Marine Litter Accumulation and Distribution on Durankulak Beach (Black Sea coast, Bulgaria)

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Abstract—**Marine litter is a worldwide concern because of its negative impact on coastal and marine ecosystems due to anthropogenic pressure. Despite implementation of the Marine Strategy Framework Directive (MSFD 2008/56/EC) there is an inability for national monitoring to cover all significant areas in particular Descriptor 10, indicator D10C1 ''Beach macrolitter''. This study represents marine litter accumulation and distribution on Durankulak shoreline, Bulgarian North East Black Sea coast. Through regular monitoring along a fixed sampling unit by an unmanned aerial vehicle (UAV) to acquire georeferenced images of the coastline, the report provides detailed data on seasonal variability of accumulation, abundance and typology of beach macrolitter. Marine litter accumulation surveys were carried out in four seasons from May 2024 to January 2025. Marine debris was collected, quantified and categorized in order to determine its abundance, composition and seasonal variations in accumulation rates. The results showed that accumulation alters from 183 to 600 items per 100 m section in different seasons. Total number of items recorded is 2821, with a total amount of 67.887 kg. Marine litter was classified in to eight main categories ''Artificial polymer materials'' (90.18% of total number of items), ''Rubber'' (2.52%), ''Cloth/ Textile'' (0.78%), ''Paper/ Cardboard'' (0.96%), ''Processed/ Worked wood'' (1.31%), ''Metal'' (2.16%), ''Glass/ Ceramics'' (1.95%), and ''Unidentified'' (0.14%). Significant amount of marine litter collected was of transborder origin. The results shows that there was variation on aggregation and composition of beach litter. Predominant category is „Artificial polymer materials" and that trend remains unchanged in a seasonal plan.**

Keywords— Bulgarian Black Sea coast, Marine litter, MSFD, monitoring, seasonal accumulation.

I. INTRODUCTION

As a significant environmental issue feturing with complexity and overseas problem, marine litter (ML) is the main subject of a number of international and regional conventions, strategies and national plans (UNEP, MSFD, BSC). Republic of Bulgaria, as an EU member state, fulfils national and regional commitments on the implementation of the MSFD 2008/56/EC [1], [2]. As a Black Sea country, it participates in the activities of the Black Sea Commission and the relevant advisory groups [3]. Despite implementation of the Marine Strategy Framework Directive (MSFD 2008/56/EC) there is an inability for national monitoring to cover all significant areas in particular Descriptor 10, indicator D10C1 "Beach macrolitter".

Marine litter (ML) includes any persistent, manmade, processed or assembled material abandoned or discharged to the marine environment as a result of anthropogenic activities [1], [2]. ML has become environmental, economic, social and health, aesthetic and cultural problem at global, regional and local scale [3], [4], [5].

ML enters the environment via two main types of human activities - on land and at sea. [6]. Land-based sources include inefficient municipal waste management, illegal dumping, inefficient wastewater treatment plants, riverine and urban runoff, accidental discards [7]. ML with a sea-based origin enters the marine environment due to maritime activities, fishing, platforms and waste dumping at sea [4],[8].

The composition of ML includes a huge variety of materials and the plastics are the biggest part of it [9],[10]. Increasing amount of ML worldwide, and specifically plastics are found in all marine environmental matrix – water, sediment an biota. accounting for at least 85 % of total marine litter [5]. ML has become a marker of Anthropocene with its widespread negative effect on coastal and marine ecosystems, wellbeing of societies, especially the coastal population [5]. ML affect a wide range of marine and coastal fauna by entanglement and

ingestion of parts, especially different shapes and sizes of synthetic polymer materials (plastics) [1]. Moreover plastics become a part of the food chain and end up consumed by humans.

Current study presents results of one year ML monitoring survey on beach litter, analytic results regarding ML accumulation and distribution on Durankulak shoreline, Black Sea coast, Bulgaria.

II. MATERIALS AND METHODS

The object of monitoring are beach macro litter (> 2.5 cm), as it was classified in MSFD, Descriptor D10, criteria D10C1 [1], [2].

