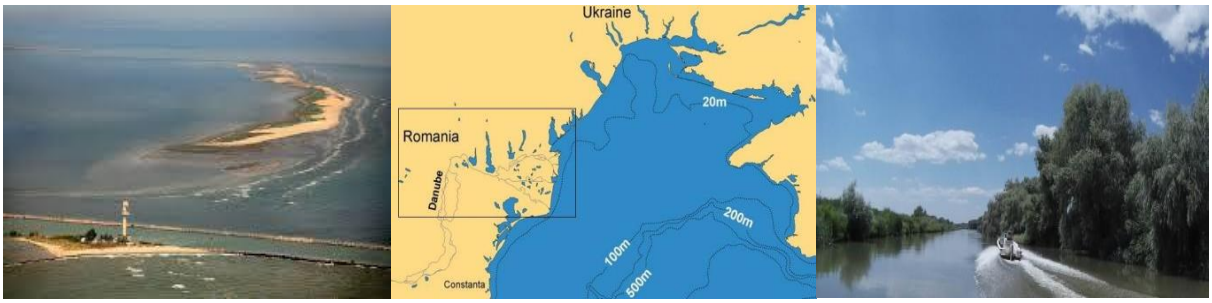
Project funded by EUROPEAN UNION

REPORT ON

Marine litter monitoring in the Black Sea area affected by the rivers: the Romanian pilot case study

GA-T2 – Field work: conducting pilot monitoring studies in selected study areas

Activity T2.1 - Study of River – Black Sea systems interactions



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1 Introduction

Currently it is widely recognized that the marine litter (ML) defined as *any persistent, manufactured or processed solid material intentionally discarded, or accidentally lost on shore or at sea* (UNEP, 1995) has affected all parts of the world's seas and oceans, being present in all marine habitats, from densely populated regions to remote points far from human activities, from beaches and shallow waters to the deepest areas of ocean.

The Black Sea does not constitute an exception from marine litter global tendency, the marine litter pollution has been identified as a major issue affecting the environmental state of the Black Sea too. However, this problem is not yet properly addressed on the regional and national scale. Marine litter monitoring is a new area for the Black Sea region, and the actual levels of ML pollution are not adequately evaluated and monitored in the riparian countries, including Romania (BSC, 2007; SoE2009- 2014/5, 2019). Therefore, implementation of common ML monitoring and assessment approach based on the standardized methodologies and assessment criteria is very critical. Moreover, it is recommended to start with small pilot researches, which would provide baseline data to establish future, full-scale monitoring programs.

The overall objective of the Activity T2.1 - *Study of River – Black Sea systems interactions* is to improve the monitoring methodologies and technologies, data and indicators to assess the impacts of land- based litter sources, particularly the main tributaries rivers on the pollution, including the marine litter pollution in the Black Sea.

For this purpose, in Romania, the NIMRD has conducted in 2019 the marine litter case study in the coastal area neighbouring the Sulina branch, one of the mouths of Danube River. Despite its recognition as the world's most international river basin (19 countries, 800.000 km, 81 million people) and the main tributary (input of 6444 m^3s^{-1} at meanflow) of the Black Sea, little information exists on the litter inputs from land-based sources, especially via the Danube River (BSC, 2009; Lechner et al., 2014). During this pilot case study, innovative technologies like unmanned aerial vehicle (UAV) were used for assessment of marine litter at two chosen Romanian beaches affected by Sulina branch. Additionally, the activity has included the monitoring of floating marine litter at the Danube River discharge and assessment of presence and type of microplastics at those marine sandy beaches located in the Danube River mouth survey area. At the end of the study a set of new and specific data and information on marine litter in Black Sea area affected by the rivers were generated for further implementation of an improved marine litter monitoring in accordance with the high priority task of the Black Sea Strategic Action Plan concerning the "*Development and improvement of the existing monitoring system to provide comparable data sets for pollutant loads (from direct discharges and river inputs*)".

2 Methods

2.1 Study site

The study was conducted in three sites located in the Sulina branch mouth survey area. Sulina branch is the central, the shortest (70 Km), and the straightest branch of the Danube River. With the water depth ranging from 7 to 18 meters, the Sulina arm carries about 20% of the total Danube's water (Panin and Jipa, 2002). One sampling site (45.1567°N, 29.6561°E) was located at 9.7 km distance from Sulina branch mouth and used for monitoring of the macrolitter floating on the water surface (Figure 1).

Figure 1 - Location of the floating litter monitoring site at the Sulina branch (Romania)

The other sites were located on two different typologies of sandy beaches (touristic and wild) and use for beach litter (both micro- and macro-) monitoring (Figure 2, Figure 3 and Figure 4).

Figure 2 - Sulina touristic beach located in the river mouth (Sulina branch) survey area (Romania, August 2019)

