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Persistent marine litter: small plastics and cigarette butts remain on beaches after organized beach cleanups

Xenia I. Loizidou · Michael I. Loizides · Demetra L. Orthodoxou

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Abstract Cyprus is an island country in the Eastern Mediterranean whose economy is largely dependent on coastal tourism. It boasts some of the cleanest waters in Europe and has the largest number of Blue Flag awarded beaches per capita in the world. These beaches are managed by local authorities and are regularly cleaned, throughout the year, at least once per day. This paper presents findings from cleanups that were organized over the summers of 2016 and 2017 on nine Blue Flag beaches around the island of Cyprus, after the beaches were cleaned by the responsible authorities. The aim was to answer the following questions: 'Are regular beach cleanups by local authorities efficient?' and 'What is left on a "clean" beach?' The results suggest that local authority cleanup efforts are quite successful at collecting larger pieces of marine litter, leaving the beach seemingly clean. However, small pieces of litter, such as cigarette butts and small pieces of plastic items related to recreational activities, remain on the beach. They likely accumulate or are buried over time, with some items becoming a nuisance to beach goers and a potential source of marine litter.

X. I. Loizidou (✉) · M. I. Loizides · D. L. Orthodoxou
ISOTECH Ltd Environmental Research and Consultancy, Office 401, 1 Kalliopis Str., 2102 Aglantzia, Nicosia, Cyprus
e-mail: xenia@isotech.com.cy
URL: https://www.isotech.com.cy

M. I. Loizides
e-mail: michael@isotech.com.cy

D. L. Orthodoxou
e-mail: project@isotech.com.cy

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Introduction

"Marine litter is defined as any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (UNEP 2009). It is a global problem, with marine litter floating in the water, washed ashore on beaches and even found in deep remote areas (Pham et al. 2014). The potential of marine litter to lead to adverse environmental effects has been recognized by the European Commission; indeed, marine litter is now listed as one of the 11 Descriptors of the Marine Strategy Framework Directive, Europe's most integrative legislation on the protection of the marine environment (European Parliament 2008). These 11 Descriptors must be maintained in good environmental status (GES) to ensure the health of European seas. GES for marine litter is defined as "properties and quantities of marine litter do not cause harm to the coastal and marine environment".

Plastics have been recognized as the most abundant and persistent form of marine litter globally. The most comprehensive study to date suggests that 4.8–12.7 million metric tonnes of plastic waste enters the oceans annually, which is equivalent to 1.7–4.4% of the total plastic waste generated by coastal countries (Jambeck et al. 2015). It is estimated that over 5 trillion plastic pieces are currently floating around the world's oceans

(Eriksen et al. 2014). The chemical and physical properties of plastics, which make plastic materials versatile and useful in our everyday life, also make plastics a priority for marine litter management. The manufacturing process of plastic items requires the addition of often toxic additives to give plastics certain properties, whereas the hydrophobic nature of plastics means that they attract persistent organic pollutants found in the water (Andrady 2011; Deanin 1975; Koch and Calafat 2009; Rochman et al. 2013a; Tanaka et al. 2013). Cigarette butts, made of cellulose acetate, a form of plastic, also contribute to the accumulation and release of pollutants in the marine environment, as they have been found to be a point source of metal contamination, which can lead to the risk of acute harm to marine organisms (Moerman and Potts 2011).

Large pieces of plastic, called macroplastics, do not biodegrade but rather break down into continuously smaller pieces forming what is known as microplastics—plastic items smaller than 5 mm (the term 'microplastics' was first coined by Thompson et al. (2004) and the definition was agreed during the Proceeding of the International Research Workshop on the Occurrence, Effects and Fate of Microplastic Marine Debris in Arthur et al. 2009).

