R E P O R T

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„Providing data for water currents and connected with them waste streams in the Black Sea“

NIKOLA VAPTSAROV NAVAL ACADEMY

• 2019 •

The current report was developed in the framework of the project Innovative techniques and methods for reducing the marine litter in the Black sea coastal areas-RedMarLitter

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Table of contents:

1. Executive summary

RedMarLitter project aims to develop innovative techniques and methods for reducing marine litter in the Black Sea coastal areas. This will be achieved by protecting the cleanliness of the sea and its coast through monitoring actions like analyzing the load, track main polluting streams and clean up the waste in specific vulnerable areas.

The present report contains data and findings on the water streams, the connected with them litter streams, and their impact on the Black sea coast.

In the report, main streams of solid (non-liquid) waste and potential waste concentration points in surface water are identified.

Understanding the dynamics of floating waste is critical to developing appropriate marine waste management strategies both globally and locally.

Sources of waste in the sea are numerous and heterogeneous and therefore measures to reduce them and to prevent them from entering the marine environment must be applied across broad geographical boundaries and social spheres

The data and findings from the present report will serve as a base for performing of monitoring of the pollution with solid waste of the coastal line in Bulgaria.

2. Data collecting for water streams in the Black Sea target areas.

There is no uniformity and clarity in some of the used basic terms in the text of the assignment for this project, for example concepts such as "water streams", "water currents", "Bulgarian Black Sea coast", etc. There are obviously some preliminary clarifications about the concepts, which will be used below in the context of the research, and it is natural to use the Bulgarian terminology already adopted by marine science. When it comes to "water flows", it is more appropriate to separate seas currents from mass flows across the boundaries of the basin (atmosphere, bottom, land): it is obvious that currents are the main factor for litter disposal, in which case they are included and the processes of turbulent exchange and diffusion. The direct influence of the other constituents of the so-called "Water streams" - river flow and flow through the straits as sources of litter in the marine environment are absent or localized directly around the river estuaries; the indirect impact reaches us precisely through the currents. Therefore, in the present study, the main focus is on the field of the marine currents, as well as the assessment of the magnitude of the river flow from our coast. Another important component of the water balance of the sea (which should also be part of the "water flows") - precipitation does not seem to lead to direct dumping of garbage in the sea (if we exclude the possibility of a certain amount of wash out to the shore and hence to the sea I case of longer or intense rainfall) and is therefore not considered in the presented report. The concept of the Bulgarian Black Sea coast does not sufficiently define whether the area ("coastline") taken into consideration, includes (and to what extent?) or not the adjacent land and what part of the marine sea area is encompassed. The environmental division of bathing areas or mass of water (such as the Marine Strategy Framework Directive 2008/56 / EC and the Marine

Environment Ordinance) is not appropriate for describing the dynamics of water mass. Therefore, the text below refers to a coastal (shallow), open, deep-sea shelf, continental slope, and an abbyssal (deepwater). The observation points at sea are called (oceanographic, hydrological) stations.

The area of the Black Sea Basin is 1760 km2, it has an asymmetrical shape, covering vast parts of Central and Eastern Europe and 4.4 times the sea area. The large water (about 350 km3 / year) and the alluvial (72.106 tons / year) river flow are the reasons for large cross-border transport of biogenic substances and pollutants in the Black Sea. The largest rivers are the Danube (208 km3 / year), the Dnieper (43.4 km3 / year), Riony (13.38 km3 / year), Dniester (9.1 km3 / year), Chorohi (8.71 km3 / Kazal-Irmaq (5.6 km3 / year). The main part (over 70%) of river water flows to the northwestern part of the country, about 13% and 10% are the outcome of the Georgian and Turkish coasts respectively. The internal annual water balance has two distinct periods: spring maximum from March to June and autumn minimum (from September to November). The largest Bulgarian river, which flows into the Black Sea, is Kamchia and it has a catchment area of 5357.6 km2, an average annual flow of 27.7 m3 / s (water quantity 0.62 km3 / year) and an alluvial flow of 462 000 t per year. With such a ratio of river flow, it is obvious that a much stronger (though mediated) pressure of adverse impacts on the rivers of neighboring Bulgarian territories in Romania and Ukraine is expected.

The Basin Directorate for the Management of the Black Sea Basin and the National Institute of Meteorology and Hydrology (NIMH) monitor the outflow of Kamchia (at the Grozdjovo village, number of HMS 43800), Ropotamo (near Veselie village number of HMS 83620), Aitoska river. The Faqi River and the Provadiya River - only the first two flow directly into the sea and can be the subject of this study. On the other hand, data from the monthly newsletters of NIMH, submitted for the last three years in table. 1, show negligible small amounts of water coming from the two rivers, even more when compared to the outflow of the big Black Sea rivers. The impact of the Bulgarian rivers on the research problem of flow of litter in the Black Sea at this stage can also be overlooked due to the fact that their estuaries do not belong to the inland waters of the Bourgas Bay, which is the main subject of this study.

Another component of the water balance of the Black Sea in the case of the studied problem can also be ignored, namely - the flow through the Bosforski straits (according to instrument data from the last years 653 km3 / year passes through the Upper Bosphorus current and 145 km3 / year is infused with Lower Bosphorus) and Kerchenski (an average of 50 km3 / year and 17 km3 / year respectively from and to the Azov sea). Due to the remoteness of both straits their contribution to the pollution of the sea waters off the Bulgarian coast will be taken into account, as in the case of the rivers, integrally by the litter discharged with the general circulation.

