OCCURRENCE AND DEGRADATION OF SINGLE-USE PLASTIC IN COASTAL AREA

KAIRE TORN, TIIA MÖLLER-RAID & GEORG MARTIN
Estonian Marine Institute, University of Tartu, Estonia.

ABSTRACT

Increasing trend of littering of coastal areas and marine environment is recognized globally. In the European Union, 80–85% of marine litter is plastic, among which single-use plastic (SUP) products represent 50%. The study confirmed that the primary source of SUP items on urban beaches of Tallinn, Estonia, is direct littering by beach visitors. The level of littering is highly dependent on the intensity of beach use. In total, 1492 macrolitter items per 100 m of beach length were registered at urban beach Russalka, while remarkably lower values were registered at semi-urban beach Kakumäe. The most frequently found SUP items at urban beach were cigarette butts, followed by various packages and sweet wrappers. To assess how quickly the fragmentation of selected SUP products takes place in the natural environment, field experiments were carried out. The degradation of disposable paper plates, biodegradable plates and biodegradable waste bags was studied in two terrestrial (open-air vs. buried in soil) and two marine (submerged in seawater above sediment vs. buried in sediment) treatments. The experiment showed that the degradation of biodegradable SUP items is limited in natural environment and varied depending on the character of the material of the product and the environment it was exposed to. The studied biodegradable plates had the fastest degradation rate (4 months) and the loss of material was the highest during the first months. In open-air conditions, the degradation process was the slowest. For the biodegradable plastic bags, noticeable decomposition took place only in the seawater above sediment; in other environments, the degradation was slower. Therefore, to decrease the impact of plastic, instead of using biodegradable material, the guidance of consumers toward reducing, reusing and recycling of plastic should be promoted.

Keywords: Baltic Sea, beach litter, biodegradable products, discarded macrolitter, disposable plastic, marine debris, plastic pollution.

1 INTRODUCTION

Both terrestrial and marine environments are facing an increasing trend of littering, with plastic being the main component of anthropogenic litter [1]. Accumulation of plastic debris is most visible in coastal marine ecosystems like beaches and shallow nearshore seabed. In the European Union (EU), 80–85% of marine litter is plastic, among which single-use plastic (SUP) products compose 50%. SUP products include a diverse range of commonly used consumer products that are discarded after having been used once for the purpose for which they were provided. These products are rarely recycled and are prone to becoming litter. SUP products are therefore a particularly serious problem in the context of marine litter as they pose a severe risk to marine ecosystems, to biodiversity and to human health [2].

The production and use of biobased and/or biodegradable plastics are rising globally [3]. SUP is a difficult material to manage as it is usually not easily degraded under common waste management practices. In the context of mitigating the negative effect of the use of plastic, it seems to be more attractive to use biodegradable polymers. The SUP products (both non-degradable and biodegradable) often end in the marine environment, which is not an optimal media for biodegradation as the necessary conditions for full degradation are not met (e.g. low temperature and oxygen-level conditions present in marine environment) [4]. Although degradation under laboratory conditions vs. degradation under natural conditions

ISSN: 2398-2640 (paper format), ISSN: 2398-2659 (online), http://www.witpress.com/journals
DOI: 10.2495/EI-V5-N2-105-115

vary greatly [5], there is only a small number of studies investigating the fate of macrolitter in nature [6], especially in the marine environment [7]. Studies performed in an artificial environment could be used to test the stability of a material and are not suitable for describing the effect of complex environmental conditions.

Describing the distribution of most common litter items in coastal areas is needed to effectively fight against littering of the marine environment. The topic of marine litter is included in the Marine Strategy Framework Directive developed by the EU to manage and protect the marine environment across Europe more effectively as one of the 11 descriptors of Good Environmental Status. The EU requires the member states to ensure that the composition and amount of litter in the sea area are at levels that do not cause adverse effects on the biological communities. Therefore, litter shall be monitored along the coastline and sea area and information on the source and pathway of the litter shall be collected where feasible [8]. Although the number of articles on marine litter has increased in recent years, there is limited information available on the composition and quantities of beach litter in the northern Baltic Sea [9].

