>3. Defining the mass of waste allowed to be disposed on each particular substandard landfill</li> <li>4. Monitoring the quantity of waste disposed on substandard landfill in real time by means of electronic system recording the production and flow of waste (e-ONTO)</li> <li>5. Preventing the disposal of quantities exceeding those permissible on substandard landfills by introducing gate fee</li> <li>6. Procurement of works, services and equipment aimed at bringing landfills into compliance</li> <li>7. Introducing a ban on waste disposal on substandard landfills after 31 December 2018</li> </ol>

DISPOSAL OF BIODEGRADABLE MUNICIPAL WASTE	<p>a. Disposal of no more than 378.088 tons of biodegradable municipal waste<sup>1</sup> on all landfills in the Republic of Croatia during 2016, 2017, 2018 and 2019 calendar years – presently we are at 800.000 t</p> <p>b. Disposal of no more than 264.661 tons of biodegradable municipal waste on all landfills in the Republic of Croatia during 2020 and 2021 calendar years</p>	<ol style="list-style-type: none"> <li>1. Designating the mass of biodegradable waste allowed for disposal at a particular landfill</li> <li>2. Designating the share of biodegradable waste in mixed municipal waste</li> <li>3. Reducing the quantity of mixed municipal waste produced</li> <li>4. Reducing the share of biodegradable waste in mixed municipal waste (stimulating composting in a household, stimulating the construction and outfitting of local plants for biological treatment-composting yards, anaerobic decomposition, etc. of biodegradable waste from restaurants, parks and from green markets, cessation of waste status for compost and anaerobic digestate)</li> <li>5. Reducing the quantity of mixed municipal waste for landfilling (sorting plants for dry fraction and for mixed waste, introducing the standard for minimum processing of waste prior to landfilling, introducing new methods of municipal waste bins content control and user identification)</li> <li>6. Stimulating the reduction of total quantity of waste landfilled by introducing the landfill gate fee</li> </ol>
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<sup>1</sup> refers to paper and cardboard, timber, kitchen waste, waste from canteens, biodegradable garden waste, waste from green markets and mixed municipal waste with established biodegradable part

*Table 2. The list of measures to be taken for separate waste collection system to be operational.*

RESOURCE	MEASURES
<ul style="list-style-type: none"> <li>• Paper, metals, plastics and glass</li> <li>• Special categories of waste<sup>2</sup></li> <li>• Separate biowaste collection system for the sake of composting and anaerobic digestion</li> </ul>	<ol style="list-style-type: none"> <li>1. Providing for the operation of separate collection of paper, metal, plastics and glass</li> <li>2. Providing for the operation of separate collection of special categories of waste</li> <li>3. Providing for the operation of separate biowaste collection</li> <li>4. Providing for the operation of local mixed municipal waste collection system</li> </ol>

<sup>2</sup> electrical and electronic waste, waste batteries and accumulators, end of life vehicles, end of life tyres, waste lubricating oils, waste textile and footwear, medical waste, asbestos waste



Table 3. *The measures ensuring appropriate processing of waste streams.*

NATIONAL TARGETS IN PROCESSING WASTE STREAMS	MEASURES
<p>a. Ensuring that at least 50 % of the mass of waste paper, metals, plastics and glass produced during calendar year in households and from other sources is recovered in the process of preparing for reuse or processed in a recovery process considered to be recycling (for 2020, 2021) – presently we are at 17%</p> <p>b. Ensuring that at least 70 % of the mass of non-hazardous construction waste is recovered in the process of preparation for reuse or is treated in a recovery process that is considered to be recycling or the process that involves the use of such material for backfilling (for 2019, 2020, 2021)</p> <p>c. Introducing compulsory sorting of waste that is not separated or is partially separated in a household</p> <p>d. Providing for appropriate treatment of waste that remains after extracting waste paper, metal, plastics and glass from mixed municipal waste</p>	<ol style="list-style-type: none"> <li>1. Instituting a ban on disposal for separately collected waste paper, metals, plastics and glass as well as waste paper, metals, plastics and glass extracted from mixed municipal waste, instituting an obligation of delivery of minimum quantities of separately collected and from mixed municipal waste separated waste paper, metals, plastics and glass for recycling with the scope of achieving national waste management targets, introducing and extending recycling capacities</li> <li>2. Stimulating the recovery of construction waste and stimulating cessation of the status of waste for certain construction waste types</li> <li>3. Proceeding with the construction of waste management centres in order to ensure the processing of mixed municipal waste, but not exceeding 25% of the originally designed capacity</li> <li>4. Stimulating the compliance with requirements for the cessation of waste status</li> </ol>