Table 1. Monthly information of the flow of river Kamchiya and river Ropotamo

Water quantity, m3/s: average and extreme values for the period 2016-2018 г.; -999 – lack of data

Month	Kamchiya river				Ropotamo river			
	average monthly quantity	deviation from the monthly norm	monthly table maximum	monthly minimum	average monthly quantity	deviation from the monthly norm	monthly table maximum	monthly minimum
2016								
1	14.23	-7.31	54.39	7.2	-999	-999	-999	-999
2	36.17	0.94	41.35	25.99	1.8	10.92	35.19	0.02
3	40.56	3.77	68.51	26.17	0.05	17.91	2	0.63
4	22.894	-5.172	43.964	15.2	-999	-999	-999	-999
5	16.648	-7.357	30.5	9.6	-999	-999	-999	-999
6	13.618	-4.809	18.912	9.8	-999	-999	-999	-999
7	8.568	-1.236	9.8	8	-999	-999	-999	-999
8	8.239	0.73	8.6	8.2	-999	-999	-999	-999
9	8.22	0.696	8.4	8.2	-999	-999	-999	-999
10	8.245	1.98	8.6	8.2	-999	-999	-999	-999
11	8.29	-2.34	9	8.2	-999	-999	-999	-999

12	9.04	-6.42	8.6	8.2	-999	-999	-999	-999
2017								
1	10.23	-11.31	10.84	9.02	-999	-999	-999	-999
2	14.15	-21.09	29.97	10.84	-999	-999	-999	-999
3	20.33	-16.46	56.72	11.25	-999	-999	-999	-999
4	14.52	-13.54	17.22	11.77	-999	-999	-999	-999
5	10.22	-13.79	12.36	6.97	0.25	-7.54	0.69	0.19
6	9.12	-9.3	21.79	5.36	0.23	-3.47	0.54	0.18
7	7.49	-2.31	29	5.17	-999	-999	-999	-999
8	5.33	-2.18	6.29	5	-999	-999	-999	-999
9	5.22	-2.3	6.29	4.84	0.32	-1.37	2.21	0.11
10	6.43	0.16	25.72	4.68	0.71	-2.24	3.02	0.19
11	5.05	-5.57	5.76	4.76	0.48	3.2	0.71	0.4
12	7.55	-7.9	10.44	5.6	0.9	-7.78	3.96	0.98
2018								
1	8.55	-12.99	15.89	7.31	1.47	-11.19	4.40	0.73
2	23.62	-11.71	16.56	9.09	1.64	-17.08	2.83	0.87
3	96.53	59.74	124.2	31.67	1.21	-16.75	2.69	0.63
4	56.02	27.96	114.00	21.63	0.79	-10.93	1.15	0.54
5	15.01	-8.99	20.00	11.57	0.48	-7.30	0.88	0.43
6	13.46	-4.97	26.53	10.12	0.44	-3.25	0.56	0.41
7	15.89	6.09	26.53	10.12	0.76	-1.15	0.56	0.41
8	9.64	2.13	15.36	6.12	0.99	-1.44	1.01	0.98
9	6.13	-1.4	7.75	3.92	0.98	-0.71	1.01	0.98
10	5	-1.27	7.28	4.4	1.03	-1.92	1.32	0.98
11	5.19	-5.43	8.7	4.4	1.19	-2.48	3.83	1.01
12	6.44	-8.02	8.21	5.6	1.05	-7.63	1.21	0.98

Point sources of domestic sewage - sewage treatment plants and sewerage sewage - discharges of sewage treatment plants (STPs) and sewerage of settlements and agglomerations along the Bulgarian Black Sea coast can be considered as specific water flows. There are 16 discharge points of treated and untreated domestic sewage in the Bulgarian territorial waters of the Black Sea. These include 15 STPs serving a population over 2000 p.e. and/or resort complexes, as well as the resort "Elenite" as a point source of domestic sewage. STPs and sewage discharged into the Black Sea are presented in Table 1.

Table 1. Point sources of domestic sewage discharged into the Black Sea

Point sources of domestic sewage discharged into the Black Sea			
Code and name of the water area	Name of the point sources of domestic sewage	**Treated / untreated waters**	Source of domestic sewage