Encounters between marine litter and 693 species of marine organisms have been reported in literature, nearly 90% of which involve plastic litter (Gall and Thompson 2015). Such encounters have detrimental impacts on marine organisms. Macroplastics, such as plastic bags, six-pack rings, and fishing-related items, can be ingested by larger marine organisms causing blockages of the intestinal tract leading to starvation and reduced fitness (Bjorndal et al. 1994; Ryan 1988; Spear et al. 1995). Marine organisms can also become entangled in these items, causing incapacitation, reduced preying/feeding abilities, lacerations, suffocation, and drowning (Derraik 2002; Gregory 2009; Laist 1997). Microplastics can be ingested by marine wildlife transferring organic pollutants to their bodies, which can cause various health impacts, such as reduced energy reserves (Rochman et al. 2013b; Wright et al. 2013). Recent studies have shown that this can have important impacts on the food chain, as ingested microplastics have been identified in marine organisms destined for human consumption (Browne et al. 2008; Van Cauwenberghe and Janssen 2014). The possible effect that this can have on human health remains uncertain.

Over the years, several studies have investigated the amount and distribution of marine litter, and specifically plastics, in Europe and the Mediterranean (e.g., Aliani et al. 2003; Alomar et al. 2016; Baztan et al. 2014; Collignon et al. 2014; Eryaşar et al. 2014). Most recent estimates suggest that there are approximately 1455 t of floating plastic in the Mediterranean, with microplastics—most with surface area of 1 mm^2—being ubiquitous (Ruiz-Orejón et al. 2016). An investigation of microplastic ingestion in the fish *Boops boops* in the Mediterranean has found that 68% of examined stomach samples from this species in the Balearic Islands had microplastics in them, at an average of 3.75 items/fish (Nadal et al. 2014), highlighting that Mediterranean marine biodiversity is under threat from the increasing presence of plastics (Deudero and Alomar 2015).

Understanding where litter comes from, and through which pathways it enters the marine environment, is paramount to addressing the problem of marine litter. Identifying the sources of marine litter in general, and plastics in particular, is not an easy task, but the type of items collected through cleanup activities can give an indication of the main polluters (Pettipas et al. 2016). Perhaps the largest global cleanup campaign, implemented entirely by volunteers, is the International Coastal Cleanup (ICC), coordinated by the Ocean Conservancy and running in September each year. The 2017 edition of the ICC involved over 500,000 volunteers who collected nearly 14 million items from 24 km of coastline in 112 countries (Ocean Conservancy 2017). The top ten items collected worldwide highlight the abundance of plastics: cigarette butts (13.5%), plastic beverage bottles (11.4%), plastic bottle caps (5.9%), food wrappers (5.5%), plastic grocery bags (3.7%), plastic lids (3.0%), straws/stirrers (3.0%), glass beverage bottles (2.8%), other plastic bags (2.7%), and foam take away containers (2.6%). In the Mediterranean, a UNEP (2009) analysis of coastal cleanup data identifies the main sources of marine litter as shoreline and recreational activities (52%), smoking-related activities (40%), ocean/waterway activities (5%), medical and personal hygiene (2%), and dumping activities (1%). This information, however, is based on a limited dataset deriving from coastal cleanups in a small number of Mediterranean countries. Ideally, more extensive, country-specific datasets should be available to provide more accurate information.

Cyprus has some of the cleanest waters in Europe (European Environment Agency 2017), and the largest number of Blue Flag awarded beaches per capita in the world—63 beaches along 350 km of coastline (www.

blueflag.global). Blue Flag is an international eco-label for beaches, marinas, and boats, operated by the Foundation for Environmental Education (Foundation for Environmental Education 2017). The Blue Flag is awarded to beaches by an independent national jury following the evaluation of whether stringent environmental, educational, safety-related, and access-related criteria are met. One of the program's environmental criteria is that a beach must be cleaned and maintained at all times. In Cyprus, Blue Flag beaches are managed by local authorities and are regularly cleaned, at least once a day. However, despite the fact that the economy of Cyprus is heavily dependent on tourism (7% of the GDP; Republic of Cyprus 2017), there is very little published information on the amount of litter found on its beaches, floating in its waters or resting on its seabed, and its likely effect on tourism. Given that 85% of beach goers would not visit beaches with more than 2 items of litter per meter and 97% would not return to a beach with over ten large items of litter (Ballance et al. 2000), it is crucial to understand whether regular beach cleanups by local authorities are efficient and what, if anything, is left on a 'clean' beach.