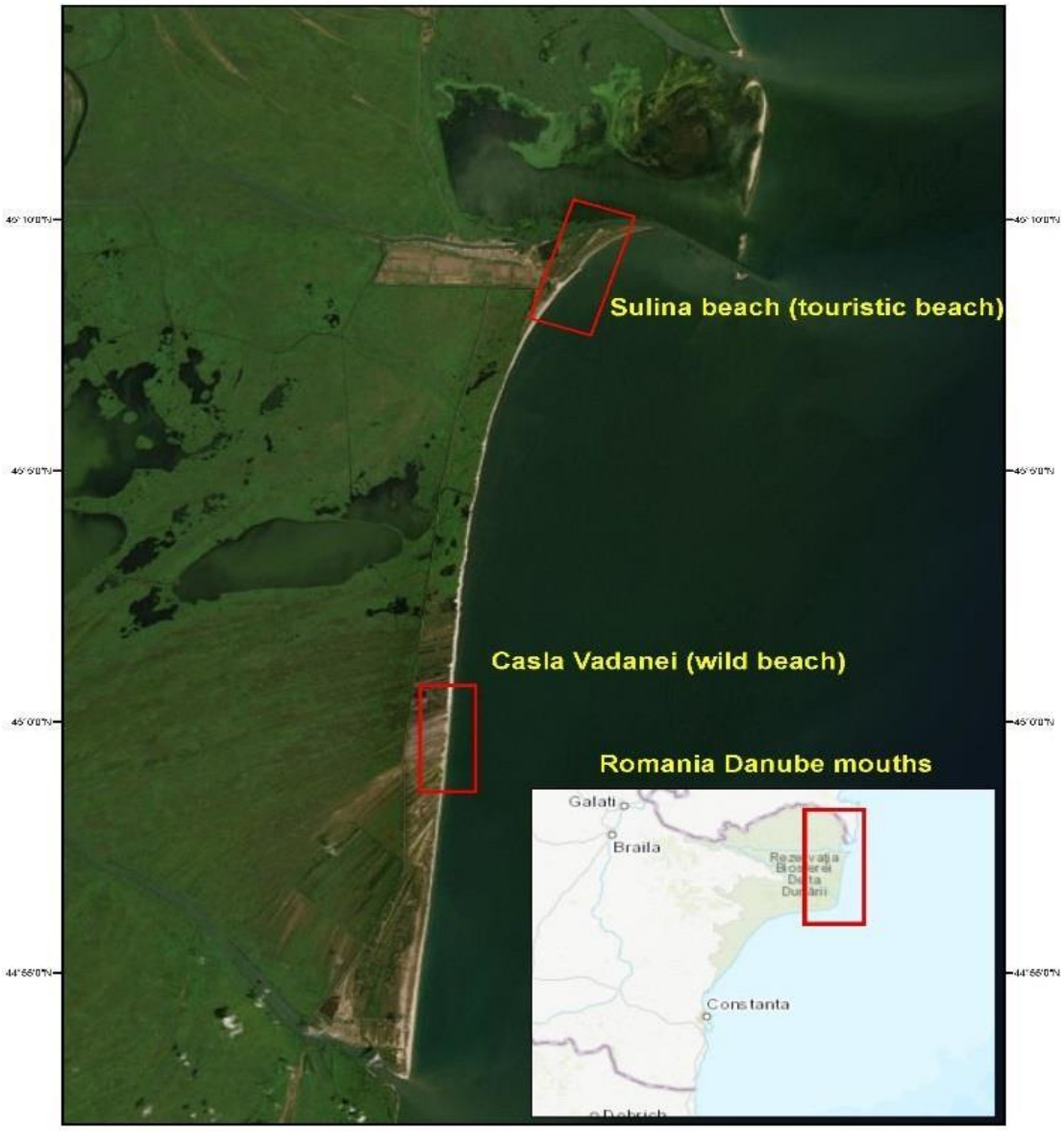

Figure 3 - Map with the location of the two sandy beaches: Sulina and Casla Vadanei

Figure 4 - The wild Casla Vadanei beach located in the river mouth (Sulina branch) survey area

(August 2019)

2.2 Monitoring the floating river litter entering the Black Sea

In-situ human visual observation of floating macro litter (> 2.5 cm) on the Danube river (Sulina branch) surface was used as method to account for floating litter entering the Black Sea, following the protocol developed by the MSFD TG-ML (JRC, 2015; González et al., 2016). The visual observation site was located 9.7 km upstream of the Danube River Black Sea/boundary (Figure 1). The floating litter was recorded (35-min transect counts) by two observers along a 10-m transect perpendicular to a small boat (5.8 m x1.8 m) that replaced the bridge and allowed an appropriate field of view (approximately 2

m) for identification of floating items bigger than 2.5 cm. The macro-litter items were based on the MSFD Master List of Categories of Litter Items (Galgani et al., 2013) and the obtained data was collected by using the EC-JRC Floating Litter Monitoring Application (Figure 5).

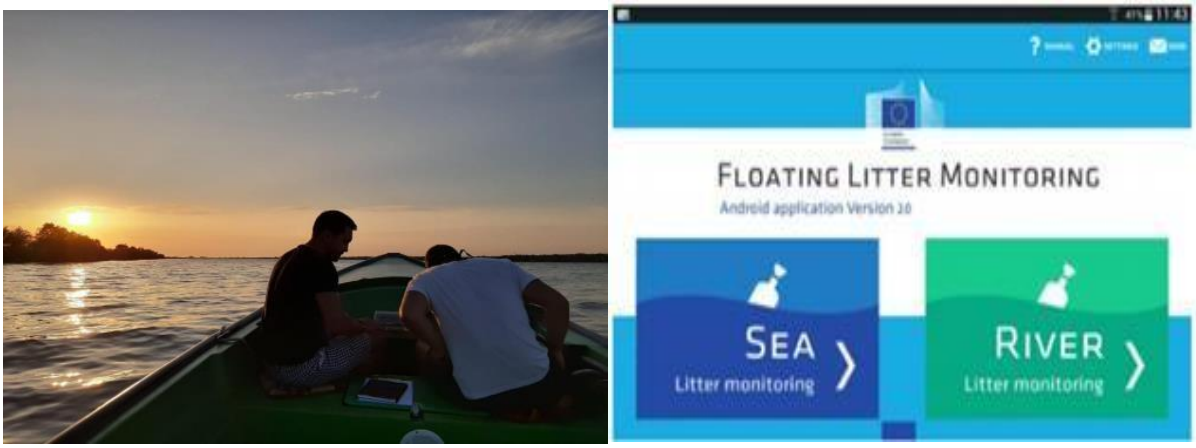

Figure 5 - Counts the floating litter entering the Black Sea (Sulina branch, August 2019)

2.3 Beach macro-litter monitoring

2.3.1 Beach-visual inspection

Data on litter deposited on the Sulina and Casla Vadanei beaches were collected in august 2019 by using the Marine LitterWatch mobile app and following the work protocol described in the EU MSFD TG10 "*Guidance on Monitoring of Marine Litter in European Seas – 2013 -JRC Scientific and Policy Reports* "(Galgani et al., 2013). The methodology implies the visual identification of 100 m long fixed section of beach covering the whole area between the water edges (where possible and safe) or from the strandline to the back of the beach (Figure 6). All litter items (> 2.5 cm) provided by the mobile application categorized according to TSG – ML code given in the Annex 8.1. of the Guidance were gathered, sorted and quantified.