Potential locations of sorting plants are shown in figure 1.



Figure 1. Potential sorting plants sites [23].

An overview of planned waste management system is shown in figure 2, and targeted material flows are shown in figure 3.

## 8. Proposed approach to marine litter issue

The Draft Waste Management Plan 2016-2022 [23] embraced marine litter issue as well in an integrated manner. Given that about 80% percent of marine litter originates from land base-sources, it stated that in regulating the system of special categories of waste particular attention should be paid to preventing that waste ends up in the sea. The purpose of marine litter management is to ensure: a) the prevention of discarding of waste into marine environment or of handling waste in a way that it gets in marine environment and coastal area that is in direct contact with the sea, b) removal to the greatest possible extent of the existing quantities of marine litter in marine environment (sea surface, water column or sea bottom) and coastal area that is in direct contact with the sea using environmentally-friendly methods.

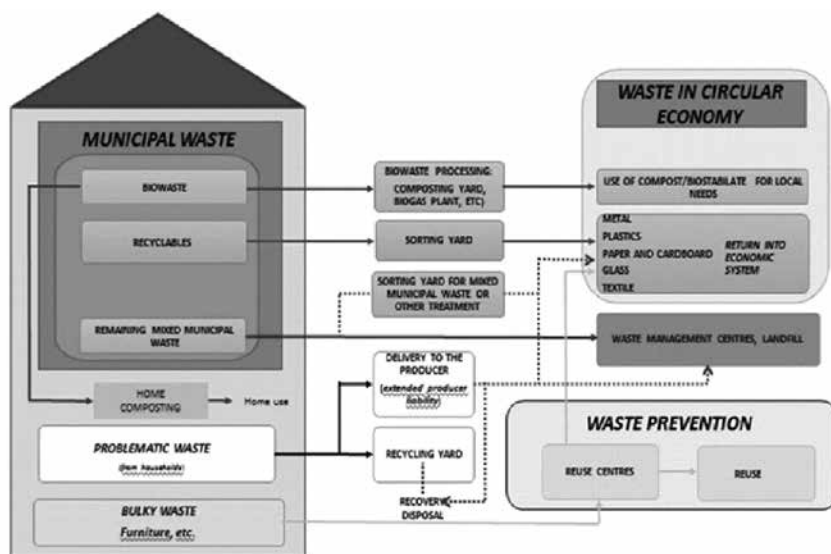


Figure 2. Flow diagram of planned municipal waste management system [23].

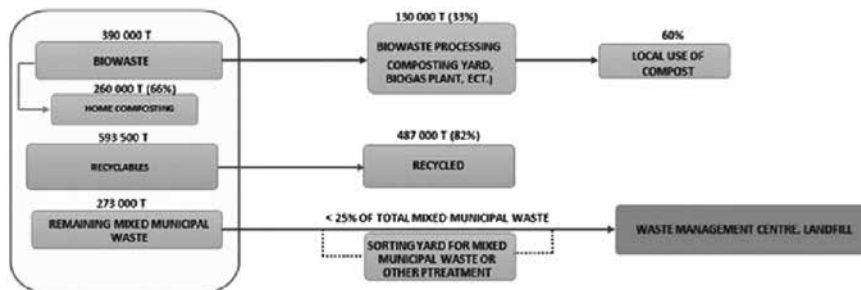


Figure 3. Targeted values of waste flow [23].

