Original article

Dynamics of Coastal Litter Density on the Beaches of the Northeastern Black Sea Coasts in 2016–2021

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Abstract

The article presents the results of coastal litter monitoring on the beaches of the Black Sea from 2016 to 2021. The study was conducted on five beaches of the northeastern Black Sea coast, including urban and suburban areas. The Marine Strategy Framework Directive (MSFD) methodology of the European Commission was used for the collection and classification of litter items. During 13 monitoring sessions, a total of 2633 litter items (108 types, 8 categories) were identified, with plastic being the predominant component, averaging 71.7% of the total litter volume. The second predominant category was metal, averaging 8.2% of the found litter. The litter density varied from 47.66 pcs./100 m to 1163 pcs./100 m. The litter density median was 118.26 pcs./100 m on all studied beaches. The inter-annual variability in the litter amount on the beaches shows a decreasing trend in all monitored areas with pronounced peaks in the summer and winter seasons. The main source of the coastal litter pollution was recreational activities, the impact of which was aggravated by lack of developed waste management infrastructure as well as by the proximity of transport routes. The obtained data highlight the necessity of continued monitoring and implementation of measures to reduce pollution, such as improving waste management systems and reducing plastic production and usage. These data can also contribute to legislative and practical initiatives for the protection of the Black Sea marine ecosystems as developed both by the government and people at large.

Keywords: marine pollution, marine beach litter, Black Sea, microplastics

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Динамика плотности берегового мусора на пляжах северо-восточного побережья Черного моря с 2016 по 2021 год

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Аннотация

Рассмотрены результаты мониторинга берегового мусора на пляжах Черного моря с 2016 по 2021 г. Исследование проводили на пяти пляжах северо-восточного побережья Черного моря, включая городские и пригородные участки. Мусор собирали и классифицировали по методике Рамочной директивы Европейской комиссии по морской стратегии. Всего за время 13 мониторинговых обследований было собрано 2633 частиц мусора из 8 категорий 108 типов. Преобладающим компонентом стал пластик, составляющий в среднем 71.7 % от общего количества мусора. Второй преобладающей категорией стал металл, доля которого в среднем составила 8.2 % от найденного мусора. Плотность пляжного мусора варьировала от 47.66 шт. / 100 м до 1163 шт. / 100 м. Медиана плотности мусора на всех исследуемых пляжах составила 118.26 шт. / 100 м. В межгодовой изменчивости количества мусора на пляжах отмечается тенденция к уменьшению во всех обследуемых районах с явными пиками в летние и зимние сезоны. Основным источником мусорного загрязнения побережья стала рекреационная деятельность, воздействие которой усиливалось из-за отсутствия развитой инфраструктуры по утилизации отходов, а также близости транспортных путей. Полученные данные свидетельствуют о необходимости продолжения мониторинга и принятия мер по снижению загрязнения, таких как улучшение систем управления отходами и уменьшение производства и использования пластика. Эти данные могут использоваться при выработке рекомендаций и практических инициатив по защите морской экосистемы Черного моря как со стороны государства, так и со стороны научного сообщества и обычных граждан.

Ключевые слова: морской мусор, загрязнение моря, загрязнение пляжей, Черное море, микропластик

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Introduction

Marine debris pollution of beaches is a growing global problem that requires a comprehensive approach. An important step against marine pollution is continuous monitoring of the scale and dynamics of the problem. Based on analyses of the collected data on the composition, quantity and sources of litter on beaches, effective measures to prevent pollution are developed [1]. Awareness-raising campaigns and improved waste management systems can help to reduce pollution and protect ecosystems and human health [1), 2)].

Like any closed body of water, the Black Sea is vulnerable to marine debris pollution. Both terrestrial and marine factors contribute to its accumulation. The terrestrial factors include litter entering the seas from rivers in industrialised countries, uncontrolled landfills, growing tourism, recreational activities, and port activities in coastal cities [1)], whereas the marine factors include fishing and intensive shipping [3, 4]. Due to the large-scale circulation of the Black Sea, litter is spreading throughout the basin and this is becoming a growing transborder problem [5].

The main litter component is plastic [6–9]. The widespread use of plastic is due to its utility, availability and demand in all spheres of life. However, there is no enzyme in nature that can degrade this material. Plastic is not evenly redistributed in the environment and thus accumulates in large quantities and affects it negatively [10].