Littering the environment is a great concern on both local and global levels. In order to make changes, an integrated approach is needed, including knowledge of e.g. human behaviour, material science, global economy and ecology. Current study expands our knowledge of the distribution of litter in the coastal area of NE Baltic Sea and the durability of SUP products both in the natural terrestrial and marine environment. The aims of this study were to (1) quantify and identify the composition of SUP and macrolitter in urban and semi-urban coastal areas, (2) evaluate the influence of human activity on beach littering and (3) assess the degradability of single-use products under different environmental conditions. We hypothesized that natural conditions occurring in coastal zone (both terrestrial and marine environment) are not suitable for full degradation of biodegradable products.

2 MATERIAL AND METHODS

2.1 Occurrence of SUP

The abundance and composition of macrolitter were studied at the two sandy beaches: Russalka and Kakumäe (Fig. 1). Both studied beaches are located in the Estonian capital city Tallinn, which has a population of about 446,000 inhabitants. The beach cleaning activities on both beaches are irregular and take place mostly during the summer season. To have the longest possible litter accumulation period beforehand and have least effect from cleaning activities, our sampling was performed before cleaning events in spring, May 2020.

The studied beaches are very different in terms of human activity. Urban beach Russalka is in the vicinity of residential areas with large apartment buildings and a population of over 100,000 inhabitants. Due to the promenade and other leisure facilities, the Russalka area is highly visited all year round. The coastline is especially popular as a beach walk area. Although widely used, the beach lacks public toilets. The Russalka beach is 1 km from the regular ferry lines and active ferry harbour. Kakumäe Peninsula is an area of private houses with a population of 2,000. Outside of the summer season, the beach is mostly visited by locals and could be classified as a semi-urban beach.

Sampling followed the OSPAR beach monitoring guidelines [10]. The standard monitoring area of the OSPAR methodology is 100 m long and the width of the monitoring area extends

Figure 1: Location and the main facilities of the studied beaches. Sampling transects are marked with red line, 1 – seafront promenade, 2 – seating areas, 3 – sport facilities, 4 – children playground and 5 – parking lot.

from the waterline to the beginning of the vegetation. In this area, all the litter objects are counted and determined. The beach width ranged between 15 and 25 m in both sites. The minimum size of the longest side of the coastal macrolitter is set at 2.5 cm. This size also includes bottle caps and majority of cigarette butts [11].

2.2 Degradation of SUP

In situ degradation experiment was carried out between June 2018 and April 2019 in Kõiguste, Saaremaa Island, Estonia. The local climate features four seasons of near-equal length. Monthly average air temperatures varied from 20.3 °C in summer to −1.9 °C in winter (State Weather Service data). Environmental data are given in more detail in [12].

The following disposable items were tested in a degradation experiment: 1) paper plate (15 cm in diameter), the main material is cellulose with a thin layer of polyethene, 2) biodegradable plate (15 cm in diameter) and 3) biodegradable waste bag (capacity of 6 L). The last two products were labelled as 100% biodegradable and compostable.

The dry weight of each product was measured prior to the experiment. Each item was placed into its own mesh bag with a mesh size of 4 × 4 mm. The used mesh size allowed the passage of invertebrates during the experiment. All mesh bags were labelled before closing. Three replicate samples for every three products were used to investigate each of the environmental conditions. Each sample bag was sampled only one time.