BG2BS000C001 From Durankulak to p. Shabla	Shabla	Treated	STP over 2,000 p.e.
BG2BS000C1004 From p. Kaliakra to Kavarna	Vacation club “Villa Romana”	Treated	STP under 5,000 cub.m/day
BG2BS000C1004 From p. Kaliakra to Kavarna	Kavarna	Treated	STP over 2,000 p.e.
BG2BS000C1013 From Kavarna to p. Galata	Balchik	Treated	STP over 2,000 p.e.
BG2BS000C013 From Kavarna to p. Galata	“Albena” resort	Treated	STP over 2,000 p.e.
BG2BS000C1013 From Kavarna to p. Galata	Sewerage system “Golden Sands”	Treated	STP over 2,000 p.e.
BG2BS000C1008 From p. Emine to Sveti Vlas	“Elenite” resort	Untreated	-
BG2BS000C1108 From p. Emine to Sveti Vlas	Sewerage system with LSTP of hotel complex “Zornitsa sands”, Sveti Vlas town – entrance	Treated	STP under 5,000 cub.m/day
BG2BS000C1108 From Sveti Vlas to Pomorie	Sewerage system Ravda – Sunny Beach - Nessebar	Treated	STP over 2,000 p.e.
BG2BS000C1208 From Pomorie to Sarafovo	Pomorie	Treated	STP over 2,000 p.e.
BG2BS000C1208 From Pomorie to Sarafovo	Pomorie spa hotel	Treated	STP under 5,000 cub.m/day
BG2BS000C1011 From p. Akin to p. Maslen	Sewerage system “Sozopol – Chernomorets – Ravadinovo”	Treated	STP over 2,000 p.e.
BG2BS000C1011 From p. Akin to p. Maslen	Residential group on point “Humata”	Treated	STP under 5,000 cub.m/day
BG2BS000C1012 From p. Maslen to the mouth of river Rezovska < 30 m	Lozenets	Untreated	STP over 2,000 p.e.
BG2BS000C1012 From p. Maslen to the mouth of river Rezovska < 30 m	Tsarevo	Treated	STP over 2,000 p.e.
BG2BS000C1012 From p. Maslen to the mouth of river Rezovska < 30 m	Sewerage, Sinemorets village	Treated	STP over 2,000 p.e.

It is of concern that untreated or insufficiently treated domestic sewage is still discharged into coastal seawater. This is the case with STP “Lozenets” and resort “Elenite”.

Only on the territory of the Black Sea basin management area other 65 urban and local sewage treatment plants and sewerage systems discharge into the rivers flowing into the Black Sea. The sewage treatment plants are presented in Table 2 and the discharges of the sewerage systems in Table 3. Treated domestic sewage from 6 treatment plants with a low flow rate (under 5,000 cubic meters per day) flows into the waters of Dobrudza Black Sea rivers.

10 urban sewage treatment plants discharge in the Kamchia River - 7 STPs serving settlements with a population of over 2,000 p.e and 3 of agglomerations of under 2,000 p.e. Regarding the water quality of the Kamchiya river, the problem is the lower downstream discharge from the 6 sewerage systems in small settlements which do not have built and/or functioning domestic sewage treatment plants.

Mandrian rivers take domestic water from 3 sewage treatment plants and untreated waters from 2 rural sewerage systems.

The Provadiyska River, which flows into Beloslav Lake, receives treated sewage from 6 STPs serving over 2,000 p.e. and sewage from the sewerage systems of two small towns: Kaspichan and Novi Pazar.

7 STPs of small settlements with up to 2,000 p.e. discharge into the Southern Bourgas rivers, 3 of which do not provide the necessary degree of treatment of domestic sewage.

The Northern Bourgas rivers experience the influence of 18 point sources of domestic sewage. These include 7 sewerage systems, whose waters are untreated, 7 low-capacity local sewage treatment plants, 3 STPs of settlements with over 2,000 p.e. and 1 STP serving up to 2,000 p.e.

The Veleka River takes the untreated waters of 4 sewerage systems: the town of Malko Tarnovo and the villages of Zabernovo, Brashlyan and Gramatikovo.

Table 2. STPs discharging into the rivers flowing into the Black Sea

Point sources of domestic sewage within the territory of Black Sea basin management

Code of updated surface water bodies	Name of the point source	**Treated/ Untreated domestic sewage**	**Source of domestic sewage**
Dobrudza Black Sea rivers			
BG2DO800R001	134 residential buildings in Lyahovo village	Treated	STP under 5,000 cub.m/day
BG2DO800R002	"Recreational marine complex", General Kantardzievo village	Treated	STP under 5,000 cub.m/day
BG2DO800R002	Sewerage system of a housing complex, Osenovo village	Treated	STP under 5,000 cub.m/day
BG2DO800R002	Local sewage treatment plant of "Mimoza" villa complex	Treated	STP under 5,000 cub.m/day
BG2DO800R002	Local sewage treatment plant of "Alen Mak" resort	Treated	STP under 5,000 cub.m/day
BG2DO800R002	Holiday homes	Treated	STP under 5,000 cub.m/day
Kamchiya river			
BG2KA130R002	Dolni Chiflik	Untreated	Sewerage
BG2KA130R002	"Kamchiya" resort	Treated	STP over 2,000 p.e.
BG2KA130R002	Dalgopol	Treated	STP over 2,000 p.e.
BG2KA400R042	Kotel	Treated	STP over 2,000 p.e.
BG2KA400R042	Zheravna village	Treated	STP under 2,000 p.e.
BG2KA400L024	Manolich village	Treated	STP under 2,000 p .e.
BG2KA578R1003	Shoumen	Treated	STP over 2,000 p.e.
BG2KA800L029	Loznitsa	Treated	STP over 2,000 p.e.
BG2KA800R1131	Targovishte	Treated	STP over 2,000 p.e.
BG2KA400R1111	Lyulakovo village	Treated	STP under 2,000 p.e.
BG2KA900R019	Veliki Preslav	Treated	STP over 2,000 p.e.
Mandrenski rivers			
BG2MA100L001	Sewerage system, Meden rudnik complex in the town of Bourgas	Treated	STP over 2,000 p.e.
BG2MA600R015	Sewerage system STP	Treated	STP under 5,000 cub.m/day
BG2MA700R006	STP Sredets	Treated	STP over 2,000 p.e.
Provadiyska river			
BG2PR100L001	Town of Varna	Treated	STP over 2,000 p.e.
BG2PR100L001	Micro STP of BFV	Treated	STP under 5,000 cub.m/day
BG2PR100L002	STP at ПСОВ at a stationary compartment of the ODPFZS-Varna	Treated	STP up to 2,000 p.e.
BG2PR100L002	Beloslav	Treated	STP over 2,000 p.e.
BG2PR210R1005	Devnya	Treated	STP over 2,000 p.e.
BG2PR345R1107	Provadiya	Treated	STP over 2,000 p.e.
BG2PR500R008	Vetrino village	Treated	STP over 2,000 p.e.
Southern Bourgas rivers			
BG2IU100R003	Sewerage in Marinka village	Untreated	STP up to 2,000 p.e.
BG2IU200L017	STP in Dyuni village	Treated	STP up to 2,000 p.e.