The ML monitoring survey polygon was chosen on Bulgarian North East Black Sea coast in the range of Durankulak beach competely composed of sand (Fig.1). Monitoring site was selected according to Guidance on Monitoring of Marine Litter in European Seas, EC, MSFD, TG "Litter"[11], [12]. It fulfils the requirement and criteria – more than 1 km length, sufficient to have 2 sampling units with length of 100 m each, along the water edge.

Sampling units of 100 m in length (Section 1 - North and Section 2- South) were monitored, covering the whole area between the water edge and dunes (the back of the beach). The width of beach sampling unit was mesured perpendicular to the shoreline in four seasons. Location is accessible during the all seasons for continuous monitoring.

Fig. 1. ML survey polygon: Durankulak beach, Black Sea coast, Bulgaria.

Monitored area falls into 2 protected areas of NATURA 2000 - "Durankulak Lake", code BG0002050, Directive 79/409/EEC on the conservation of wild birds and "Durankulak Lake", code BG0000154, Directive 92/43/EEC on the conservation of natural habitats and wild flora and fauna [13]. The chosen sampling units in accordance to [14],[15], reflect different pressures and levels to exposure to litter. Durankulak beach strip is orientated E-NE (Fig.2), adjacent to the water edge,

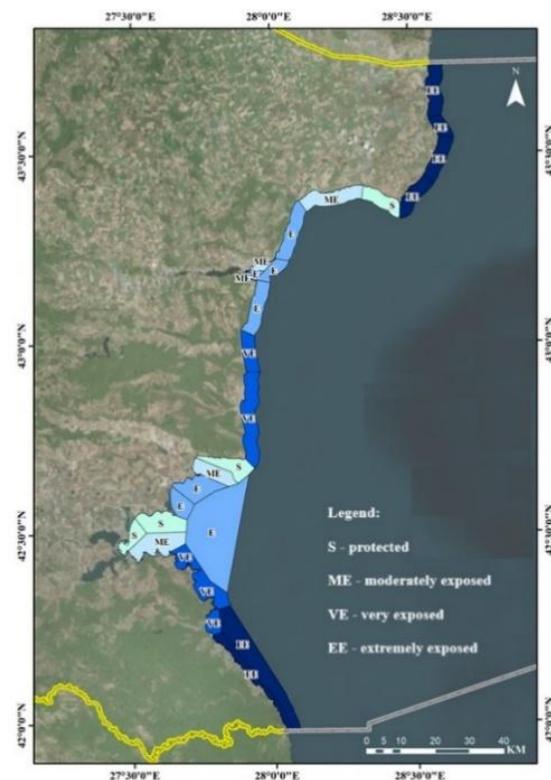extremely exposed to waves and prevailing winds from N-NE [16].

Fig. 2. Exposure to sea waves, Black Sea coast, Bulgaria (modified from BSBD, [16]).

Beach macrolitter surveys were organised regularly in four seasons in 2024-2025. Monitoring campaings were carried out once in each season in 2024-2025, spring (May), summer (July), autumn (September) and winter (January) [12], [17].

Fig. 3. ML items, Durankulak beach.

Sampling and all collected ML items from each section were recorded, quantified and categorized in 8 main categories according to the type of material: ''Artificial polymer materials''(APM), ''Rubber'', ''Cloth/ Textile'', ''Paper/ Cardboard'', ''Processed/ Worked wood'', ''Metal'', ''Glass/ Ceramics'', and ''Unidentified''. Classification, calculation and weight measurement were done on site in accordance to Guidance on Monitoring of Marine Litter in European Seas, EC, MSFD, TG "Litter" [12],[13],[17].

III. RESULTS AND DISCUSSION

Total number of items recorded in 4 seasons is 2821noc., broken down by seasons as follows: 867 noc. in spring season, 783 noc. in the winter monitoring season,

followed by summer – 656 noc., and autumn with 515 noc.

The total amount of ML for the hole monitoring period is 67.887 kg. The biggest weight recorded in spring 25.168 kg, followed by autumn with total weight of 22.081 kg. On third place is 11.123 kg for summer season. And last is winter season with the lowest ML of 9.515 kg. The findings show during the spring season the quantity of beach litter is higest both in number of items and wight but in the rest of monitored period there is not full correlation between thne number of ML and their recorded weight due to the diversity of collected materials.