The degradation rate of the assessed products was tested in two terrestrial (open-air, buried in soil) and two marine (submerged in seawater above sediment and buried in sediment) environments. The degradation experiment was conducted in these environments as in coastal areas litter may be easily trapped either in sea or land – e.g. light litter items are easily transported inland by the wind and change of water level and these litter items may stay on the ground or get buried within sediment and organic material (leaves, grass, etc.). A terrestrial setup was performed in a mowed lawn in Kõiguste (58.3733°N, 22.9818°E) where humus-rich garden soil prevails. Field experiments in marine conditions were conducted in shallow, semi-enclosed Kõiguste Bay, northern Gulf of Riga, NE Baltic Sea (58.3714°N, 22.9816°E). Bottom substrate of the location was fine sand with mud (90% and 10%, respectively), water depth with normal water level was 0.5 m. The distance between terrestrial and marine experimental plot was 250 m. Sample bags were anchored in place for each of their associated environmental conditions. The buried samples were covered with a 5-10 cm thick layer of soil or sediment.

The samples were removed from the experimental sites 2, 3, 4 and 10 months after installation. The samples were packed separately and transported into lab for further analysis. The material was removed from the bag, cleaned gently and dried at room temperature to constant weight. Weight loss was used to quantify the extent of degradation. Results were expressed as the percentage of remained dry weight of material compared to initial weight.

The results of the degradation experiment were statistically analysed using the factorial ANOVA. The effects of factors (type of products, sampling time, and test environment) on the loss of weight were tested. Tukey's HSD post hoc test was used to analyse the differences between groups.

3 RESULTS

3.1 Occurrence of SUP

A total number of 1,492 macrolitter items per 100 m of beach length were registered at urban beach Russalka; 75% of litter was composed of plastic. Glass and ceramic formed 17%, metal 3% and processed wood 2% of the material. Other materials (chemicals, rubber, paper, textile and food waste) each accounted for less than 1%. Altogether, 67 items were found at semi-urban beach Kakumäe, plastic formed 73% of that, followed by processed wood (21%). Only single items of other materials (metal, paper and food waste) were found.

Table 1: SUP waste composition and proportion collected from Russalka and Kakumäe beaches in May 2020.

	Russalka		Kakumäe	
SUP items	Items/100 m of beach length	Percentage among SUP, %	Items/100 m of beach length	Percentage among SUP, %
Cigarette butts	481	63.2	3	16.7
Plastic packages	87	11.4	10	55.6
Sweet wrappers	85	11.2	0	0
Plastic bags	25	3.3	0	0
Sanitary items	25	3.3	2	11.1
Take-away (drink, food) containers	24	3.2	0	0
Bottle caps and rings	13	1.7	2	11.1
Bread bag closure	10	1.3	0	0
Tableware, cutlery, and straws	9	1.2	0	0
Other items	2	0.3	1	5.6

At Russalka beach, SUPs formed 51% of all collected litter items (761 out of 1492) and 68% of all collected plastic items (761 out of 1114) (Table 1). The rest of the plastic items were mostly fragments of film and plastic, whose origin could not be identified. The most frequently found SUP items were cigarette butts, followed by various packages and sweet wrappers. At Kakumäe beach, the percentage of SUP products among plastic was lower; 27% of all collected litter items (18 out of 67) and 37% of all collected plastic items (18 out of 49) (Table 1). Plastic packages were most often found.

3.2 Degradation of SUP

The results of the experiments showed that degradation rates varied both between the material of the products and tested environments (ANOVA, $F = 4.6$, df = 18, $p < 0.05$). Amongst all tested materials, degradation was highest when the products were submerged in seawater above sediment, where 83-100% of the material was decayed at the end of the experiment (Fig. 2, Tukey HSD test, $p < 0.05$). The remarkable loss of mass took place during the first 3 months (Fig. 3). The next tested environment that promoted the degradation was terrestrial and buried in soil, and degradation was slowest when products were exposed to open air. In open air, the maximum weight loss was 17% after the 10-month exposure period.

When comparing the materials, the biodegradable plates showed the maximum degradability (Tukey HSD test, $p < 0.05$). The biodegradable plates had completely disappeared from the mesh, while plates were buried in soil in terrestrial environment or laid above sediment in marine environment (Fig. 2). Paper plates showed comparable values while submerged in seawater above sediment but had remarkably lower loss while buried in soil (Tukey HSD test, $p < 0.05$). Biodegradable bags showed the lowest degradation rates in all environments. The weight loss of the bags was below 20% in three tested environments (Fig. 2).