The effects of marine pollution are diverse. Non-degradable plastic often causes death of marine organisms, which may get trapped in nets and plastic substrates or swallow it. Microplastics, derived from larger plastic items, enter food chains, affecting the entire biological cycle [2]. Litter on beaches can affect human health both directly, leading to injuries and cuts, and indirectly through interaction with toxic waste [3)]. In addition, polluted beaches lose their attractiveness to tourists, which negatively affects the local economy [4)].

The work aims to analyse the qualitative and quantitative composition of the collected litter in order to assess its seasonal variability and to compare the pollution levels of the north-eastern Black Sea coast with other parts of the coast.

[1)] BSC, 2007. *Marine Litter in the Black Sea Region: a Review of the Problem*. Istanbul: Black Sea Commission Publications, 2007. 160 p.

[2)] European Parliament, 2008. *Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008. Marine Strategy Framework Directive*. Available at: https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32008L0056 [Accessed: 2 December 2024].

[3)] UNEP, 2005. *Marine litter: An analytical overview*. 47 p.

[4)] UNEP, 2009. *Marine Litter: A Global Challenge*. 232 p.

Materials and methods

Study area

The study area is located in the north-eastern Black Sea coast (Fig. 1). According to [3], the study area is one of the most polluted parts of the coast.

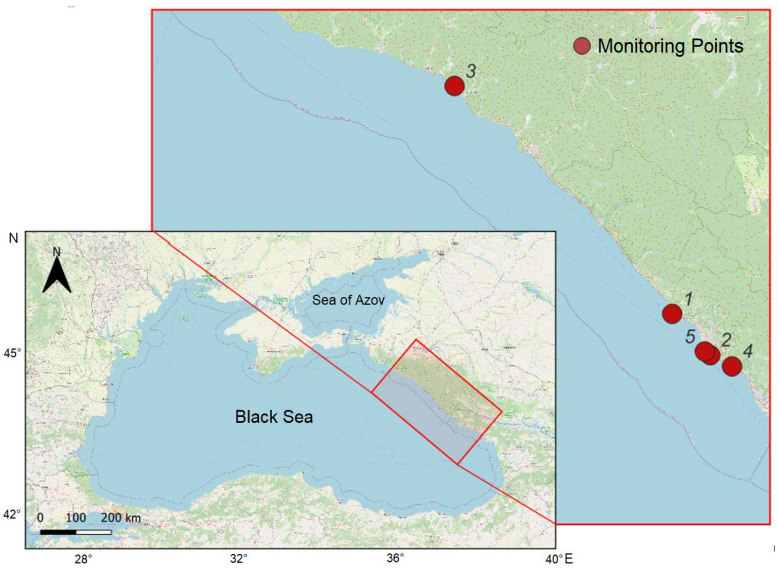
In addition to the large recreational load, this area is under seasonal spatial and temporal variability of currents, which is one of the main determinants of pollution spreading on the sea coasts and is taken into account when identifying possible sources of marine litter inputs [11].

Two types of beaches were selected for monitoring: urban and suburban ones. The urban beaches are Loo, Primorsky and Sochi Beaches located in resort areas near the central district of the city of Sochi. Loo (84 m long) and Sochi (104 m long) Beaches are pebbly, while Primorsky Beach (128 m long) is sandy.

Vostok and Maly Akhun Beaches are located in the suburbs. The nearby infrastructure is not well-developed, and the proximity of motorways and railways is noted. Near Vostok Beach, forest vegetation prevails. Vostok Beach (87 m long) is sandy, while Maly Akhun Beach (104 m long) is pebbly.

Data collection

Marine litter monitoring was conducted from 2016 to 2021 at five beaches. In order to ensure comparability and data quality, this study used the methodology of the European Commission's Marine Strategy Framework Directive



F i g . 1 . Monitoring area. The numbers indicate beaches: *1* – Loo; *2* – Sochi; *3* – Vostok; *4* – Maly Akhun; *5* – Primorsky

(MSFD) [5] to assess marine litter pollution on the north-eastern Black Sea coasts. This strategy aims at the protection and sustainable use of marine ecosystems.