BG2IU200L019	Sewerage system of "Liliite" holiday complex	Treated	STP up to 2,000 p.e.
BG2IU200R004	Rosen village	Untreated	STP up to 2,000 p.e.
BG2IU200R004	Ravna gora village	Treated	STP up to 2,000 p.e.
BG2IU200R004	Veselie village	Untreated	STP up to 2,000 p.e.
BG2IU600R013	Sewerage system Kiten-Primorsko	Treated	STP over 2,000 p.e.
Northern Bourgas rivers			
BG2RE400R002	Sewerage system of villa complex	Treated	STP under 5,000 cub.m/day
BG2SE200R001	Housing complex in Rudnik village	Treated	STP under 5,000 cub.m/day
BG2SE200R001	STP of recreational base	Treated	STP under 5,000 cub.m/day
BG2SE400R006	STP Obzor-Byala	Treated	STP over 2,000 p.e.
BG2SE500R01012	Sewerage system of a seasonal housing complex, town of Nessebar	Treated	STP under 5,000 cub.m/day
BG2SE600R01015	Sewerage system of a wine house "Santa sara"	Treated	STP under 5,000 cub.m/day
BG2SE800R019	Sewerage system of a residential building	Treated	STP under 5,000 cub.m/day
BG2SE900L037	Bourgas	Treated	STP over 2,000 p.e.
BG2SE900L037	Sewerage system of Gorno Ezerovo complex	Treated	STP over 2,000 p.e.
BG2SE900R026	Sewerage system of sports complex "Akulite"	Treated	STP under 5,000 cub.m/day
BG2SE900R035	Krastina village	Untreated	STP under 2,000 p.e.

Table 2. Sewerage systems discharging into the rivers flowing into the Black Sea

Code of updated surface water bodies	Name of the settlement / point source	**Treated/ Untreated domestic sewage**	**Source of domestic sewage**
Kamchiya river			
BG2KA130R002	Dolni Chiflik	Untreated	Sewerage
BG2KA500R010	Medovets village	Untreated	Sewerage
BG2KA578R1003	Osmar village	Untreated	Sewerage
BG2KA578R1003	Troitsa village	Untreated	Sewerage
BG2KA578R1003	Han Krum village	Untreated	Sewerage
BG2KA600R018	Smyadovo	Untreated	Sewerage
Mandrenski rivers			
BG2MA200R003	Sewerage s ystem of Izvor village	Untreated	Sewerage
BG2MA400R004	Sewerage system of Zidarovo village	Untreated	Sewerage
Provadiyska river			
BG2PR567R1011	Kaspichan	Untreated	Sewerage
BG2PR600R1012	Novi Pazar	Treated	Sewerage
Northern Bourgas rivers			
BG2SE400R006	Sewerage system of Popovich village	Untreated	Sewerage

BG2IU100R003	Sewerage system of Marinka village	Untreated	Sewerage
BG2SE800R020	Sewerage system of Aheloy	Untreated	Sewerage
BG2SE900L028	Sewerage system of Kableshkovo	Untreated	Sewerage
BG2SE900R025	Sewerage system of complex Vetren, Mineralni bani and Banovo	Untreated	Sewerage
BG2SE900R030	Aytos	Untreated	Sewerage
BG2SE900L027	Town of Kameno	Untreated	Sewerage
Veleka river			
BG2VE109R001	Town of Malko Tarnovo	Untreated	Sewerage
BG2VE109R001	Zabernovo village	Untreated	Sewerage
BG2VE109R001	Brashlyan village	Untreated	Sewerage
BG2VE109R001	Gramatikovo village	Untreated	Sewerage

By 2018 there are 6 point sources of domestic sewage pollution which are defined as “hot spots” - land-based sources with a significant negative impact on the Black Sea state: STP Golden Sands; STP Varna; STP Asparuhovo; STP Balchik; STP Tzarevo and STP Bourgas.

There are 6 sewerage systems defined as “hot spots” - land-based sources with a significant negative impact on the Black Sea state: the towns of Sozopol, Ahtopol and Chernomorets; complex Sarafovo - Bourgas; the village of Varvara and the village of Sinemorets. It is expected that litter will also be introduced into the sea water at these point sources of domestic sewage pollution.

Water flows from urban and local sewage treatment plants are not critical to the distribution and accumulation of marine waste. This is due to the fact that STPs are generally not a source of marine waste (D10 descriptor according to RDMC), and when discharged into coastal marine waters their influence on the direction and rate of the sea currents is practically negligible. The sea currents, the wave activity and the river discharge are leading factors regarding the distribution and deposition of marine waste along the Bulgarian Black Sea coast.