Figure 6 - Visual inspection of beach litter on marine sites located in the river mouth survey area

2.3.2 Beach-drone inspection

An alternative innovative method based on Unmanned Aerial Vehicle (UAV) was tested for efficient beach litter monitoring in the Danube river mouth (Sulina branch) survey area. We followed the work protocol described by Martin et al., 2018 to record marine litter through image acquisition. The remote beach survey was performed using a DJI Phantom 3 Professional quadcopter paired with a gimbal mounted 12 Mega Pixel camera. The drone was used for surveillance after checking the meteorological conditions and the No Fly Zones according with local regulations. (e.g. borders, densely populated areas). The UAV flight covered the same beach surface inspected by visual observation at Sulina (100-m long and 20-m wide) and Casla Vadanei (100-m long and 14-m wide). The UAV was flown at 2 m/s at an altitude above ground level (AGL) of 10m. The photos were taken from drone at 90 degrees from the ground. A total of 267 (Sulina beach area) and 146 (Casla Vadanei beach area) images (each 4000*3000 pixels in size; i.e. 12MP) were acquired automatically every 2 s which were further processed using the Agisoft Metashape, resulting in an orthophotoplan of the areas (Figure 7). Each aerial picture was then visually/manually screened to count the litter items and to categorize them according to TSG – ML code given in the Guidance on Monitoring of Marine Litter in European Seas – 2013 (Galgani et al., 2013).

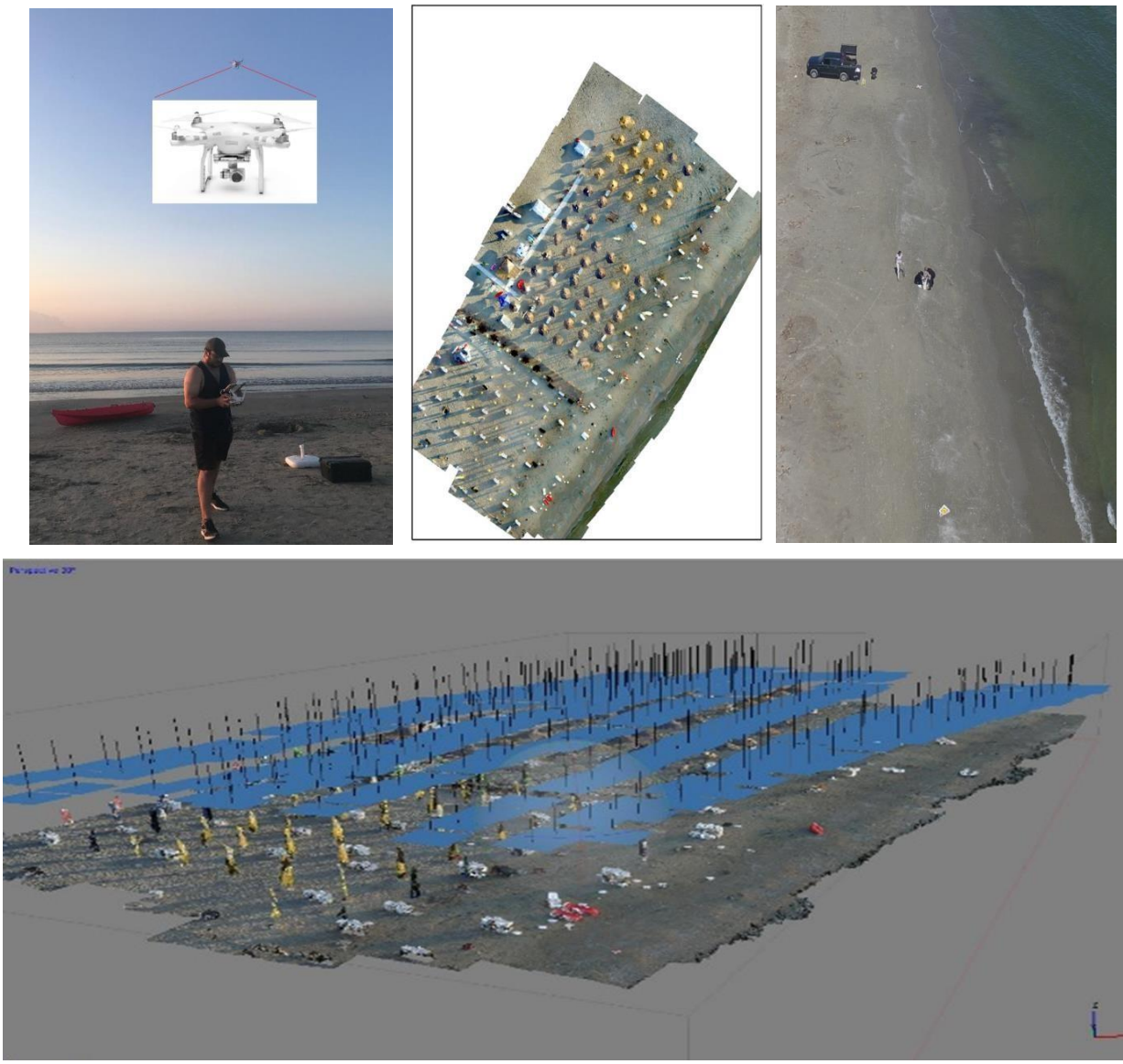

Figure 7Figure 8. Aerial drone-inspection of beach litter on marine beaches located in the Danube River mouth survey area. An example of orthophotoplan and aerial photos of Sulina touristic beach derived from the DJI Phantom 3 Professional drone.

2.4 Microplastic monitoring

The protocol used for assessment of abundance and the main categories of microplastics (particles in the size range 1-5 mm) on sandy beaches Sulina and Casla Vadanei was based on the recommendations given in the Guidance on Monitoring of Marine Litter in European Seas produced in 2013 by the Technical Subgroup on Marine Litter of the European Commission's Marine Strategy Framework Directive (MSFD). The protocol involves the following steps (Figure 8):

(1) *Collection of the sand samples from the survey site*: For each study site, we collected sand from five replicate 50x50cm quadrats (sampling squares) that was positioned randomly along two transects of 100m length. Each replicate was separated by 5m. The sediment was sampled by collecting with a metal spoon the top 5cm of sand from the area contained within sampling squares (quadrat) and stored in a non-plastic container (e.g. metal container or paper/textile bag) until the next step.