According to the methodology, litter larger than 2.5 cm was collected during the monitoring works on a site about 100 m long and 5 m wide. The found litter was then categorised into a basic list of litter categories and assigned a code number with a letter designation from G1 to G217 according to the chosen methodology. The data was recorded using the Marine Litter Watch mobile application for marine litter monitoring by trained observers using the MSFD methodology.

A total of 108 different types of litter were identified and broken down into the following categories: Plastic, Clothing/Textiles, Glass/Ceramics, Metal, Paper/ Cardboard, Engineered Wood, Rubber and Unidentified. The amount of litter per 100 m was then calculated for each beach to allow comparison between the obtained data and to identify the density of litter pollution at each beach during different seasons.

Results

Density and composition

From 2016 to 2021, 13 monitoring surveys were conducted with a total of 2,633 pieces of litter collected. The density of beach litter ranged from 47.66 pieces / 100 m to 1163 pieces / 100 m. The predominant category of litter on all beaches and in all seasons was Plastic, averaging 71.7% of all litter found (Table). The second predominant category was Metal, averaging 8.2% of the litter found.

Maly Akhun Beach

The highest litter concentrations were observed in the summer period of 2020 (245.2 pieces / 100 m) and in the winter period of 2021 (212.5 pieces / 100 m) (Fig. 2).

In summer 2020, 255 litter particles were found. Plastic particles amounted to 168 (65.88%). The most common types were hygiene products (G96) – 22 items, cigarette ends and filters (G27) – 19 items and plastic parts up to 50 cm (G79) – 17 items. The remaining categories were distributed as follows (pcs.): 8 Clothing/ Textiles (3.14%), 5 Glass/Ceramics (1.96%), 43 Metal (16.86%), 22 Paper/ Cardboard (8.63%), 5 Wood (1.96%) and 4 Rubber (1.57%) items. In the Metal category, 11 particles were from tin cans (G175) and 10 from bottle caps (G178).

In autumn 2020, 187 litter particles were identified. Of these, 110 items were Plastic (58.82%), 10 were Clothing/Textiles (5.35%), 11 were Glass/Ceramics (5.88%), 22 were Metal (11.76%), 17 were Paper/Cardboard (9.09%), 14 were Wood (7.49%), and 3 were Rubber (1.6%). Cigarette ends and filters also predominated in the Plastic category (G27) – 24 items, and in the category Wood it was engineered wood (G161) – 13 items.

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Marine litter density in different seasons

Place of collection	Season	Litter density, pcs./100 m	Proportion of plastic, %	Predominant litter	
				Type	Proportion of the total amount, %
Maly Akhun	Summer 2021	118.27	76.42	Cigarette ends and filters	17.07
Primorsky		47.66	78.69	Cigarette ends and filters	52.46
Maly Akhun	Spring 2021	106.73	71.17	Bottles ≤ 0.5 L	10.81
Primorsky		67.97	85.06	Cigarette ends and filters	37.93
Maly Akhun	Winter 2021	212.50	62.44	Plastic parts 2.5–50 cm	10.86
Primorsky		78.91	81.19	Cigarette ends and filters	41.58
Maly Akhun	Autumn 2020	179.81	58.82	Cigarette ends and filters	12.83
Primorsky		61.72	56.96	Cigarette ends and filters	34.18
Maly Akhun	Summer 2020	216.35	65.88	Personal hygiene supplies	8.63
Primorsky		75	72.92	Cigarette ends and filters	45.83
Vostok	Summer 2017	151.72	78.03	Cigarette ends and filters	28.03
Sochi	Autumn 2017	224.04	73.82	Cigarette ends and filters	51.07
Loo	Autumn 2016	1163.09	70.28	Cigarette ends and filters	20.57