In response to these two questions, this paper presents findings from cleanups that were organized over the summers of 2016 and 2017 on nine Blue Flag beaches around the island of Cyprus, immediately after the beaches were cleaned by the responsible authorities. The data were captured using a consistent methodology highlighting the importance of citizen science in marine litter data capture.

Method

Cleanup campaigns were organized between the months of May and August in the summers of 2016 and 2017. The campaigns were based on civic action, aiming to incorporate members of the public to provide repeated sampling for time series. A key challenge was to ensure standardized methods and quality control so that the samples and data could legitimately be compared and used in peer-reviewed research (Zettler et al. 2017).

To ensure a consistent approach, the beach cleanups were structured and implemented as follows:

- Standardized method: The Ocean Conservancy's International Coastal Cleanup Protocol, which includes a standardized data form composed of 41 discrete items (Zettler et al. 2017), was used to record litter and identify its source. The Protocol was used by Akti Project and Research Centre (AKTI; akti means 'coast' in Greek), the NGO organizing and implementing this research in Cyprus, for the following reasons: (i) the International Coastal Cleanup, implemented by the Ocean Conservancy, a non-governmental organization based in the USA, is one of the most successful examples of citizen science used to monitor marine litter globally. The organization coordinates a global cleanup and data capture effort and presents the resulting data in an online database and an annual report. Therefore, the Ocean Conservancy's International Coastal Cleanup Protocol is the one with which most volunteers and NGOs are familiar, (ii) AKTI is the national coordinator of the Ocean Conservancy in Cyprus and this is the protocol that it uses in all its cleanups. Therefore, its use in these occasions ensured consistency in data capture, and (iii) The International Coastal Cleanup Protocol is simple, easy to follow, and user-friendly. This was particularly important, as in some occasions, the cleanup participants were children.
- Selection of beaches: The nine beaches included in the campaign were chosen based on their popularity/touristic activity and ease of access. This was the initial and very important step, since the beaches to be selected would be the beaches to implement the campaign every year in order to have comparative results.
- Method of cleanup/source identification: these dedicated beach cleanups took place once a year, on the same beach, at the same period of time (within the same week). There was a specified duration for each cleanup and a specific area to be covered. Furthermore, litter was collected and recorded in categories per item. This allowed for calculations and results in terms of litter per meter of coast.
- Involvement of local stakeholders and decision makers: to raise awareness and develop 'ownership' for 'clean beaches', it is important to have the active participation of local stakeholders and decision makers. To make the campaign more attractive to local authorities, AKTI contacted Blue Flag Cyprus proposing to include this activity as one of the five obligatory environmental activities that a local authority must implement every year to maintain the Blue Flag Award. Blue Flag Cyprus accepted the proposal and actively supported the implementation every year:

local authorities with Blue Flag beaches were contacted in mid-spring each year and a cleanup schedule was set up. This cooperation among AKTI and Blue Flag proved to be a very smart and effective 'win-win tool' of engagement: local authorities supported the campaign inviting local stakeholders to participate. Once the cleanup schedule was determined, a call for volunteers was published on social media. On the day of the cleanups, staff from AKTI met up with local authority staff and volunteers on the beach in the morning (around 9 am), after the local authority had cleaned the beach.

- Hands-on awareness raising and training: The staff of AKTI implemented a short training to all the participants before the cleanup on how to apply the Ocean Conservancy Protocol to record the amount of litter collected, so that everyone was familiar with the protocol and the data record sheets.