(2) *Sieving the sand:* The sand collected was sieved to collect all items in the sand that were between 1 and 5mm in size. This was done in laboratory of NIMRD Constanta and involved sieving the dry beach sand samples by placing a sieve with a 5mm mesh on top of a sieve with a 1mm mesh.

(3) *Collecting the items between 1 and 5mm in size:* By means of a metal spoon we transferred the items from each sieve (1mm and 5mm mesh) into a paper bag or a glass jar for storage until the next step of procedure. The bag/jar were labelled with the study site, date, transect number, quadrat number and type of the sieve used.

(4) *Density separation of microplastics from the other 1 to 5mm items: t*o extract the microplastics from the sieved samples, we carefully transferred the contents into a glass serving dish containing filtered seawater or a salt water solution (approximately 35g/L), as the most microplastics items are a lighter density than the salt water.

(5) *Classifying and recording the microplastics:* the microplastics were recorded one by one as we taken them out of our sample of 1 to 5mm items and transferred into a petri or other small glass labelled dish to view their size, shape and color under the stereomicroscope at 4.5x – 10x magnification or the digital microscope (Optika Microscope B-150DB bino-digital, 40x-1000x). Representative microplastic particles were removed from samples using tweezers and stored on microscope slides.

Figure 8Figure 9. Flow diagram for the analysis of microplastics in beach samples (Sulina and Casla Vadanei)Results and discussion

3 Results and discussion

3.1 Floating litter in the Sulina branch: abundance and composition

During the litter pilot study in Romania, the observers identified a total of 19 floating river litter items fitting in two material categories: 4 plastic and 1 paper. The obtained data corresponds to one dataset and 0.35 hour of monitoring. The composition of floating debris is depicted in Table 1 and Figure 9. The distribution of items by material showed a clear predominance of plastic (up to 95% of the total items). Use plastics such us foam packaging/ insulation/polyuretan (42.10%) and cover/packaging (36.84%) ranked among the most frequently found floating litter. Our preliminary results are in accord with the existing findings on the sources and categories of marine litter of the Black Sea. Plastic is the dominant litter in the Black Sea (47% of total items), potentially introduced by river currents (Topcu et al., 2013). The input of plastic into the Black Sea via the Danube was estimated of 4.2 t per day and 1533 t per year (Lechner et al., 2014).

Table 1 - Monitoring results of riverine floating litter at Sulina branch (45.1567°N, 29.6561°E) in 2019

Item	Size	Unit	Category/ Material	MSFD Code	% of Total Items
Cover / packaging	2.5-5 cm	Item/hour	Plastics	G38	36.84
Synthetic rope	30-50cm	Item/hour	Plastic	G48	5.26
Other paper items	2.5-5cm	Item/hour	Paper	G158	5.26
Plastic pieces 2.5cm - 50cm	2.5-5cm	Item/hour	Plastic	G79+G80	10.52
Foam packaging/ insulation/polyuretan	2.5-10cm	Item/hour Item/hour	Plastic	G74	42.10

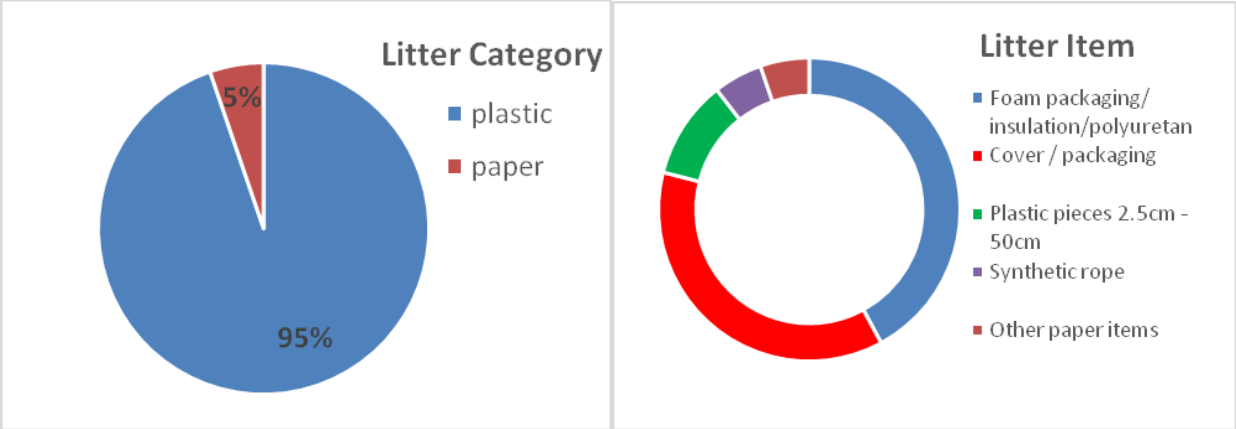

Figure 9Figure 10. Composition of the floating litter visually observed on the Sulina branch surface water in August 2019Beach macro-litter

3.2 Beach macro-litter

3.2.1 Drone-inspected beach macro-litter in the Danube River mouth survey area

At Sulina beach, a 50-min flight allowed an area of approximately 2000m^2 to be covered. The manual screening of the aerial pictures reported a total of 234 litter items, yielding an average density of 0.12 items/m^2. Five main categories (plastic, cloth/textile, paper /cardboard, wood, and metal) were identified at surveyed area. The most abundant were cigarette butts and filters (n=136, 58.11% of total debris), followed by plastic pieces 2.5 > < 50 cm (n=10, 4.27% of total debris), and other paper items, (n=9, 3.84%). Only 12 items were not plastic debris and included cloth/textile (n=3), paper /cardboard (n=7), wood (n=1), metal (n=1). Unidentified items were also present (n=25, 10.68%). (Table 2)

Table 2 - Results from drone-survey at Sulina beach: abundance (n of items) and relative proportion (%) of the categories detected