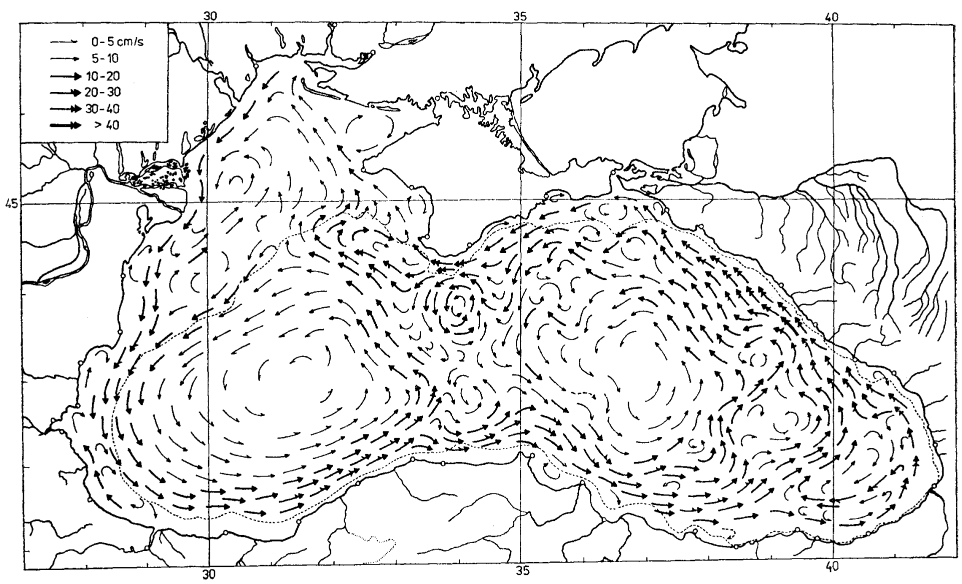
Sewerage systems and urban sewerage, as well as gullies discharged or drained into surface water bodies - rivers and coastal sea waters - are often also carriers of waste from all major groups according to the classification of the OSPAR Commission. The transport and deposition of marine waste is determined by the weather conditions, hydrodynamic processes and the nature and extent of the waste.

2.1. GENERAL CHARACTERISTIC OF THE SURFACE CIRCULATION OF THE BLACK SEA WATERS

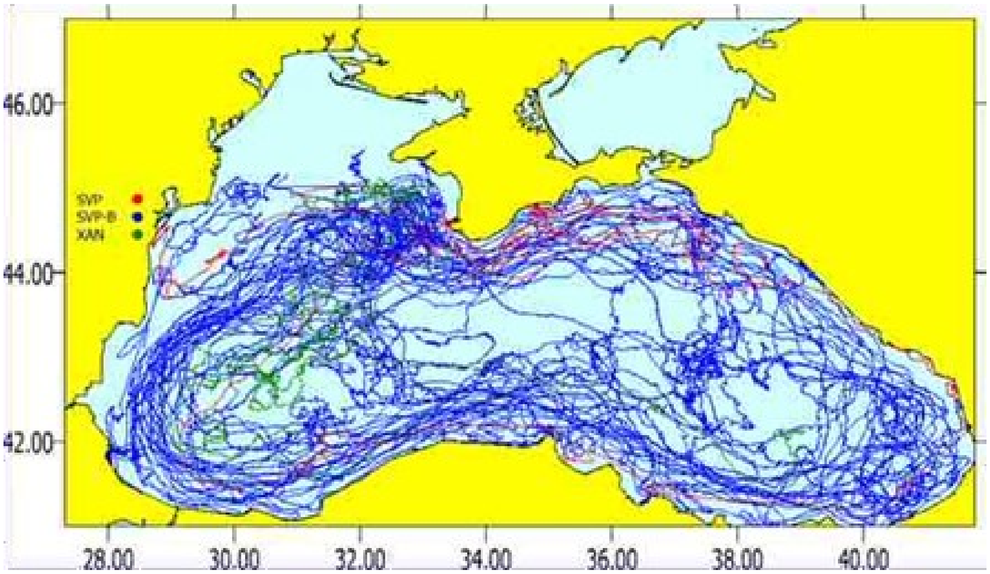
The total circulation of water on the surface of the sea is carried out by a cyclonic (i.e. clockwise) scheme with the main dynamic pattern of the Main Black Sea Current (MBC) (Figure 1-1). The latter represents a frontal jet stream, an average width of about 70-100 km and an average rate of 40-60 cm / s. The total cyclonic circulation exists throughout the year in the upper 300-500-meter layer, but during the warm half-year it weakens two or more times (depending on the level of kinetic energy). The stream MBC is usually located at the end of the shelf and over the continental slope, and due to hydrodynamic instability, it experiences wave-like fluctuations from its middle position (Figure 1-2). The intensity of meandering, wavelength and amplitude of the meanders varies from region to season: from weak fluctuations to almost closed or highly stretched formations.