Results

An area of 20,980 m^2 was cleaned by 214 participants who collected a total number of 7658 items of litter during the summer 2016 and 2017 cleanup campaigns from nine Blue Flag beaches around Cyprus (i.e., a total of 18 cleanup events, nine each year) (Table 1). The cleanup data were broken down into types of items, as they were recorded on the Ocean Conservancy's International Coastal Cleanup datasheets (see Table 2). The top ten list of identifiable collected litter by number was made up of cigarette butts ($n = 4552$; 59.4%), food wrappers ($n = 452$; 5.9%), straws ($n = 434$; 5.7%), plastic bottle caps ($n = 124$; 1.6%), other plastic or foam packaging ($n = 119$; 1.6%), beverage cans ($n = 80$, 1.0%), metal bottle caps ($n = 70$; 0.9%), plastic grocery bags ($n = 63$; 0.8%), balloons ($n = 63$; 08%), and plastic cups and plates ($n = 55$; 0.7%) (plastic pieces smaller than 2.5 cm made up a significant proportion of the collected litter ($n = 488$; 6.4%), but as these items are not identifiable, they were excluded from the top ten list). There are some similarities between the top ten list of these cleanups, with that of the 2017 International Coastal Cleanup, specifically the inclusion of cigarette butts, food wrappers, straws, bottle caps, and grocery bags (Ocean Conservancy 2017). The data presented herein are in greater agreement with the data presented in Pettipas et al. (2016), collected during the Great

Table 1 Cleanup sites and basic cleanup information

Cleanup No.	Cleanup site	Longitude	Latitude	Length cleaned (m) every year	Width cleaned (m) every year	Area cleaned (m^2)	No. of participants (2016)	No. of participants (2017)	No. of collected items (2016)	No. of collected items (2017)
1	Akti Olympion A	33.0602	34.6843	40	15	600	4	11	421	651
2	Geroskipou Beach	32.443	34.7363	20	15	300	15	25	461	636
3	Governor's Beach	33.2746	34.7174	90	8	720	10	12	230	453
4	Kourion Beach	32.8772	34.6659	60	17	1020	2	13	233	425
5	Mackenzie Beach	33.6377	34.8894	40	25	1000	4	30	454	1224
6	Makronisos Beach	33.9551	34.9829	75	30	2250	8	19	279	326
7	Panagies Beach	33.1689	34.7117	90	30	2700	3	12	152	269
8	Pyrgos Lemesou SODAP Beach	32.4215	34.7502	50	20	1000	8	20	217	649
9	Souli Beach	32.3844	35.0416	90	10	900	6	12	322	256
Total				555 per year	170 per year	10,490 per year	60	154	2769	4889

Table 2 Type, number, and percentage of collected items from18 cleanups (nine per year)

Item	No. collected 2016	Percentage of total (by number) 2016	No. collected 2017	Percentage of total (by number) 2017	Total No. collected or both years	Percentage of total for both years
Cigarette butts	1545	55.80	3007	61.51	4552	59.44
Food wrappers	98	3.54	354	7.24	452	5.90
Take out containers Plastic	24	0.87	9	0.18	33	0.43
Take out containers Foam	2	0.07	0	0	2	0.03
Bottle caps plastic	46	1.66	78	1.60	124	1.62
Bottle caps metal	13	0.47	57	1.17	70	0.91
Lids plastic	17	0.61	26	0.53	43	0.56
Straws	252	9.10	182	3.72	434	5.67
Forks knives spoons	12	0.43	13	0.27	25	0.33
Beverage bottles plastic	34	1.23	10	0.20	44	0.57
Beverage bottles glass	11	0.40	2	0.04	13	0.17
Beverage cans	71	2.56	9	0.18	80	1.04
Grocery bags plastic	51	1.84	12	0.25	63	0.82
Other plastic bags	23	0.83	6	0.12	29	0.38
Cups plates paper	9	0.33	0	0	9	0.12
Cups plates plastic	36	1.30	19	0.39	55	0.72
Fishing buoys pots traps	1	0.04	0	0	1	0.01
Fishing net pieces	2	0.07	6	0.12	8	0.10
Rope	17	0.61	3	0.06	20	0.26
Fishing line	0	0	2	0.04	2	0.03
Other plastic foam packaging	0	0	119	2.43	119	1.55
Other plastic bottles	2	0.07	1	0.02	3	0.04
Strapping bands	0	0	46	0.94	46	0.60
Tobacco packaging wrap	11	0.40	3	0.06	14	0.18
Balloons	13	0.47	50	1.02	63	0.82
Cigarette lighters	5	0.18	2	0.04	7	0.09
Construction Materials	0	0	2	0.04	2	0.03
Condoms	3	0.11	0	0	3	0.04
Tampon applicators	0	0	1	0.02	1	0.01
Foam pieces < 2.5 cm	11	0.40	48	0.98	59	0.77
Glass pieces < 2.5 cm	27	0.98	3	0.06	30	0.39
Plastic pieces < 2.5 cm	322	11.63	166	3.40	488	6.37
Number of other	111	4.01	653	13.36	764	9.98
	2769	100.00	4889	100.00	7658	100.00