Marine litter categories	Abundance (n)	Proportion (%)
PLASTIC		
Shopping Bags incl. pieces	8	3.41
Drink bottles <=0.5l	1	0.42
Plastic caps/lids drinks	5	2.13
Cigarette butts and filters	136	58.11
Crisps packets/sweets wrappers	8	3.41
Cups and cup lids	3	1.28
Straws and stirrers	8	3.413
Rope (diameter more than 1cm)	4	1.70
Plastic pieces 2.5 > < 50 cm	10	4.27
Plastic pieces > 50 cm	5	2.13
CLOTH/TEXTILE		
Clothing / rags (clothing, hats, towels)	1	0.42
Rope, string and nets	1	0.42
Other textiles (incl. rags)	1	0.425
PAPER /CARDBOARD		
Cardboard (boxes & fragments)	1	0.42
Cigarette packets	1	0.42
Cups, food trays, food wrappers, drink containers	2	0.85
Paper fragments	3	1.28
Other paper items	9	3.84
WOOD (PROCESSED/WORKED)		
Ice-cream sticks, chip forks, chopsticks & toothpicks	1	0.42
METAL		
Other metal pieces > 50 cm	1	0.42
UNIDENTIFIED ITEMS	25	10.68

For Casla Vadanei beach, 104 litter items were reported in total after manual screening of the aerial pictures taken during a 40-min drone flight covering the area of 1400 m^2. The average density yielded was of 0.07 items/m^2. Five main categories (plastic, paper/cardboard, wood, metal, and glass) were identified at this surveyed area. The most abundant were plastic pieces 2.5 > < 50 cm (n=22, 21.15% of total debris), followed by drink bottles >0.5l (n=17, 16.34% of total debris), drink bottles <=0.5l, (n=14, 13.46%

of total debris), and plastic caps/lids drinks (n=6, 5.76% of total debris). Only 7 items were not plastic debris and included paper/cardboard (n=3), wood (n=1), metal (n=4), and glass (n=2). Unidentified items were also included (n=22, 21.15% of total debris) (Table 3).

Table 3 - Results from drone-survey at Casla Vadanei beach: abundance (n of items) and relative proportion (%) of the categories detected

Marine litter categories	Abundance (n)	Proportion (%)
PLASTIC		
Small plastic bags, e.g. freezer bags incl. Pieces	4	3.84
Drink bottles <=0.5l	14	13.46
Drink bottles >0.5l	17	16.34
Food containers incl. fast food containers	2	1.92
Plastic caps/lids drinks	6	5.76
Crisps packets/sweets wrappers	1	0.96
Cups and cup lids	1	0.96
Plastic pieces 2.5 > < 50 cm	22	21.15
Medical/Pharmaceuticals containers/tubes	2	1.92
Flip-flops	3	2.88
PAPER /CARDBOARD		
Cartons/Tetrapack (others)	1	0.96
Paper fragments	2	1.92
WOOD (PROCESSED/WORKED)		
Processed timber	1	0.96
METAL		
Aerosol/Spray cans industry	2	1.92
Cans (beverage)	1	0.96
Bottle caps, lids & pull tabs	1	0.96
GLASS		
Bottles incl. pieces	2	1.92
UNIDENTIFIED items	22	21.15

For a comparison with its time-efficiency, for each beach, the survey was initially conducted by drone- inspection followed by visual census on the same surface. Item classification obtained from the two approaches is shown by Figure 10.

At Sulina beach, 227 litter items were detected through visual census, while manual screening of the UAV picture of the same area reported 234 litter items. For Casla Vadanei beach, the ground assessment allows to detect 148 litter items, while the litter identified from 10-m altitude pictures totaled only 105 items. Detection probability varied between size-category of items. Thus, the detection of probability was above the 100% in case of Sulina survey possibly due to the high % of unidentified items that were found by manual screening of the UAV pictures. At Casla Vadanei beach, the detection of probability was 70.94% this may be due to different abilities of the two procedures in detecting smaller items (e.g. plastic pieces of 2.5 cm which were the most dominated in this survey area). Exclusion of these small (< 4 cm) items as well as of the unidentified items, led to detection of probability of 100%.