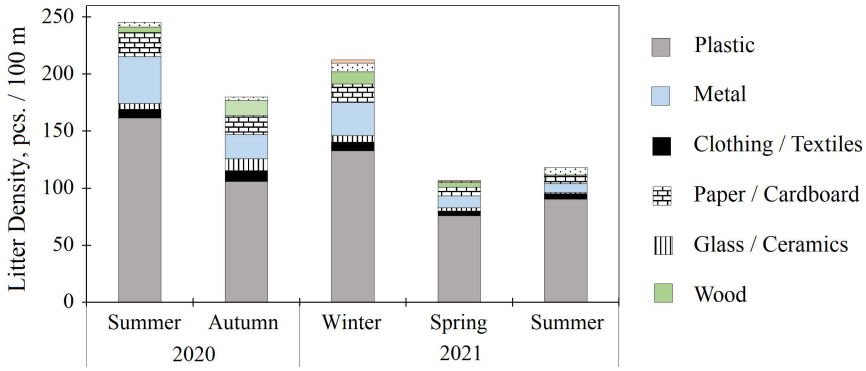

Fig. 2. Seasonal distribution of marine litter on Maly Akhun Beach

In winter 2021, 221 litter particles were detected. Of these, 138 items were Plastic (62.44%), 8 were Clothing/Textiles (3.62%), 6 were Glass/Ceramics (2.71%), 30 were Metal (13.57%), 17 were Paper/Cardboard (7.69%), 11 were Wood (4.98%), 8 were Rubber (3.62%), and 3 were Other (1.36%). The Plastic category was dominated by unidentifiable plastic particles up to 50 cm (G79) – 24 items, 0.5 litre beverage bottles (G7) – 19 items and pieces of plastic/polystyrene up to 50 cm (G76) – 14 items. In the Metal category, there were 12 items – tin cans (G175).

In spring 2021, a total of 111 litter particles were found. Of these, 79 were Plastic items (71.17%), 4 were Clothes/Textiles (3.60%), 3 were Glass/Ceramics (2.70%), 11 were Metal (9.91%), 8 were Paper/Cardboard (7.21%), 4 were Wood (3.60%), 1 was Rubber (0.9%), and 1 was Other (0.9%). In the Plastic category 0.5 litre beverage bottles prevailed (12 pcs.).

In summer 2021, 123 particles were detected. Of these, 94 were Plastic items (76.4%), 5 were Clothing/Textiles (4.1%), 1 was Glass/Ceramics (0.8%), 8 were Metal (6.5%), 7 were Paper/Cardboard (5.7%), 1 was Wood (0.8%), and 7 were Rubber (5.7%) (Fig. 2). The Plastic category was dominated by cigarette ends and filters (G27) – 21 pcs. and hygiene products (G96) – 10 pcs.

Primorsky Beach

On Primorsky Beach, the highest litter concentrations were also recorded in summer 2020 (75 pcs./100 m) and the winter of 2021 (78.9 pcs./100 m) (Fig. 3).

In summer 2020, 96 marine litter particles were found. Of these, 70 items were Plastic (72.92%), 1 was Clothing/Textiles (1.04%), 6 were Metal (6.25%), 14 were Paper/Cardboard (14.58%), 3 were Wood (3.13%), and 2 were Other (2.08%). The Plastic category was dominated by cigarette ends and filters (G27) – 44 pcs. The Paper/Cardboard category entirely consisted of paper fragments (G156).

In autumn 2020, 79 particles were found. Of these, 45 items were Plastic (56.96%), 2 were Clothing/Textiles (2.53%), 7 were Metal (8.86%), 23 were Paper/Cardboard

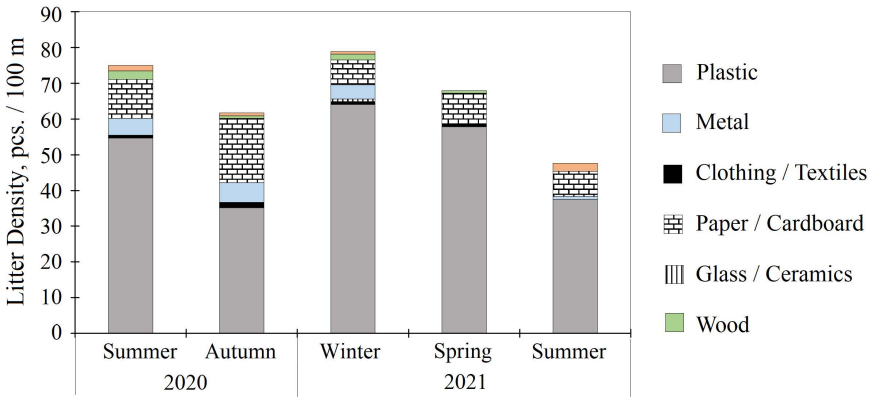

Fig. 3. Seasonal distribution of marine litter on Primorsky Beach

(29.11%), 1 was Wood (1.27%), and 1 was Other (1.27%). The category Plastic was dominated by cigarette ends and filters (G27) – 27 pcs. In the Paper/Cardboard category, 22 pcs. were paper fragments (G156).