Canadian Shoreline Cleanup for Canada and Nova Scotia in 2014, as eight of the top ten items are the same.

All the items in the top ten list presented herein are single-use plastics, most of them are relatively small in size, and the majority of them are as a result of either smoking-related or recreational activities (Fig. 1). Smoking-related items (consisting of cigarette butts, lighters, cigar tips, and tobacco packaging) made up 59.7% of the total items collected. Recreational items (consisting of food wrappers, plastic take-out containers, foam take-out containers, plastic bottle caps, metal bottle caps, plastic lids, straws, forks, knives and spoons, plastic beverage bottles, glass beverage bottles, beverage cans, paper cups and plates, plastic cups and plates, foam cups and plates, balloons and condoms) made up 18.9% of the total items collected, other plastic items (consisting of plastic grocery bags, other plastic bags, other plastic/foam packaging, other plastic bottles,

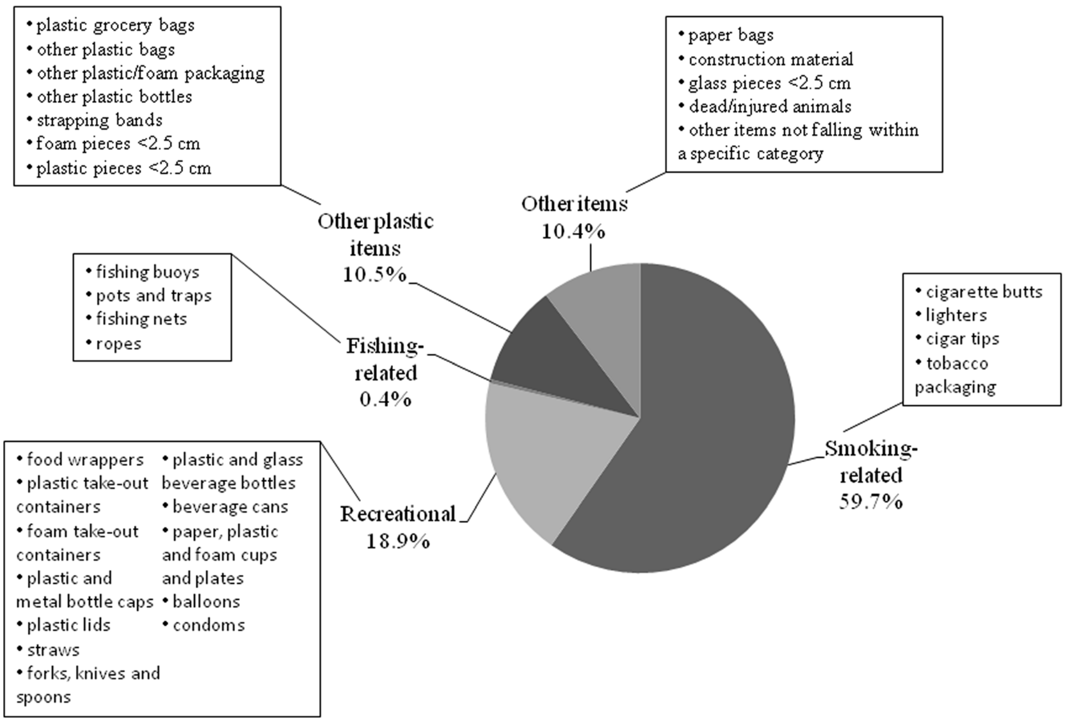

Fig. 1 Breakdown of items collected, by generating activity (average for 2016 and 2017). Text in boxes lists the items included within each generating activity

strapping bands, foam pieces < 2.5 cm and plastic pieces < 2.5 cm) made up 10.5%, other items (consisting of paper bags, construction material, glass pieces < 2.5 cm, dead/injured animals, and other items that did not fall within a specific category) made up 10.4% and fishing-related items (consisting of fishing buoys, pots and traps, fishing nets, rope) made up just 0.4%.