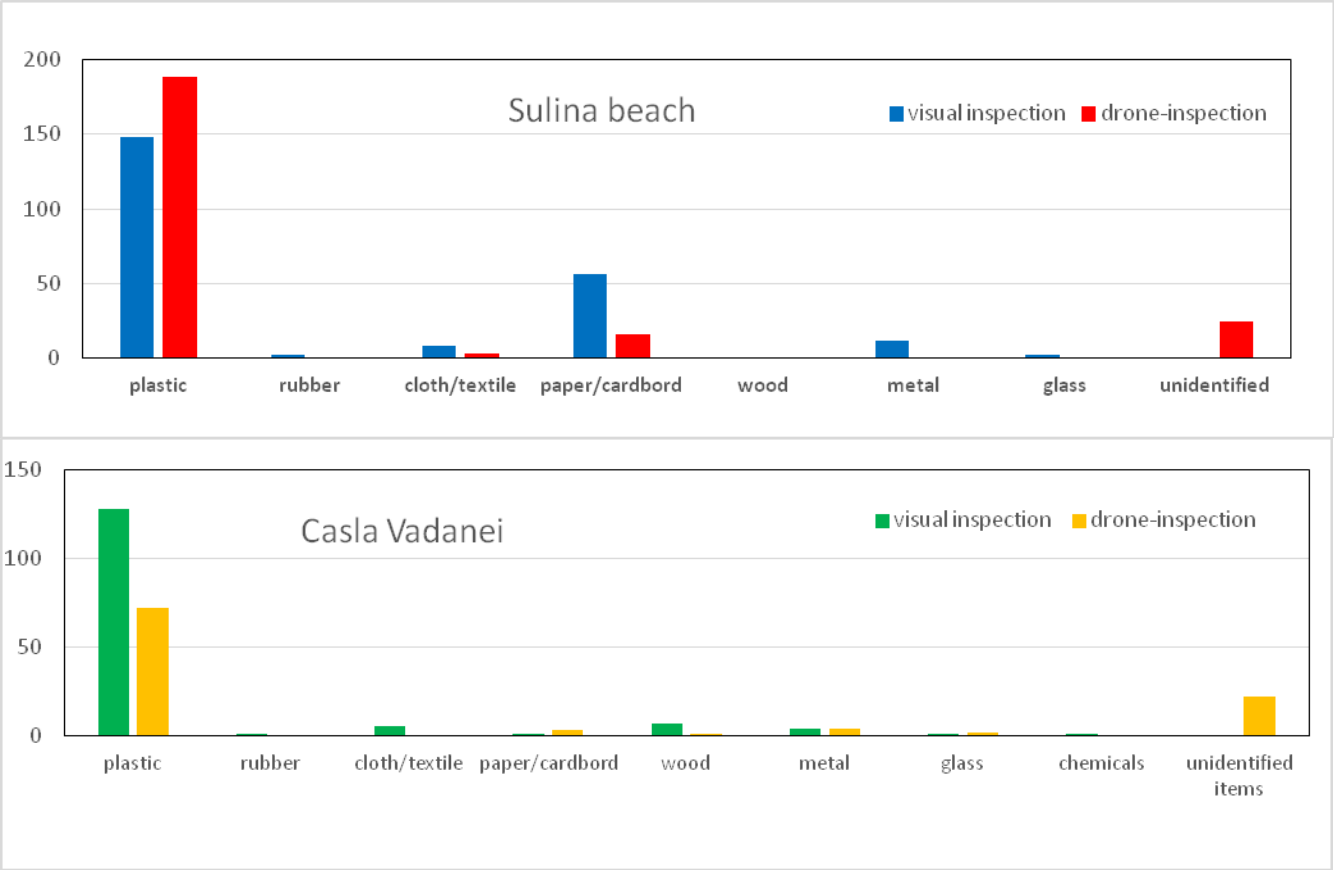

Figure 10 - Comparison of results obtained from two monitoring methods on the Sulina and Casla Vadanei area

Figure 11 - Example of aerial images of marine litter obtained by means of the DJI Phantom Professional quadcopter during the aerial survey of Sulina and Casla Vadanei beach (Original Photos: NIMRD Constanta, Romania)

3.2.2 Visual-inspected beach macro-litter in the Danube River mouth survey area

In August 2019 were monitored two Black Sea beach sectors (Sulina and Casla Vadanei) with a total surface of 3.400 m^2, located in the Danube (Sulina branch) river mouth survey area. In terms of *litter abundance*, this was 0.11 items/m^2, and the sector with the highest abundance was Sulina touristic beach with 0.066 items/m^2. The lowest abundance was registered on Casla Vadanei, 0.043 items/m^2.

Regarding the *litter distribution on survey areas*, the sector with the higher number of marine litters was the wide, touristic sandy beach wide sandy beach located about 2.5 kilometers from Sulina (227), followed by the more Southern, narrower wilde beach called Casla Vadanei (148) (Figure 12).

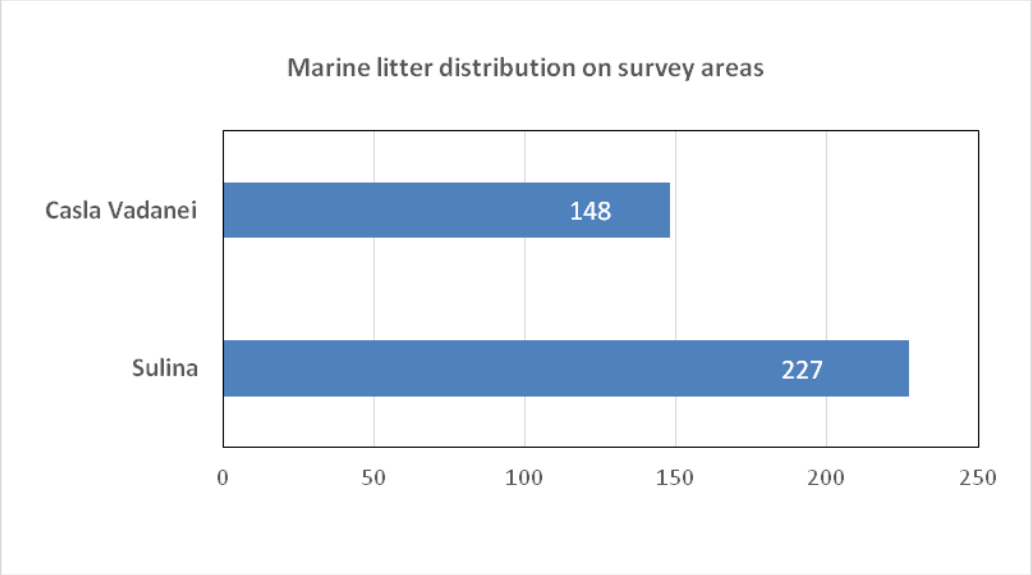

Figure 12 - Litter distribution (number of items/area) on Sulina and Casla Vadanei Beach, August 2019

Concerning the categories, the artificial polymer materials (plastics) prevailed (276 items) representing 73.6% of total, plastics being the most dominant category of litter collected from both Sulina (65%) and Casla Vadanei (86%) beach in August 2019. This category was followed at a great distance by paper/cardboard (56 items), as well as metal (12) and wood (7 items). The fewest belonged to rubber (2 items) and glass (1 item).

For the touristic beach (Sulina), the most of inventories, in case of artificial polymeric material, were cigarette butts (72 items) while for the wilde beach (Casla Vadanei) the plastic pieces 2.5 > < 50 cm constituted the highest number of artificial polymeric material (41). Figure 13 and Figure 14 show the distribution of marine litter per each survey area and categories where it can be seen the very large difference between artificial polymer material and other categories.

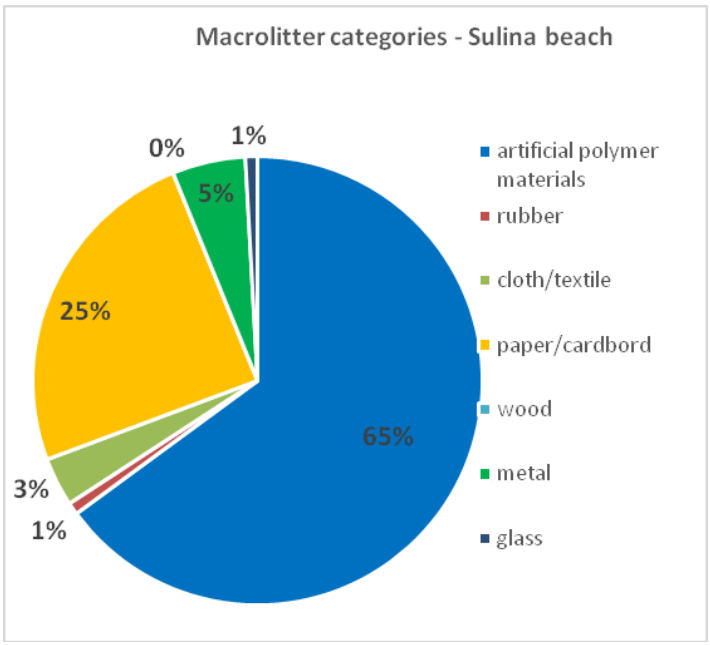

Figure 13 - Distribution among litter material categories on Sulina beach during the summer season 2019