TABLE 1 ML SEASONAL ACCUMULATION BY MAIN CATEGORIES, [NOC.]

Main category	Beach litter noc. per season, 2024-2025			
	Spring	*Summer*	*Autumn*	*Winter*
Artificial polymer materials	787	565	467	725
Rubber	19	19	21	12
Cloth/ Textile	8	6	0	8
Paper/ Cardboard	3	19	2	3
Processed/ Worked wood	14	8	10	5
Metal	21	14	8	18
Glass/ Ceramics	14	24	6	11
Unidentified	1	1	1	1
Total iems, noc.	867	656	515	783

Data obtained on beach litter accumulation and distribution per category, with regard to the main group of materials, are presented in Table 1 and Table 2.

The results showed that accumulation alters from 515 to 867 items in different seasons. The biggest number of items belongs to main category „Artificial polymer materials" for the hole period of monitoring. The seasanol variation in APM category is in the interval: 467 noc.(Autumn) – 787 (Spring).

Seasonal varriation of ML shows domination of different items varying in composition and number with the highest level of abundance recorded on Durankulak beach in the spring (867 items). Prevailing in summer (total 656 item) were plastic/polystyrene pieces, followed by crisps and sweets rappers. In the autumn season (510 items) collected ML was dominated by plastic caps/lids

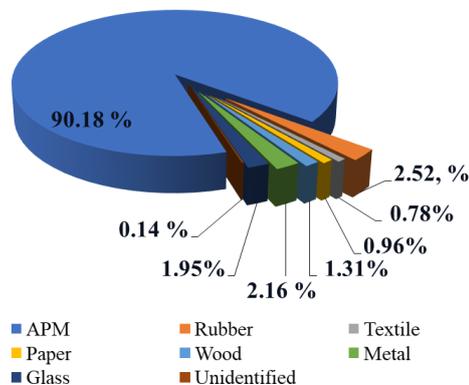drinks. Winter ML accumulated (783 items) was prevalent by plastic and polystyrene pieces.

Fig. 4. Percent composition of total marinel litter items.

TABLE II ML SEASONAL ACCUMULATION BY MAIN CATEGORIES, WEIGHT [KG]

Main category	Beach macrolitter weight, [kg] per season, 2024-2025			
	Spring	*Summer*	*Autumn*	*Winter*
Artificial polymer materials	15.823	1.115	1.115	1.115
Rubber	3.217	0.024	0.024	0.024
Cloth/ Textile	1.115	2.500	2.500	2.500
Paper/ Cardboard	0.024	1.075	1.075	1.075
Processed/ Worked wood	2.500	1.414	1.414	1.414
Metal	1.075	0.000	0.000	0.000
Glass/ Ceramics	1.414	1.115	1.115	1.115
Unidentified	0.000	0.024	0.024	0.024
Total wight, [kg] per season	25.168	11.123	22.081	9.515

Predominant category from 8 main types [12],[17] is APM with realative share of 90.18 % of the total number of items collected. Second main group of materials abondoned on Durankulak beach is ''Rubber'' with 2.52 % (Fig. 4).

All items included in Top 10 belong to the main category APM which determines their predominance (Table III). During the monitoring and sampling was identified presence of significant amounts of ML with transborder origin mainly from food products, packaging

and beverages („Plastic caps/lids drinks", „Plastic caps/lids chemicals, detergents", „Crisps packets/sweets wrappers"). The general circulation in the Black Sea basin is influenced by the inflow of fresh water from the Danube, Dnieper and Dniester bringing waste of terrestrial origin [18]. The presence of ML of crosborder origin confirms the influence of the main Black Sea current on their transport and distribution along the Bulgarian Black Sea coast.