There are some differences between the data presented here and other data reported by UNEP (2009) and the Marine Conservation Society (2017). UNEP reported that 40% of collected litter had smoking-related activities as its origin whereas 52% originated from recreational activities. On the other hand, Marine Conservation Society data attribute around 30% of collected litter to a source defined as 'public', which includes food and drink packaging and smoking-related debris. The differences in the data could be attributed to various factors, most importantly to the fact that the cleanups presented herein were implemented after the regular cleanups by local authorities and to the different protocols used. What emerges, however, is that cigarette butts and smoking-related debris and single-use plastics regularly make up the largest portions of marine litter collected on beaches (Marine Conservation Society 2017; Ocean Conservancy 2017; Pettipas et al. 2016).

Discussion

In accordance with the Blue Flag programme criteria, all of Cyprus's 63 Blue Flag beaches, including the nine incorporated in this research effort, are cleaned on a daily basis (at least once a day) by the responsible local authority. The data captured and presented herein suggest that these local authority cleanups are quite successful at collecting larger pieces of marine litter, leaving the beach seemingly clean. However, the aim of this research was to indicate what is left on the 'cleanest' beaches. Here, we show that small pieces of litter, such as cigarette butts and small pieces of single-use plastic items related to recreational activities, remain on the beach. It is not surprising that plastic is the most abundant type of litter found on beaches in terms of numbers, as other research has also demonstrated that this is the case (Derraik 2002; Nelms et al. 2017). Neither is it surprising that cigarette butts are recovered in large numbers (Martin 2013; Pettipas et al. 2016), especially from Mediterranean beaches (UNEP 2009). Nonetheless, the relative abundance of these items is quite worrying, considering that they are possibly never removed and may accumulate over time.

Given the negative impacts of small plastic items and cigarette butts already discussed above, the data presented in this paper suggest that it is particularly important to implement measures that will reduce the abundance and leakage of single-use plastics from land-based sources. Educating and raising awareness of the general public to the issue of marine litter is one such measure, as they are the main culprits for this small persistent marine litter. The general public must become aware of the fact that the items left on beaches are a direct result of their activities (smoking, drinking, eating) and are dangerous for the environment and public health. Citizen science and coordinated actions are important pillars in addressing the issue of marine litter internationally.

The cleanup activities themselves are an important education and awareness-raising tool, particularly as they involve volunteers. As demonstrated above, the number of volunteers joining AKTI in its cleanup efforts increased dramatically between 2016 and 2017, demonstrating the effects of interactive processes and of active involvement of citizens in the research effort (i.e., on implementing protocols, hands-on data capture etc.). At the end of each cleanup and after the conclusion of the source identification process, the staff of AKTI discussed with the participants the issues of microplastics, the impacts of marine litter on marine life, on public health etc. Best practices and examples of effective marine litter management were presented as a tool for capacity building and a source of inspiration (Loizidou et al. 2014). Participants were surprised of their own findings regarding the abundance of this small, 'unknown' danger, and of the sources of marine litter found on clean beaches. As a result, they felt committed to act. The increase in the number of volunteers joining the cleanup events likely confirms the positive effect participation in cleanups had on the campaign. In fact, environmental education can have a positive effect on awareness and concern regarding marine litter and can also enhance the performance of litter reducing activities, especially in children (Hartley et al. 2015).