There is a significant seasonal variability of dynamics, with the most intense currents in the winter when the stability of MBC is greater. In the warm half-year with a reduction in rate, the intensity of meandering increases. The scale of movement is extremely wide: if MBC is the major large-scale feature of air circulation, the mid-scale movements of spatial separation include cyclonic circles in the centers of the two sub-basins - the Eastern and Western sub-basins (the so-called glasses of Knipovich), the coastal anticyclonal vortices and their physical evolution during the various months - cf. Fig. 1-2. An example of the latter is the reported weakening of the rate of the MBC and the complication of its structure from March to September; in most parts of the Black Sea, the local turbulence of the field in September is opposite to the March one.

Since to the right of the stream of MBC coastal anticyclone vortices usually appear, develop and slacken, then a special rhythm of the currents is created in the narrow coastal line. Reverse type currents are observed: they are directed alongside the shore often changing their direction to the opposite side. The change takes place quickly - in a few hours. As a final result of this high degree of change in a more continuous averaging of the rate vector, the medium vector module has low values. Off the Bulgarian coast, two regions are mostly influenced by the anticyclonal vortices: the region south of Kaliakra and east of Galata and the the water area south of cape Emine and east of the Bourgas Bay, as shown schematically in Fig. 1-3a.



a)



b)

Fig. 1-1. Surface water circulation: Neumann's diagram (a) and trajectories of drifting buoys from September 1999 to August 2003

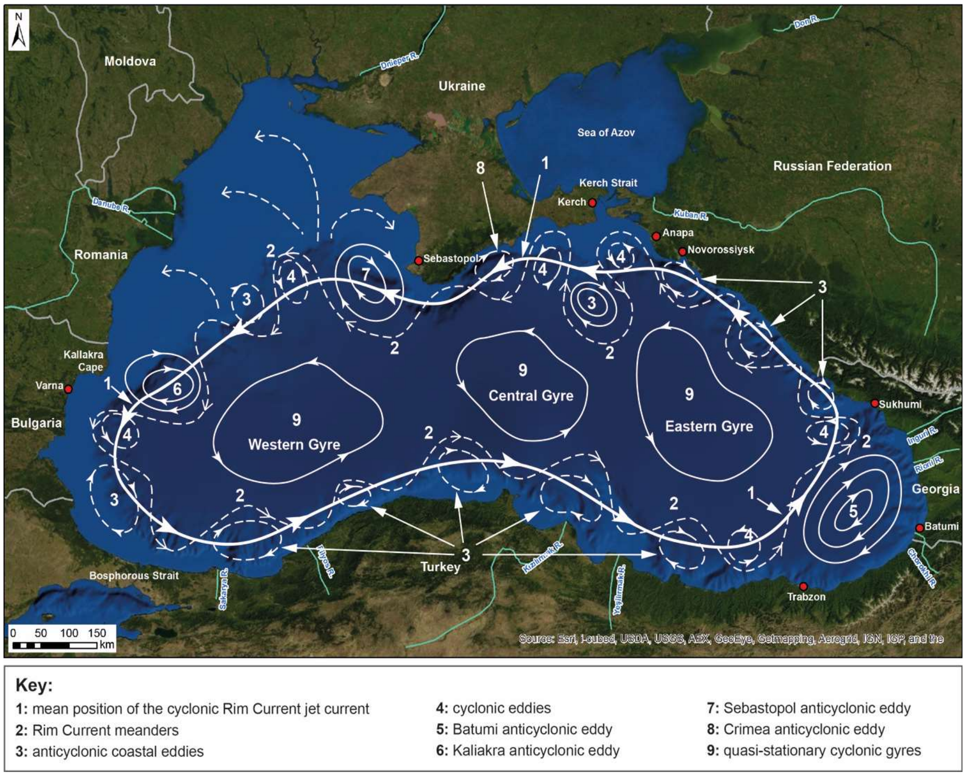
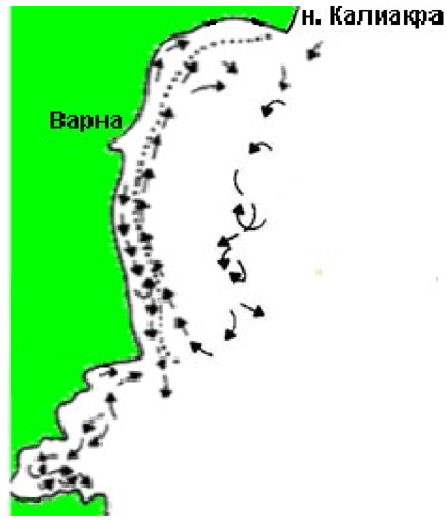


Fig. 1-2. General Diagram of the Circulation in the Upper 500-meter Layer.
Mean location (1) and meanders (2) of MBC, anti-cyclonic (3) and cyclonic (4) coastal vortices; quasi-static anticyclonal vortices (5-8), mid-size anticyclonal vortices (9)

2.2. FEATURES OF THE REGIONAL CURRENTS OFF THE BULGARIAN COAST

The local water circulation and the coastal flow regime are mainly determined by the specific features of the total circulation in the upper layer of the sea and by the nature of the wind, in the area north of cape Kaliakra is strongly expressed the direct impact of the river discharge created by the flow of water from the rivers in the Northwest Black Sea and above all from the Danube. Typical coastal flow rates vary between 5-20 cm / s, but in some cases, with strong winds may reach 30-40 cm / s. The dynamics of the water masses over the coastal shelf of Bulgaria is very high, there is a rapid reaction of the sea to the changes in the field of the wind. The nature of the drift currents in the coastal zone has a strong impact on the shape of the shoreline and the nature of the changes in the depths of the coastal slope. The latter two factors play a major role in the emergence and development of offset currents and those characteristic of the upwelling and downwelling processes, an example of which is shown below.