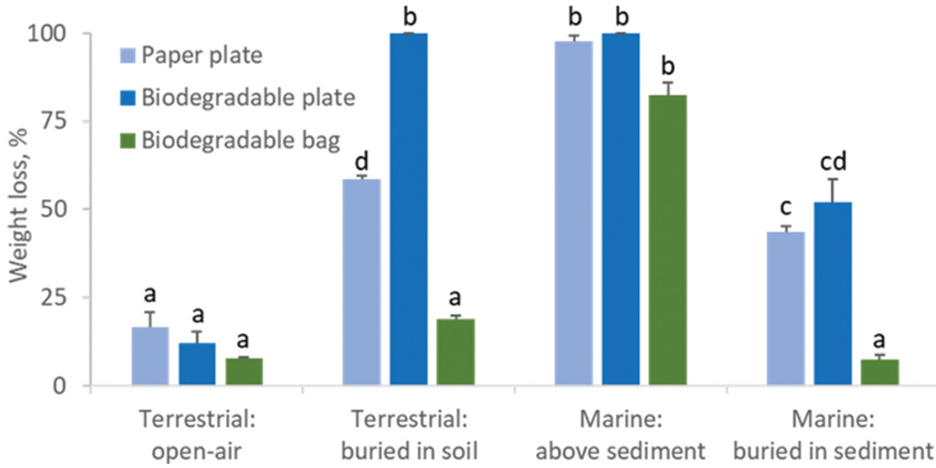

Figure 2: Average weight loss + S.E. of three SUPs in different environmental conditions at the end of the experiment (10-month exposure period). Columns indicated by the same letter did not differ significantly (Tukey HSD test, $p > 0.05$).

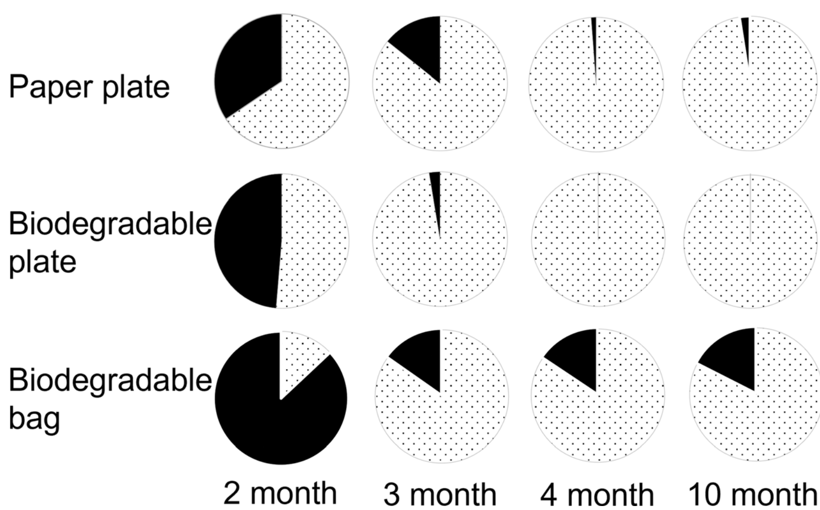

Figure 3: Average loss of weight of three SUPs exposed to marine environment above sediment.

4 DISCUSSION

The study showed that the primary source of SUP items on urban beaches is direct littering by beach visitors. The level of littering was dependent on the intensity of the beach use. Plastic products and fragments formed up to 75% and SUP items up to 51% out of all litter items. The experiment showed that the ability of degradation of biodegradable SUP items is limited in natural environment and varies depending on a product's material composition and the environment it is immersed in. The degradation of the biodegradable bags was remarkably lower compared to the other materials under consideration. The greatest loss of material was observed for biodegradable plates buried in the soil and in the sea above sediment; full decomposition took place within 3-4 months. Additionally, standard paper plates displayed a higher rate of degradation when compared to biodegradable bags.