TABLE III ML ACCUMULATION, TOP 10

| № | Top 10 ML items | | | |
	General Name	*TSG-ML*	*NOC*	*Share, [%]*
1	Plastic/polystyrene pieces 0 - 2.5 cm	G75	378	13.40
2	Plastic caps/lids drinks	G21	336	11.91
3	Other plastic/polystyrene items (identifiable)	G124	187	6.63
4	Plastic/polystyrene pieces 2.5 cm > < 50cm	G76	155	5.49
5	Plastic caps/lids chemicals, detergents (non-food)	G22	146	5.18
6	Crisps packets/sweets wrappers	G30	127	4.50
7	Plastic construction waste	G89	89	3.15
8	Small plastic bags, e.g. freezer bags incl. pieces	G4	85	3.01
9	Foam sponge	G73	73	2.59
10	Cigarette butts and filters	G27	62	2.20

Lolly sticks", TSG-ML General code, G31 and „Straws and stirrers" TSG-ML General code, G35, are not part of the Top 10. Recorded amounts in this study are close to those of cigarette butts and significantly lower than accumulation indicated in previous studies [19],[20]. Although they are not dominant factor in the studied area should be considered as an important factor on ML accumulation and distribution.

Seasonal variation in accumulation rates for two sections demonstrates similarity in spring, summer and autumn but differences in winter with a maximum number of items per 100 m collected (Fig. 5).

Weight of ML is determined in D10 national monitoring, criteria D10C1 but in other international studies it is not considered as a factor in relation to Clean Coat Index (CCI), Plastic Abundance Index (PAI), accumulation index (AI), etc.[19], [20]. Analysis of the weight of ML component is not included in the present study and the focus is on the number of identified ML items and their inclusion in the main classification groups and subgroups.

Seasonal distribution of ML at both monitored sections is dominated by APM followed by category „Rubber". Results gained show similarity in the distribution of the main groups of materials. The main difference in seasonal variations is the minor presence of

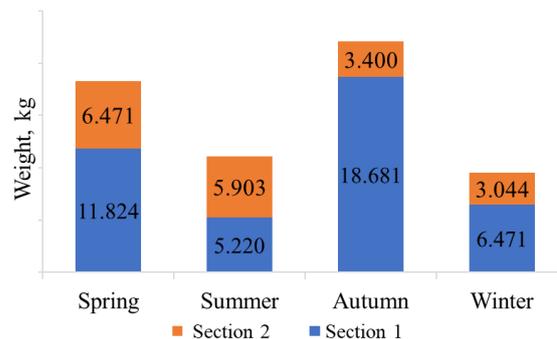„Paper/cardboard" in the southern section (Fig. 6 and Fig.7).

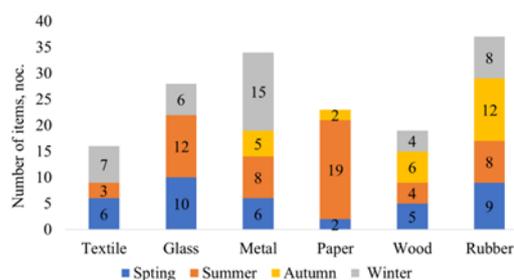Fig. 5. ML seasonal accumulation, weight [kg] per section.

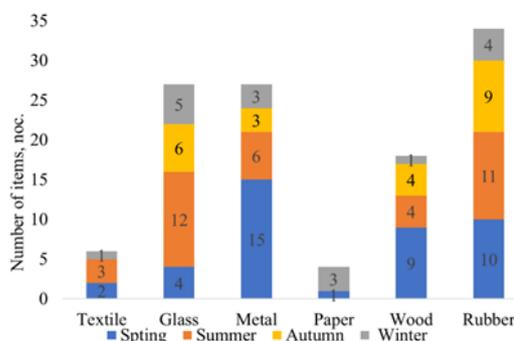Fig. 6. Seasonal accumulation of main group materials, Section 1 (North)

Fig. 7. Seasonal accumulation of main group materials, Section 2 (South).

All the samples of marine beach litter were processed, classified, categorized and quantified. The data gained from the 4 monitoring campaigns were analyzed and the Top 10 marine litter items were identified.