In winter 2021, 101 particles of litter were detected. Of these, 82 items were Plastic (81.19%), 1 was Clothing/Textiles (0.99%), 1 was Glass/Ceramics (0.99%), 5 were Metal (4.95%), 9 were Paper/Cardboard (8.91%), 2 were Wood (1.98%), and 1 was Other (0.99%). Cigarette ends and filters in the Plastic category (G27) – 42 pcs.

In spring 2021, 87 particles were detected, of which 74 were Plastic (85.06 %), 1 was Clothing/Textiles (1.15 %), 11 were Paper/Cardboard (12.64 %), and 1 was Wood (1.15 %). Cigarette ends and filters in the Plastic category (G27) amounted to 33 pcs.

In autumn 2021, 61 particles were identified. Of these, 48 were Plastic (78.69%), 1 was Metal (1.64%), 9 were Paper/Cardboard (14.75%), and 3 were Other (4.92%). Cigarette ends and filters in the category Plastic (G27) amounted to 32 pcs.

Loo Beach

A total of 979 pieces of litter were found on the beach, of which 688 were Plastic items (70.28%), 13 were Clothing/Textiles (1.33%), 56 were Glass/Ceramics (5.72%), 144 were Metal (14.71%), 58 were Paper/Cardboard (5.92%), 15 were Wood (1.53%), 3 were Rubber (0.31%) and 2 were Other (0.2%). The predominant type in the Plastic category was cigarette ends and filters (G27) – 29.2% of all plastic found and 20.5% of all identified litter. Bottles, including fragments, accounted for (G45) 80.3% of all litter collected in the Glass/Ceramic category. In the Metal category, the predominant types were bottle caps and tin can tabs (G178), 34%, and other metal objects less than 50 cm (G198), 22.2%. No predominant type was identified in other litter categories.

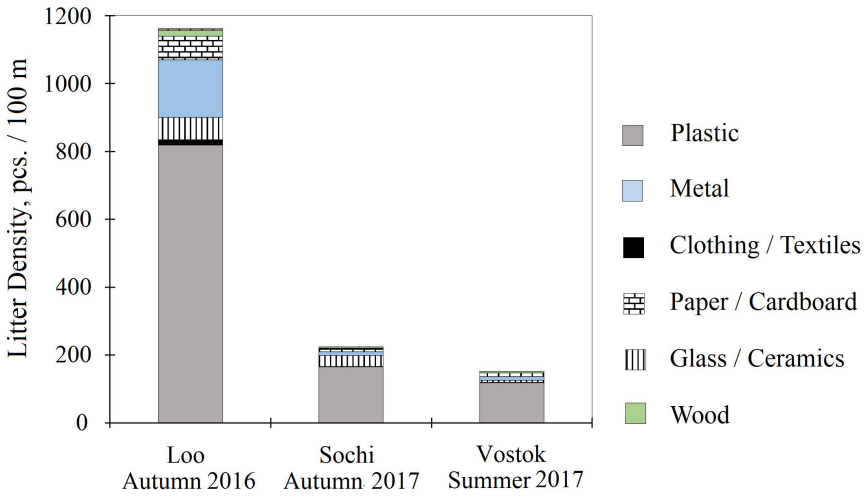

Fig. 4. The density of marine litter on the beaches of Loo, Sochi, Vostok

Sochi Beach

A total of 233 pieces of litter were found on the beach. The distribution by material was as follows: 172 items were Plastic (73.82%), 1 was Clothing/Textiles (0.43%), 34 were Glass/Ceramics (14.59%), 11 were Metal (4.72%), 11 were Paper/Cardboard (4.72%), 4 were Wood (1.72%). The predominant type in the Plastic category was also cigarette ends and filters (G27), 69.2% of all plastic collected and 51% of all litter found. The Glass/Ceramics category consisted of one type of litter, which was bottles, including shards and fragments (14.6% of all litter).