The most popular beaches and urban beaches are under high anthropogenic pressure by littering and thus having a huge negative impact on the environmental quality of marine ecosystems [13], [14]. The effect of litter on the different components of the environment is very complex. Macrolitter is reported to be harmful for wildlife by entanglement or ingestion of litter [15]. Once plastic materials are discarded in the environment, both chemical degradation (initiated by heat and UV radiation) and physical degradation (mainly caused by mechanical stress in the environment) occur [7]. The risk of ingestion by biota increases with the degradation of the macroplastic into a microplastic. As a result, the organisms are affected by the release of hazardous chemicals [15].

It is reported that locally manufactured products may form over 90% of litter at urban beaches, while remote beaches receive 30% or less of local litter [16]. The number of litter items per 100 m of popular tourist areas or urban beaches may vary from hundreds to thousands [17], [18]. In the Baltic Sea, the northern Baltic Sea (Gulf of Finland, Bothnian Sea and northern Baltic Proper) is considered as the most littered region. Based on data from eight countries, 258 litter items per 100 m in urban and 169 items in semi-urban beaches have been reported [19]. Compared to Baltic Sea averages and data from the current study, the abundance of litter was more than five times higher at urban beach Russalka and two times less at semi-urban beach Kakumäe. Maximum; 20 items per 100 m coastline on average was agreed as an acceptable amount of litter indicating good environmental status of assessment unit by EU member states. The complete absence of beach litter cannot be expected as unintentionally lost items and existing litter occurs [20].

Plastics used only once (plastic bags, packages, cutlery and straws) are significant sources of marine plastic pollution [21]. The most frequently occurring SUP products in beach litter items on Baltic Sea scale are attributed to eating, drinking or smoking activities, such as food wrappings, bottles or lids, as well as plastic pieces of different sizes [19]. Contrarily, in areas with limited access, higher proportion of products with higher buoyancy (e.g. pellets, foam and bottles) can be found [22], [23]. Similar to other easily accessed coastal areas in Europe [24], cigarette butts and plastic packages were found most often both at Russalka and Kakumäe beaches. The remarkably large number of cigarette butts in the beach suggests that people's awareness of the harmful effects of filters on marine life is still low.

It is widely known that litter begets litter [25], [26], [27] and, in the fight against littering, environment-responsible behaviour is one crucial aspect [28], [29], [30]. The social pressure to condemn littering is rising both on global and local levels, and the altruistic behaviour as such is rising (e.g. World Cleanup Day and Nordic Coastal Cleanup, [31], [32]). Both altruistic and self-interest behaviours are positively associated with pro-environmental behaviours [33], [34]. The differences in litter amount and composition in our studied beaches can be partly explained by the different behaviours of beach visitors. Kakumäe beach is a small beach-for-all with a strong local community feeling, and the regular everyday visitors clean the beach from litter items during most of their visits. What Kakumäe beach is facing currently most is the litter from remote areas (blown by the wind from the terrestrial part or carried by the waves from the marine environment); the on-sight direct littering by beach users has significantly decreased (though not fully disappeared). As for Russalka beach, the public feels more that it is the responsibility of the municipality to keep it clean, and there is no core group to take care of the tidiness of the beach. Also, the lack of dustbins and nearby public toilets explains the amount and composition of litter in Russalka beach.

Whereas the use of plastics cannot be completely avoided, there should be an increasing focus on reducing, banning or recycling SUP products. Various biodegradable materials have been developed to reduce the negative effects of SUP. Unfortunately, there are limitations to developing plastic materials that decompose rapidly and completely under natural environmental conditions while maintaining their properties for a suitable duration in consumer products [34].