Regarding the achieved results „Plastic/ polystyrene pieces 0 - 2.5 cm", TSG-ML General code G75 are the largest and most abundant amount of ML. At section 1 in the winter season were recorded 172 items. Results present lower amount at section 2 an in the spring they are even absent at both sections (Fig. 8).

„Plastic caps/lids drinks", TSG-ML General code G21 is presented in all seasons, at both sections. This ML item dominates at section 1 in the winter, and section 2 in the

spring but decrerases in autumn along the monitored units (Fig. 9).
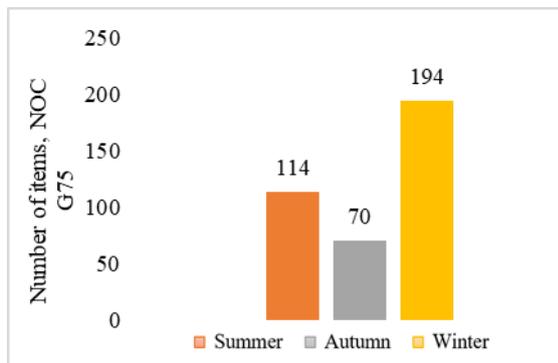

Fig. 8.   Seasonal distribution of „Plastic/polystyrene pieces 0 - 2.5 cm" (TSG-ML General code G75).
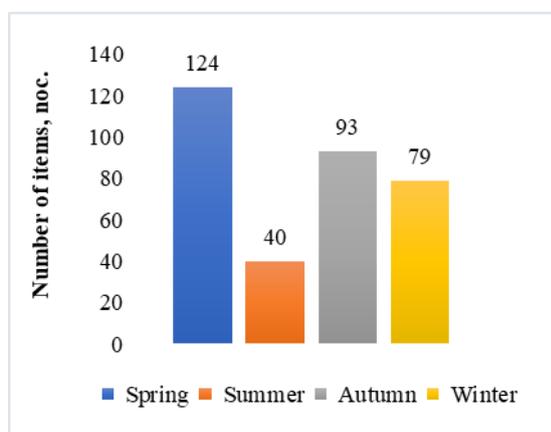

Fig. 9.   Seasonal distribution of Plastic caps/lids drinks (TSG-ML General code G21).

Subcategory „Other plastic/polystyrene items (identifiable)", TSG-ML General code G124, is the third in order regarding monitoring data but shows a stable presence in both sections, throughout the year. A maximum number of plastic cups is noted in winter at the northern part of the studied area (Fig.10).
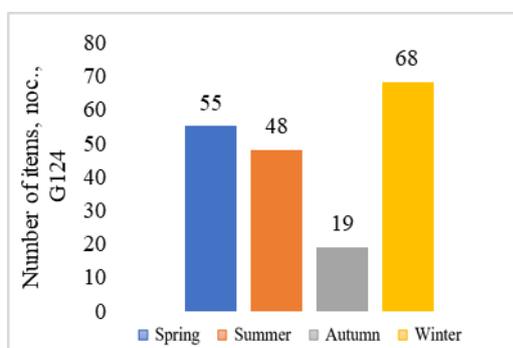
Fig. 10.   Seasonal distribution of Other plastic/polystyrene items (identifiable)", TSG-ML General code G124).

„Plastic/polystyrene pieces 2.5 cm > < 50cm", TSG-ML General code G76 is the fourth most popular item of ML on Durankulak beach. in regards to results.

Seasonal dynamics shows strong presense at North section with high values in the winter. At South section it is less represented, in the spring season it is not even available (Fig. 11).

„Plastic caps/lids chemicals, detergents (non-food)", TSG-ML General code G22 in the studied area has a constant presence, sampled during the all monitoring period and slightly increased values in the spring season at section 2 (Fig. 12).
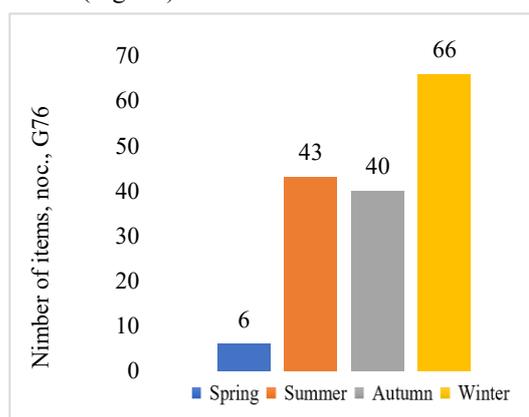