Vostok Beach

On Vostok Beach 132 pieces of litter were found: 103 items were Plastic (78.03%), 1 was Clothes/Textiles (0.76%), 5 were Glass/Ceramics (3.79%), 10 were Metal (7.58%), 9 were Paper/Cardboard (6.82%), 4 were Wood (3.03%). As on the other beaches, cigarette ends and filters (G27) predominated, accounting for 35.9% of litter in this category and 28% of all litter.

Discussion

The results of the work show that the main component of beach litter, registered during the monitoring, was plastic. Its share ranged from 56.96 to 85.06% of the total amount of litter in the monitoring surveys, averaging 71.7%. Similar results were also noted in papers [6–9], where the share of plastic was 71.58, 80.6, 84.3 and 61.65%, respectively.

At the urban Primorsky Beach, paper litter prevailed, in addition to cigarette ends and filters, which may indicate a significant contribution of leisure travellers to the appearance of litter on the beach (proximity of food outlets, including takeaways, advertising leaflets). The following types of litter prevailed on the suburban

Maly Akhun Beach: cigarette ends and filters, drink bottles, plastic fragments 2.5–50 cm large, hygiene products.

The lack of infrastructure and rubbish bins nearby increases the amount and variety of litter on suburban beaches. In addition to recreational activities, Maly Akhun Beach is also affected by the proximity of a motorway, railway and a nearby river, which raises the overall litter density.

During the entire observation period, a total of 424 litter particles were found on urban Primorsky Beach, while on suburban Maly Akhun Beach twice as many particles were detected (867). These differences may be explained by regular clean-ups on the urban beaches and equipped litter disposal sites, which reduces the amount of litter on the beach itself. This study revealed no differences in the composition and amount of litter in terms of the beach type (sandy, pebbly).

When comparing the results of single-season observations at Loo, Sochi and Vostok Beaches, Loo Beach had the highest amount of litter, of which plastic accounts for 70.28%. The beach is remote from the city centre, with the Gorny Vozdukh railway station nearby, and the beach itself is located on a small ledge in the sea. It is likely that due to this location, litter accumulates due to not only recreational impacts, but also to marine litter cast ashore.

The interannual variability of litter density on the studied Black Sea beaches shows a decreasing trend in the amount of litter found in all surveyed areas, with clear peaks in summer and winter. The increase in the litter amount in winter can be attributed to the large number of storm days and litter brought directly by the sea, whereas in summer it can be explained by the increasing number of tourists.

The qualitative composition of litter by season also supports this: in summer, plastic bags, cigarette ends, hygiene products and paper fragments predominated, while in winter, plastic bottles and plastic fragments/details of all sizes prevailed.

The median litter density on all the beaches studied was 118.26 pcs./100 m. According to the data in paper [6], the Black Sea is the most polluted of the four regions studied (median 475 pcs./100 m), followed by the Mediterranean Sea (median 310 pcs./100 m). Less polluted beaches are found in the Baltic Sea (median 71 pcs./100 m) and the north-eastern Atlantic Ocean (average 133 pcs./100 m).

Differences in the median values of this study and study [6] for the Black Sea may be due to the fact that the monitoring works were carried out in different areas and in different seasons. However, the exceeding of the threshold value for marine litter on the coastline (20 pcs./100 m) [7] in each study season and each monitoring survey does indicate a high level of marine litter pollution of the studied beaches.

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Conclusion

The quantitative and qualitative analyses of marine litter on the north-eastern Black Sea coast allowed comparison of this site with other study regions.

The most polluted beaches were Maly Akhun Beach in 2020, Sochi Beach in 2017 and Loo Beach in 2016, with litter densities of 216.35, 224.04 and 1163.09 pcs./100 m, respectively. The predominant category of litter in all years and in each monitoring survey was Plastic, which accounted for 71.7% of the total identified litter. It is concluded that the study area is one of the most polluted points on the coast of the World Ocean.

Continued monitoring surveys are needed to investigate the general condition of beaches, sources of inputs and transport routes of beach litter as well as to assess the impact thereof, particularly plastic litter, on living organisms and the existing ecosystem as a whole. The obtained data will enable authorities and other stakeholders to take measures to reduce the production of plastic products and improve waste management both on land and in the sea. Regular monitoring surveys of specified representative beaches will help to assess the dynamics of marine litter accumulation in the area as well as to understand the efficiency of the measures taken against pollution in the Black Sea.

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