Unfortunately, there is a widespread opinion that biodegradable plastic material is somehow more environmentally friendly than other plastics. It is commonly forgotten that this biodegradable or compostable plastic should be utilized under industrial standards, which are not accessible for common households. Hence, the proper decomposition in natural environment is not feasible as the required conditions are not met. Therefore, labels for disposable biodegradable products should include information about the degradation conditions, as well as the material and additives used. In the current study, biodegradable products showed the variable degradation speed depending on the product and material (ANOVA, $p < 0.05$). Surprisingly, biodegradable plastic bags showed remarkably low rates of degradation. Only when submerged in seawater above sediment, the biodegradable bags lost about 80% of their material during the study period. The decomposition rate is directly dependent on the type of the material – in another study, the compostable plastic bags have been shown to decompose in seawater within 3-5 months [7].

Amending legislation to reduce the use of plastic bags in some countries in Europe began in the 1990s and has since expanded [21]. However, their production and global use are expected to continue to rise [36]. Therefore, new strategies need to be implemented to minimize the use of SUP, and these must be done in hand with environmental education. It must be stressed out that biodegradable and/or compostable plastics require separate sorting and treatment options. As biodegradable products are described as environmentally friendly, there is also a risk that the use of biodegradable SUP products may endorse littering behaviour.

5 CONCLUSION

Although increasing attention is being paid to the seashore and marine littering, it is still a growing problem. In the studied beaches, 73–75% of marine litter was plastic, among which SUP products represented 68% at urban beach and 37% at semi-urban beach. The most common SUP found were cigarette butts, plastic packages and sweet wrappers. At present day, the use of biodegradable materials does not solve the problem but adds another topic of discussion in regards to the pollution of the environment. Degradation under natural conditions does not meet the requirements of defined industrial standards for biodegradation.

Degradation of tested SUP materials depends on the character of environmental forcing these materials are experiencing. In our study, the fastest degradation occurred when tested materials were placed on the seafloor. Second degradation rate was measured in treatment where the material was buried in soil on land. Simple open-air treatment resulted in only 17% of the material lost in 10-month experiment. There were significant differences in degradation speed among different biodegradable materials exposed to the same environmental conditions. Therefore, to decrease the impact of plastic, instead of using biodegradable material, the guidance of consumers toward reducing, reusing and recycling of plastic should be promoted.

ACKNOWLEDGEMENTS

This work was supported by the European Regional Development Fund via the Mobilitas Pluss (MOBERA12) of the Estonian Research Council.

REFERENCES

[1] UNEP, *Single-use Plastics: A Roadmap for Sustainability*, available at https://www.unep.org/resources/report/single-use-plastics-roadmap-sustainability, 2018 (accessed 19 October 2021).

[2] Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. *Official Journal of the European Union*, **L155**, available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0904&from=EN, 2019 (accessed 19 October 2021).

[3] European Bioplastics, *Bioplastics Market Data 2019, Global Production Capacities of Bioplastics 2019–2024*, European Bioplastics, Nova-Institute, available at https://docs.european-bioplastics.org/publications/market_data/Report_Bioplastics_Market_Data_2019.pdf, 2019 (accessed 19 October 2021).

[4] Nazareth, M., Marques, M.R., Leite, M.C. & Castro, Í.B., Commercial plastics claiming biodegradable status: is this also accurate for marine environments?. *Journal of Hazardous Materials*, **366**, pp. 714–722, 2019.

[5] Rutkowska, M., Krasowska, K., Heimowska, A., Steinka, I., Janik, H., Haponiuk, J. & Karlsson, S., Biodegradation of modified poly (ε-caprolactone) in different environments. *Polish Journal of Environmental Studies*, **11(4)**, pp. 413–420, 2002.

[6] Green, D.S., Boots, B., Blockley, D.J., Rocha, C. & Thompson, R., Impacts of discarded plastic bags on marine assemblages and ecosystem functioning. *Environmental Science & Technology*, **49(9)**, pp. 5380–5389, 2015.