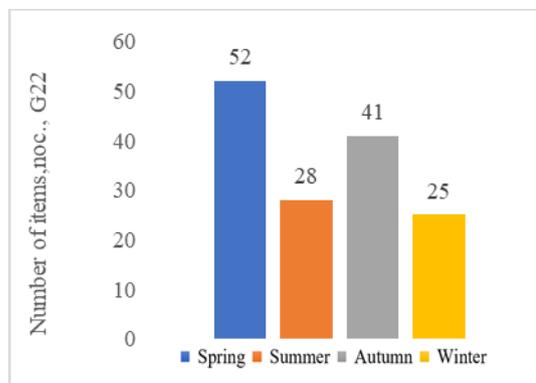Fig. 11. Seasonal distribution of Plastic/polystyrene „pieces 2.5 cm > < 50cm (TSG-ML General code G76).

Fig. 12.   Seasonal distribution of Plastic caps/lids chemicals, detergents (non-food) TSG-ML General code G22.

„Crisps packets/sweets wrappers", TSG-ML General code G30, are identified is a dominant ML item in section 2 for the summer season, lower level in spring and winter and abcent in the autumn.
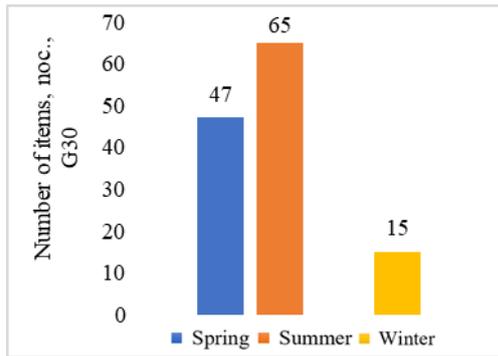
Fig. 13. Crisps packets/sweets wrappers, (TSG-ML General code G30).

„Plastic construction waste", TSG-ML General code G89 and „Small plastic bags, e.g. freezer bags incl. pieces", code G4, presented similar seasonal distribution and accumulation. Although they different in origin both items are accumulated the most in the spring, reduced to missing quantities in the summer and again available in the autumn-winter season (Fig.14, Fig. 15).
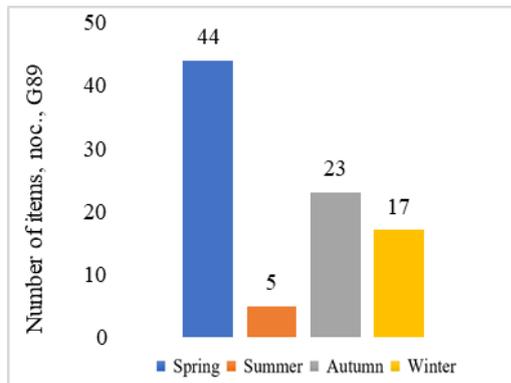

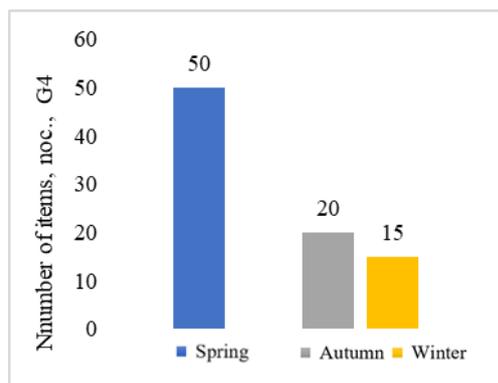Fig. 14. Plastic construction waste", (TSG-ML General code G89).

Fig. 15. „Small plastic bags, e.g. freezer bags incl. pieces", (TSG-ML General code G4).