In the northern part of the Bulgarian shelf, the coastal flow of the northwest part of the river basin flow directs to the south and in the region of cape Kaliakra merges with MBC, forming a powerful (especially at the end of the shelf near the continental slope) stream with predominant direction in the southern quarter (fig. 1-3a) and absolute maximum rates recorded for the whole basin, the pulsations of which in certain cases exceeds 1.5 m/s. Following the contour line, the stream originally has a southwest direction, then turns south-southeast, maintaining the meridional flow along the shoreline. To the right of the current - to the shore, salinity (and hence - density) is decreasing, the rate of the stream weakens and conditions for the emergence of north-going counter- currents. Close off shore, depending on its configuration, there are local currents, they are weak and they are stronger influenced by the winds, but in general the southern flow dominates (Figures 1-3b). The southern current is most intense and persistent in winter and spring, in the summer when it weakens, the northern counter-current is more noticeable, and in the autumn it is sometimes even significant.



a) b)

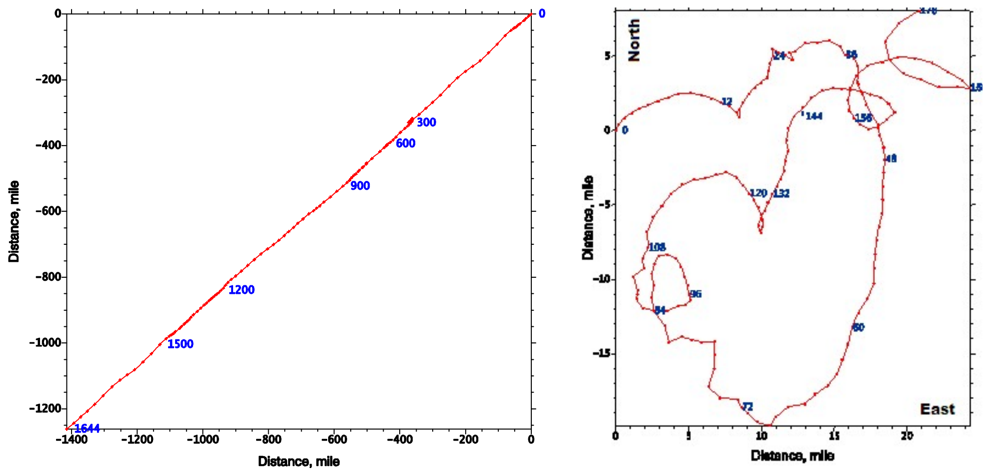
Fig. 1-3. Diagrams of average shelf (a) and coastal (b) currents

Aggregate statistical characteristics of the rate vector in the upper layer of the north (north of cape Kaliakra), central (between cape Kaliakra and cape Emine) and southern (south of cape Emine) area of the shelf are presented in Table. 1-1. Depending on the depth, regions are divided conditionally into coastal water areas (with a depth of less than 30 m), the intermediate zone of the open shelf (located to the east and reaching up to 60 m contour line) and deep shelf. The data are obtained after statistical processing of time series of long-term measurements of currents from autonomous buoy stations, the closest device to the surface being on a 5 m horizon, i.e. the measurements do not cover the surface itself. The low average flow module values show significant current variability, the average rate module is significantly bigger. In general, both in winter and summer southwest movements prevail. The average flow rate in the central water area is maximum at the end of the shelf on a horizon ~ 25 m; the stability increases with depth and distance from the shore, reaching 95% at great depths and 96-98% in the surface horizons at the edge of the shelf. At the point [42.583˚N, 28.0˚E] in the winter and spring of two different years on the 20m horizon, constant and intense currents with a rate of up to 137 cm / s are recorded. In the vertical distribution of the average current module, the maximum vertical gradients are usually marked between 10 and 25 m (with an average rate of ~25 and ~20 cm / s) respectively; in the layer 25-50 m the average rates are relatively homogeneous.

Tab. 1-1. Aggregate statistical characteristics of the rate vector in the upper 10-meter layer for different parts of the shelf of Bulgaria:

maximum $\vec{V}_{max}$ *and middle* $\bar{\vec{V}}$ *module [cm / s] and their azimuth [º]*

WATER AREA	SEASON			
	WARM		COLD	
	$\vec{V}_{max}$	$\bar{\vec{V}}$	$\vec{V}_{max}$	$\bar{\vec{V}}$
NORTH				
coastal shelf	37; 0º	7; 180º	148; 180º	62; 200º
open shelf	69; 210º	20; 202º	195; 220º	71; 220º
depth shelf	-	-	-	-
CENTRAL				
coastal shelf	59; 15º	26; 8º	77; 225º	7; 250º
open shelf	95; 40º	7; 70º	83; 195º	12.3; 227º
depth shelf	61; 170º	9.5; 220º	72; 235º	29.9; 225º
SOUTH				
coastal shelf	-	-	-	-
open shelf	55; 180º	13.4; 288º	54; 180º	38; 202º
depth shelf	46; 170º	4.7; 252º	-	-



a) b)

Fig. 1-4. Progressive vector flow charts: movements with high stability in winter (a) and low stability in summer (b).