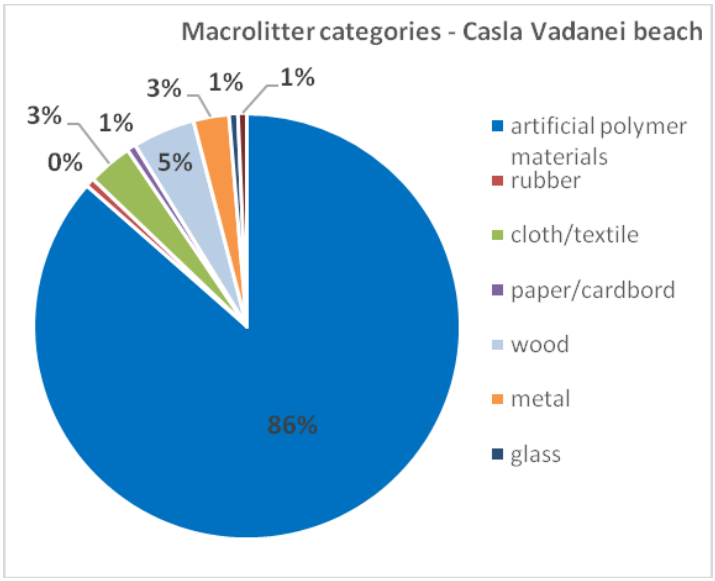

Figure 14 - Distribution among litter material categories on Casla Vadanei beach in August 2019

In addition to cigarette butts, in the category artificial polymeric materials were also found other plastic items such us shopping Bags incl. pieces (2), plastic caps/lids drinks (6), tobacco pouches / plastic cigarette box packaging (6), crisps packets/sweets wrappers (21), straws and stirrers (8), plastic/polystyrene pieces 0-2.5 cm, drink bottles >0.5l (21), food containers incl. fast food containers (5), plastic caps/lids drinks (25), medical/Pharmaceuticals containers/tubes (3) (Figure 15 and Figure 16.

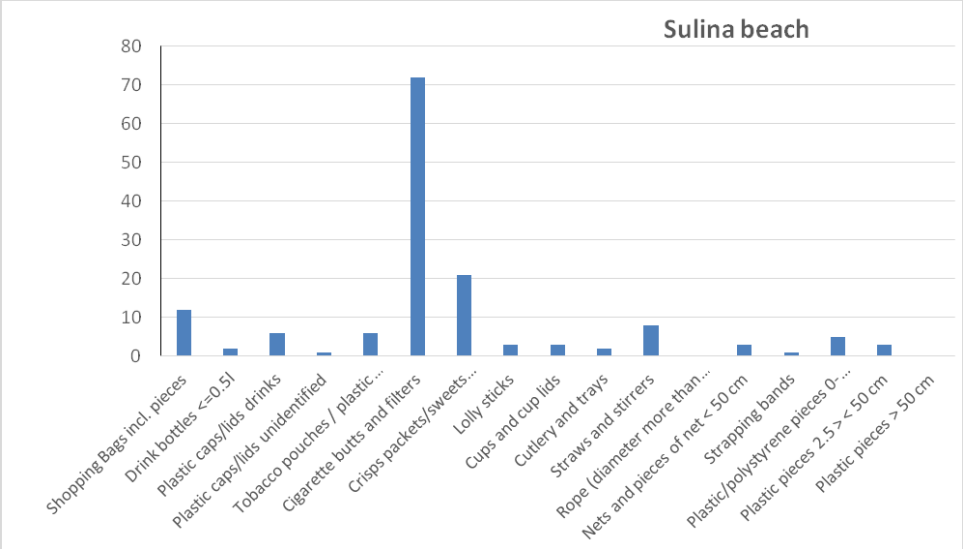

Figure 15 - Artificial polymeric materials (plastics) collected from Sulina beach in August 2019

3.3 Abundance and characteristics of microplastics in beach sediments

All of the microplastics collected from each sand sample were sorted by their shape, color and size.

Dimension of separated microplastics ranged from 0.2 to 11.3 mm.

Microplastic morphology: Five categories of microplastics were identified in sand samples of Sulina (Table 4), while only two categories were presented in the samples collected from Casla Vadanei beach (Table 5).

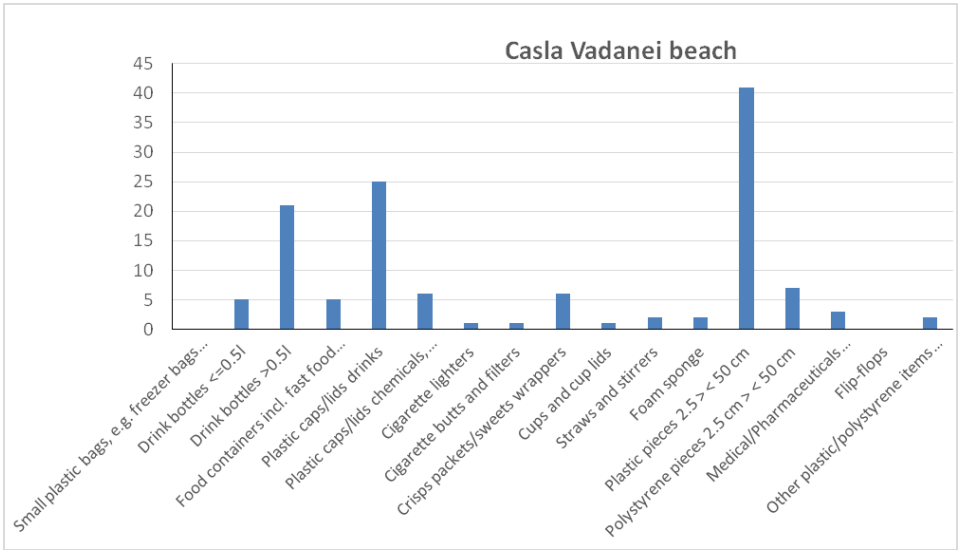

Figure 16 - Artificial polymeric materials (plastics) collected from Casla Vadanei in August 2019

Microplastic concentrations ranged from 0 to 40 particles/0.25m^2. Fragment was the

most predominant type of microplastics in the sand beach collected close to the Danube river outlet. Their concentration was about 20 times higher compared to concentrations of plastic filament or film (Table 4).