The last two items evaluated are „Foam sponge", TSG-ML General code G73 and „Cigarette butts and filters", TSG-ML General code G27. Their seasonal dynamics of accumulation shows insignificant to absent quantities. „Foam sponge" is collected in the spring and summer , and a very small amount in the winter. „Cigarette butts and filters" are last in the ranking, which is the opposite of previous studies [19],[20] (Fig.16, Fig.17).
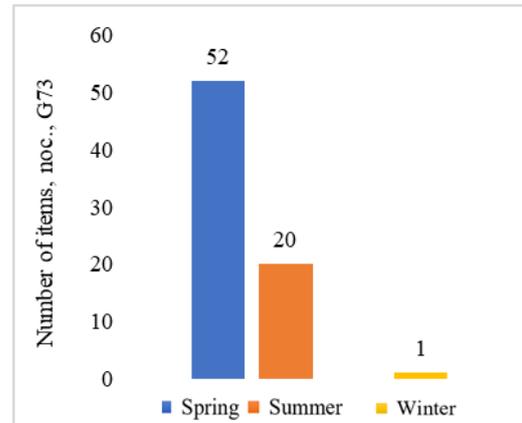

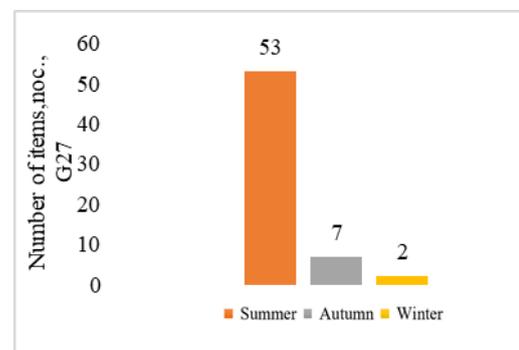Fig. 16. „Foam sponge", (TSG-ML General code G73).

Fig. 17. „Cigarette butts and filters", (TSG-ML General code G27).

IV. CONCLUSIONS

Data and information from the seasonal monitoring conducted in 2024 – 2025 presented in the report provides detailed informatin on seasonal variability of accumulation, abundance and typology of beach macrolitter on Durankulak shoreline, Black Sea coast, Bulgaria.

As a result of conducted surveys a total number of items recorded in four seasons is 2821, with a total amount of 67.887 kg. The data gained from monitoring campaigns were analyzed and were identified Top 10 of marine litter items. Syntethic polymers had the highest distribution in all seasons on Durankulak beach classified in main category „Artificial polymer materials" with 90.18 %. The second main group of abondoned materials is ''Rubber'' with 2.52 %.

The most widespread ML was determined „Plastic/ polystyrene pieces 0 - 2.5 cm" and the biggest abundant amount of this item at 100 m section was in the winter season recorded 172. The total amount of ML accumulated on section 1 is 1525 items, and 1291 on section 2. Cigarette butts, straws, stirrers and lolly sticks are not a leading factor in composition of ML, although their numbers are close to become a part of Top 10.

Predominant part of collected ML is from the group of artificial polymer waste, mainly related to food and beverages (bottles, cups, caps, packaging, bags, straws), cigarette butts and filters, polystyrene, polyurethane foam. Despite the remoteness from highly urbanized areas, it was ascertained presence of transboundary ML transfer – plastic caps from drinks, labels and packaging of beverage products.

During all seasons of monitoring Durankulak beach no dangerous or suspicious objects were found, such as military debris or ammunition but parts of shotgun cartridges, pharmaceutical packaging, medical equipment and syringes were found. There were no seen dead animal, birds or specimens nor floating pollutants were visually identified on the sea surface. Despite not a big number of cigarette butts and filters, the maximum amount in that category of materials is recorded during the summer months, when the beach is actively visited.

The data analysis showed that there is seasonal distribution and variation on aggregation of ML on Durankulak beach. Plastic materials were predominant category and that trend remains unchanged in a seasonal plan for studied coastline. As a result of the analysis, as main pressure was assumed recreational activities and transborder tranfer of ML with the significant impact of air and sea transport of small-sized and lighter materials, in particular group„Plastic/ polystyrene pieces 0 - 2.5 cm".

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