[7] O'Brine, T. & Thompson, R.C., Degradation of plastic carrier bags in the marine environment. *Marine Pollution Bulletin*, **60(12)**, pp. 2279–2283, 2010. DOI: 10.1016/j.marpolbul.2010.08.005.

[8] Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment and repealing Decision 2010/477/EU. *Official Journal of the European Union*, **L125/43**, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017D0848 (accessed 19 October 2021).

[9] Addamo, A.M., Laroche, P. & Hanke, G., *Top Marine Beach Litter Items in Europe, EUR 29249 EN*, Publications Office of the European Union: Luxembourg. JRC108181, 2017. DOI: 10.2760/496717.

[10] OSPAR Commission, *Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area*, available at https://www.ospar.org/documents?v=7260, 2010 (accessed 19 October 2021).

[11] TG Marine Litter. *Guidance on Monitoring of Marine Litter in European Seas. MSFD TG Marine Litter 2013*. Joint Research Centre. Publications Office of the European Union. JRC83985, available at http://publications.jrc.ec.europa.eu/repository/handle/111111111/30681, 2013 (accessed 19 October 2021).

[12] Torn, K., Martin, G. & Reisalu, G., Degradation of biodegradable single-use plates and waste bags in terrestrial and marine environments. *WIT Transactions on Ecology and the Environment*, **251**, pp. 49–56, 2021. DOI: 10.2495/WS210051.

[13] Kataržytė, M., Balčiūnas, A., Haseler, M., Sabaliauskaitė, V., Lauciūtė, L., Stepanova, K., Nazzari, C. & Schernewski, G., Cigarette butts on Baltic Sea beaches: Monitoring, pollution, and mitigation measures. *Marine Pollution Bulletin*, **156**, p. 111248, 2020.

[14] Garcés-Ordóñez, O., Espinosa Díaz, L.F., Pereira Cardoso, R. & Costa Muniz, M., The impact of tourism on marine litter pollution on Santa Marta beaches, Colombian Caribbean. *Marine Pollution Bulletin,* **160**, p. 111558, 2020.

[15] GESAMP, Sources, fate and effects of microplastics in the marine environment: A global assessment. *Reports and Studies*, **90**, p. 96, 2015.

[16] Ryan, P.G., Land or sea? What bottles tell us about the origins of beach litter in Kenya. *Waste Management,* **116**, pp. 49-57, 2020.

[17] Hengstmann, E., Gräve, D., Tamminga, M. & Fischer, E.K., Marine litter abundance and distribution on beaches on the Isle of Rügen considering the influence of exposition, morphology, and recreational activities. *Marine Pollution Bulletin,* **115**, pp. 297-306, 2017.

[18] Asensio-Montesinos, F., Anfuso, G., Aguilar-Torrelo, M.T. & Ramirez, M.O., Abundance and temporal distribution of beach litter on the coast of Ceuta (North Africa, Gibraltar Strait). *Water,* **13**, p. 2739, 2021. DOI: 10.3390/w13192739.

[19] HELCOM, State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016. *Baltic Sea Environment Proceedings,* **155**, 2018, available at http://stateofthebalticsea.helcom.fi/ (accessed 19 October 2021).

[20] Van Loon, W., Hanke, G., Fleet, D., Werner, S., Barry, J., Strand, J., Eriksson, J., Galgani, F., Gräwe, D., Schulz, M., Vlachogianni, T., Press, M., Blidberg, E. & Walvoort, D., A., *European Threshold Value and Assessment Method for Macro Litter on Coastlines. EUR 30347 EN*, Publications Office of the European Union: Luxembourg, 2020, ISBN 978-92-76-21444-1. DOI:10.2760/54369, JRC121707.

[21] Xanthos, D. & Walker, T.R., International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review. *Marine Pollution Bulletin,* **118**, pp. 17-26, 2017.

[22] Ghaffari, S., Bakhtiari, A.R., Ghasempouri, S.M. & Nasrolahi, A., The influence of human activity and morphological characteristics of beaches on plastic debris distribution along the Caspian Sea as a closed water body. *Environmental Science and Pollution Research* **26**, pp. 25712–25724, 2019.