It furthermore points out that the Act on Sustainable Waste Management sets out that the removal of waste discarded in the environment falls within the responsibility of communal order service of the local self-government unit, but specified responsibility for marine litter on seawater surface, seawater column and sea bottom is insufficiently regulated. The waste management measures involve ensuring the avoidance and reduction of cross-border pollution of the Adriatic Sea by instituting appropriate cooperation among the states, handling waste on land so as to ensure that such waste does not reach the sea and in a manner that it is incorporated in the regulations and acts governing waste management at all levels, the measures for handling waste generated

through operation of ships, that being regulated by special law governing the operation of port facilities for reception of waste originating from ship operation, as well as the measures for waste management collected accidentally by fishing vessels nets while fishing.

Very important aspect in abating marine litter is waste prevention. In that respect the Draft [23] is much more specific and less at the level of good intentions compared to valid WMP in that it stipulates the legislation which needs to be adopted or amended, specifies the number of waste prevention centres to be established, the institutional and regulatory actions to be taken for preventing food waste, emphasizes the importance of personal consumption of population, particularly in the part related to habits when provisioning for food and drinks, clothes, footwear, furniture and market supply. It also stresses the importance of reuse centres and domestic and EU examples of best practice. The adopted Waste Management Plan 2017-2023 furthermore designates symbolic funds of 2.500.000 HRK for instituting the marine waste management system.

## 9. Conclusion

Marine litter in the Adriatic Sea presents a significant problem for the Republic of Croatia. Although it washes the coasts of other countries, Croatia, having a long coast, is both more affected by the problem and significantly contributes to its very generation. Namely, marine litter to a great extent mirrors waste management problem on the land. Therefore in trying to resolve marine litter problems one must start with the roots and that means changing current policy with regard to waste. Relying on collection, transport (very often seaborne from the islands) and treatment of mixed waste in order to produce refuse derived fuel of low quality for which there is no market means movement of waste over great distances, non-compliance with proximity principle, its potential leakage, and production of waste in a new form and creation of new landfills for this new form of that waste. In terms of price impact of such a system it also means that more and more illegal landfills will be created in karst terrain, near watercourses and along the coastline, meaning that destination of such waste will probably be the sea.

Major contribution to the solution of marine litter problem is waste management involving source separation, numerous local sorting facilities, home composting, municipal composting and biogas production, with minimum resources left for disposal. Such a turnaround in waste policy and alignment with circular concept was undertaken during 2016, but with time the old concept is being gradually restored, meaning that national targets will hardly be reached in due time.

Another important contribution in reducing marine litter, particularly in a country that relies heavily on tourism with all its seasonality and periodical pressures on public services would be implementing the policies to reduce and modify packaging, the materials used therefor and to avoid one-use and disposable plastic materials of all types. Such an approach implies change of habits, intervention in supply chain and increasing domestic supply of agricultural goods in particular.

Such changes would besides ensuring good environmental status of the sea, rivers, air, soil and land cover present significant opportunities for eco-innovation, small local businesses and local agriculture.

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## Izazovi morskog otpada u Jadranu

### Sažetak

Morski otpad značajno opterećuje plaže, površinu mora, morsko dno i biotu Jadranskog mora. Posljedica je uglavnom neprimjerenog gospodarenja otpadom na kopnu. Rad analizira količine i sastav morskog otpada i njegove izvore, opasnost plastike, pristup kružnom gospodarstvu i gospodarenju otpadom u Hrvatskoj i iznosi prijedloge za kružni tok materijala uz najmanje moguće istjecanje u ekosustave, te novi pristup problematici morskog otpada. Rješenje problema morskog otpada je u gospodarenju otpadom s odvajanjem na izvoru, brojnim lokalnim sortirnicama, kućnom i komunalnom kompostiranju i proizvodnji bioplina, uz minimalne resurse za odlaganje, te u oživotvorenju politika za smanjenje i promjenu ambalaže, i materijala za nju i izbjegavanje jednokratnih i plastičnih predmeta, što podrazumijeva promjenu navika, zahvaćanje u dobavni lanac i povećanje domaće ponude.

**Ključne riječi:** morski otpad, Jadran, okoliš, gospodarenje otpadom