Although education, awareness-raising, and source identification are important aspects of an integrated solution to plastic marine litter management, they must be combined with the implementation and enforcement of an efficient and integrated regulatory system, waste management strategies, increased monitoring, implementation of the extended producer responsibility principle and promotion of the circular economy in order to effectively address the issue of marine litter, and especially single-use plastics, including cigarette butts, from land-based sources (Carman et al. 2015; Hastings and Potts 2013; Liu et al. 2018; Pettipas et al. 2016; Schuyler et al. 2018; Willis et al. 2018).

The implementation of the goals of the Honolulu Strategy, formulated during the Fifth International Marine Debris Conference (5IMDC) in March 2011, is a significant step in this direction. The Honolulu Strategy is a global framework for concerted actions, bringing together all the stakeholders, to address marine litter through the implementation of three goals and associated strategies (UNEP and NOAA 2011). Goal A "Reduced amount and impact of land-based sources of marine debris introduced into the sea", specifically the strategies that focus on market-based instruments to minimize waste and on creating policies, regulations, and legislation to reduce marine litter, are particularly pertinent to reducing marine pollution from single-use plastics (Xanthos and Walker 2017). Following the 5IMDC, the Sixth International Marine Debris Conference was held in San Diego, USA, in March 2018. It brought together the main stakeholders to share lessons and exchange best practices and innovative ideas on how to reduce and prevent marine litter (Walker 2018).

The EU's Action Plan for a Circular Economy, including the EU Strategy for Plastics, is in accordance with and builds on the Honolulu Strategy, as it lays the foundation to a new plastics economy that will move away from a make-use-discard model to one where plastic waste is minimized and plastic recycling is maximized through, inter alia, new and revised legislation on waste management, designing for sustainability, and extended producer responsibility, thus creating the necessary market value for plastics (EU 2014; EU 2018). Measures such as the ban or taxation on single-use carrier bags of a certain weight implemented in Ireland, England, and Portugal show encouraging results with reductions in plastic bag consumption ranging from 75 to 94% and, in certain cases, an associated overall change in environmental perceptions (Convery et al. 2007; Martinho et al. 2017; Smithers 2016). Similar bans and taxes could be expanded to include other single-use plastics, such as very lightweight and heavy-weight plastic bags, straws, microbeads used in cosmetics, and even cigarette butts (Axelsoon and van Sebille 2017; Pettipas et al. 2016; Steensgaard et al. 2017; Walker and Xanthos 2018; Xanthos and Walker 2017). Other market-based instruments, such as deposit refund schemes, can also lead to a reduction in inappropriate disposal of single-use plastics (Schuyler et al. 2018; Walker and Xanthos 2018).

In addition to these policies and measures, researchers are recommending the development of new structures or instruments to actively regulate the sources, trade and impacts of plastics, which could take the form of a "Plastics Stewardship Council", a CSR scheme along the lines of the Marine Stewardship Council model (Landon-Lane 2018), a "Global Convention on Plastic Pollution" (Worm et al. 2017) or a legally binding protocol along the basis of the Montreal Protocol (Raubenheimer and McIlgorm 2017). This suggests that, at least within a certain part of the research community, the existing legislative framework is deemed inadequate to address the land-based sources of single-use plastics, as corporate interests can pose significant resistance to anti-plastic norms (Dauvergne 2018). However, this might change if the newly proposed Directive on the reduction of the impact of certain plastic products on the environment is adopted by the European Parliament and Council (European Commission 2018). The Directive aims to restrict the use of some of the most common single-use plastic products (e.g., straws, plastic plates and cutlery, cigarette butts etc.), through a mixture of bans, consumption reduction targets, collection and recycling targets, labeling requirements, awareness-raising measures, and extended producer responsibility.

Conclusion

Here, we show that single-use plastic items deriving from recreational activities taking place on or near the beach, including smoking-related activities, remain on the beach even after the regular cleanups by local authorities. This can have important environmental and economic impacts, as they are most likely never removed and possibly accumulate. While the necessary legal framework is being put in place to address these land-based sources of plastic marine pollution, there still remains a gap in implementation. Cleanup actions by civil society organizations have an important role to play in bridging part of that gap by not only removing possibly persistent plastics from the coastal environment, but by also helping to identify the main sources of marine litter and raising awareness in the general public.

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