Colours were recorded as white, white, transparent, brown, pink and green, most of the identified microplastics being white and transparent. Some examples of the different types of microplastics found in the sand samples collected from the Danube (Sulina branch) river mouth survey areas are shown in Figure 17.

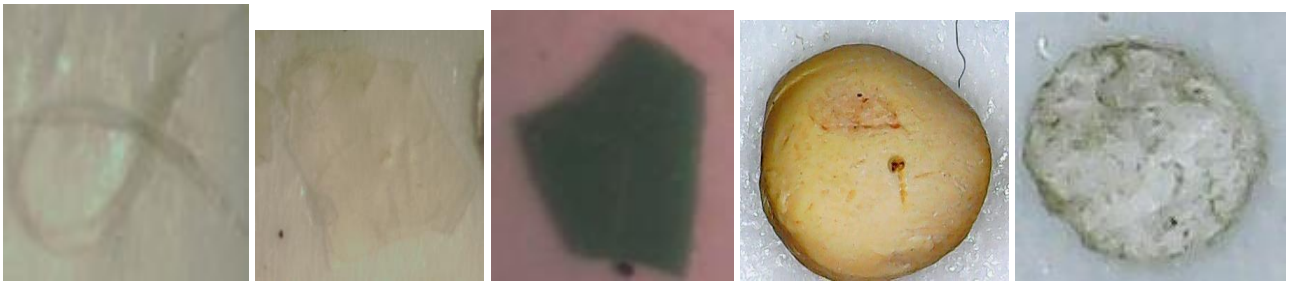

Figure 17 - Examples of the shapes of microplastics found in the Sulina and Casla Vadanei beach; From left to right: filament, film, fragment, pellet, foam. (Original Photos: INCDM, Constanta, Romania)

Table 4 - Abundance and characteristics of microplastics in sediments of Sulina beach

Shape	Abundance (Particles / 0.25 m^2)	Size (mm)						Colour
		Length		Width		Diameter		
		Min	Max	Min	Max	Min	Max	
Filament	2	7.2	8.1	0.2	0.2			transparent
Film	3	1.7	4.7	1.5	2.1	-	-	white transparent
Fragment	40	1.2	8.3	0.4	4.1	-	-	white brown pink green transparent
Pellet	1	7.2	8.1	0.2	0.2	3.8		white
Foam (Polystyrene)	22	1.5	6.5	0.9	4.4	-	-	white brown

Table 5 - Abundance and characteristics of microplastics in sediments of Casla Vadanei beach

Shape	Abundance (Particles / 0.25 m^2)	Size (mm)						Color
		Length		Width		Diameter		
		Min	Max	Min	Max	Min	Max	
Filament	0	-	-	-	-	-	-	-
Film	0	-	-	-	-	-	-	-
Fragment	1	4.6		4.5		-	-	brown
Pellet	0	-	-	-	-	-		-
Foam (Polystyrene)	8	1.5	11.3	0.4	3.1	-	-	white

Our study showed for the first time the presence of microplastics in the top 5cm of the sandy beaches in Danube estuary (Romania). We found differences between the two surveyed beaches with different characteristics. Generally, the concentration of microplastics in beach sediments was higher (40 pieces per 0.25 square meters) in more anthropic-influenced location (touristic Sulina beach) compared to the Danube freshwater-dominated site (8 pieces per 0.25 square meters at wild Casla Vadanei beach). The most dominant microplastic pieces found during this study were fragments (secondary microplastics) resulting from the breakdown of larger plastics. Our result

suggested that microplastic pollution in the estuary shorelines of Danube River is mainly a result of degradation of plastic debris.

4 Conclusions

1) Our pilot study has provided first-hand evidence of the litter presence in different compartiments (water, sediment) of the Black Sea area affected by the Danube River.
2) The visual monitoring data on the floating litter at the Danube River mouth (Sulina arm) showed a clear predominance of plastic (up to 95% of the total items), thus confirming the previous findings concerning the major input of plastic into the Black Sea via the Danube.
3) The macro-litter abundance on two marine beaches located in the Sulina arm mouth area was not significantly different (227 total items at Sulina beach versus 148 total items at Casla Vadanei beach).
4) However, the surveyed beaches have differed in macro-litter composition. Beside plastic, the most dominant category of litter collected from both sites, the paper/cardboard constituted the second abundant (56 items) litter category at Sulina beach, while wood (7 items) at Casla Vadanei beach. The composition of the macrolitter recorded on the surveyed beaches reflected its ability to reach the estuarine shoreline of Danube and the influence of the beach users.
5) Plastics made the highest share of the anthropogenic litter on both beaches (65% to 86%). Cigarette butts were the most abundant item, accounting up to 32% of the objects observed in the touristic beach Sulina. Similar, the small plastic items such us plastic pieces 2.5 > < 50 cm were much abundant (n=41) on the non-touristic, wild beach Casla Vadanei.
6) During our study we tested a more efficient method to assess marine beach litter loads involving the use of an Unmanned Aerial Vehicle (UAV) to record marine litter through image acquisition. Comparison of the results obtained from two monitoring methods (drone-inspection versus visual census) showed that that UAV marine monitoring could be more suitable approach for the Black Sea in term of time-efficiency. The variation of detection probability we found during our pilot survey suggested the necessity to improve the resolution of the aerial photos taken by drone, particularly for the small litter items such us cigarette butts and filters (G27).
7) In addition, our pilot study has shown for the first time the presence of microplastics in the top layer (5cm) of the beach sand from the Danube estuary (Romania). Fragments (as secondary microplastics) resulted from the breakdown of larger plastics were the most dominant category, suggesting that microplastic pollution in the estuary shorelines of Danube River is mainly a result of degradation of plastic debris.

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