[23] Ryan, P.G., Weideman, E.A., Perold, V., Hofmeyr, G. & Connan, M., Message in a bottle: Assessing the sources and origins of beach litter to tackle marine pollution. *Environmental Pollution,* **288**, p. 117729, 2021.

[24] Araújo, M.C.B. & Costa, M.F.C., Cigarette butts in beach litter: Snapshot of a summer holiday. *Marine Pollution Bulletin,* **172**, p. 112858, 2021. DOI: 10.1016/j.marpolbul.2021.112858.

[25] Dur, R. & Vollaard, B., The power of a bad example – a field experiment in household garbage disposal. *Environment and Behaviour,* **47(9)**, pp. 970-1000, 2014. DOI: 10.2139/ssrn.2101538.

[26] Khwaja, F.S. & Shah, A., Determinants of littering: an experimental analysis. *The Pakistan Development Review*, **52(2)**, pp. 157-168, 2013.

[27] Ojedokun, O., The role of socio-demographical and psychological factors in taking littering prevention actions. *International Journal of Advances in Psychology,* **2(4)**, pp. 197-206, 2013. DOI: 10.14355/ijap.2013.0204.03.

[28] Akintunde, E.A., Theories and concepts for human behaviour in environmental preservation. *Journal of Environmental Science and Public Health,* **1(2)**, pp. 120-133, 2017. DOI: 10.26502/JESPH.012.

[29] Steg, L. & de Groot, J.I.M., eds., *Environmental Psychology: An Introduction.* 2nd Edition. John Wiley & Sons Ltd, 2018. DOI: 10.1002/9781119241072.

[30] Pan, S.-L., Chou, J., Morrison, A.M., Huang, W.-S. & Lin, M-C., 2018. Will the future be greener? The environmental behavioural intentions of university tourism students. *Sustainability,* **10**, p. 634, 2018. DOI: 10.3390/su10030634.

[31] Pilme. M., "Let's do it" started earlier this year: serial cleaners are active in Pärnu (In Estonian: "Teeme ära" tuli tänavu varem: Pärnus tegutsevad sarikoristajad.) Pärnu Postimees 22.04.2020, available at https://parnu.postimees.ee/6955244/teeme-ara-tuli-tanavu-varem-parnus-tegutsevad-sarikoristajad?fbclid=IwAR2oJsbRZbR4vPief7ZxTD526-hPn5XcZfyA8jWwxpLJGg9gicp2hBTKST0, 2020 (accessed 19 October 2021).

[32] Svenska Yle., Young volunteers in Helsinki aim for 130 km of trash-free coastline, 4.7.2019, available at https://yle.fi/uutiset/osasto/news/young_volunteers_in_helsinki_aim_for_130_km_of_trash-free_coastline/10860883 (accessed 19 October 2021).

[33] De Dominicis, S., Schultz, P.W. & Bonaiuto, M., Protecting the environment for self-interested reasons: altruism is not the only pathway to sustainability. *Frontiers in Psychology*, **8**, p. 1065, 2017. DOI: 10.3389/fpsyg.2017.01065.

[34] Xu, Y., Li, W. & Chi, S., Altruism, environmental concerns, and pro-environmental behaviours of urban residents: a case study in a typical Chinese city. *Frontiers in Psychology*, **12**, p. 643759, 2021. DOI: 10.3389/fpsyg.2021.643759.

[35] Yin, G.-Z. & Yang, X.-M., Biodegradable polymers: a cure for the planet, but a long way to go. *Journal of Polymer Research,* **27**, p. 38, 2020. DOI: 10.1007/s10965-020-2004-1.

[36] Chen, Y., Awasthi, A.K., Wei, F., Tan, Q., & Li, J., Single-use plastics: Production, usage, disposal, and adverse impacts. *Science of the Total Environment*, **752**, p. 141772, 2021.