Time is displayed in hours; duration of observation 68.5 days (a) and 175 hours (b)

1. The most characteristic feature of the current and of all its features in the shelf water area is the significant variability of meso- and sub-meso (synoptic) scale, especially over time. In winter and early spring large-scale peculiarities dominate, and the flow of MBC is more stable (fig. 1-4a). In the summer and early autumn the current is weakened by 1.5 to 2 times: the sub-basin inhomogeneities prevail, the processes of meandering and the generation of various medium-sized and synoptic dynamic formations (Fig 1-3b, Figures 1-4b) are intensified: vortices, vortex dipoles (doubled vortices with reverse signs of vortex), streams, (so-called filaments). These structures affect the horizontal (including between the coastal and open sea zones) and vertical water flow.
2. At the average annual level, in the surface layer between the MBC and the coast in certain areas of the Black Sea, the presence of several quasi-stationary anticyclonal vortices, called Kaliakrensky, Bourgaski, Sevastopolski, Dunavski, etc., is noted, whose incidence varies from 150 to 265 days in year -

the vortex to the east of the Bourgas Bay (Figure 1-3a, Figures 1-9c), for example, is observed on average 190 days and nights a year, registered more frequently in autumn and winter, most rarely in May. The main reason for their generation from MBC, as well as their seasonal and annual variability, is related to the corresponding wind turbulence in the field of wind friction. The geographic names of these whirlwinds indicate regions of increased medium-scale activity, not only related to local formation, but also to the water areas of whirlpools already generated elsewhere and spreading in the main direction of the MBC. When the distance between MBC and shoreline exceeds the horizontal scale of the vortex or when anticyclone clears from the shore, the evolution of the anticyclone is accompanied by the generation of one to three connected non-stationary cyclonic vortices with diameters of ~ 10 km to values comparable to the diameter of the vortex or stream - the area of influence of an anticyclone is substantially greater than its diameter. There are cases of anticyclonal vortices from the Danube vortex system to affect the deep waters of the western part of the Anatolian coast. When the involving of shelf waters by the anticyclones is intense, the longitudinal flow from the north to the south is weak and the flow of substances in the south direction is limited, whereas in the absence of vortices it increases.

3. The typical radius of the vortices with average scale is ~15-100 km, they cover the upper layer (at the end of the shelf and over the continental slope they develop to a depth of ~400 m), their orbital rate is between 10 and 60 cm / s with a maximum just below the seasonal thermocline; the characteristic decrease of temperature in the centers of the anticyclones referring to the periphery and the adjacent waters is ~1-3.5 ° C. In the field of the synoptic

measurements the most frequent fluctuations of the currents are with ~90, 60, 50, 40 and 30 h. The rate of motion of the meanders appearing on the background of MBC is estimated from 3-6 cm/s to 10-15 cm/s; but sometimes the speed of travel is too small to be registered. The time for spreading this type of dynamic structure along the coastline or over the slope varies from one week (when the vortex connects to its adjacent structures or is separated from the shore) for up to five months. Some of the fluctuations of the sea currents are also of a recurrent nature because of their relationship with:

4. - day and night time, half-day and night time and breeze atmospheric variability;
5. - the local inertia period of approximately 17 hours;
6. - own fluctuations of the Black Sea waters and the particular bays.
7. Against the background of the more or less determined formations described, other fluctuations and vortex movements are developed which are intertwined with each other and with the basic ones. An important role in vertical flow processes is played by upwelling and downwelling phenomena. In the case of strong and prolonged winds from the west and south, there is a depression of surface water from the shore to the interior of the sea and offsetting rise of upwelling water. In winter, downwelling, coupled with strong coastal water cooling, creates conditions for vertical circulation and causes surface water layers to go down to larger depths. The frequency of repetition and the duration of such processes as well as a quantitative assessment of the magnitude and speed of ongoing changes in oceanographic parameters on the Bulgarian shelf and coastline have not been investigated. All this forms a complex and irregular vortex stream structure in the shelf and coastal zone.

2.3. FEATURES OF WATER CIRCULATION IN THE BAY OF BOURGAS

Brief physical-geographic characteristics of Bourgas Bay. Bourgas Bay (Fig. 1-5) is the largest bay in the western part of the Black Sea. It is to the west of the line connecting cape Emine and cape Korakya. It is indented deep into the land- it includes the westernmost point of the Black Sea (27º2654 “). The length of the coast is about 145 km. Its sea border running along the line from cape Emine to the area of Sozopol has a length of 42 km. This line is 32 km and its area is 751 km2, the maximum depth in this part reaches ~ 46 m. There are several sand banks in the bay, the largest of which is Koketrais. as well as two islands in the southern water area - St. Ivan and St. Anastasia (Bolshevik).

The coast of the Bourgas Bay is heavily indented with two larger peninsulas: Nessebar and Pomorie. The shore between cape Emine and the northern part of Sunny Beach Resort is relatively rectilineal. Between Sunny Beach and cape Foros, the coast is low, there are the Pomoriisko and Atanasovsko Lakes separated from the sea by a tongue of sand. The southern coast is heavily indented with many bays (Atia, Vramos, Sozopol, etc.). It can be assumed that between the Pomorie peninsula to the north and Akin to the south, in the westernmost part of the Big Bourgas Bay is formed the small bay of Bourgas. The width of the “entrance” in the latter is about 14 km and the total area is 22 km2.

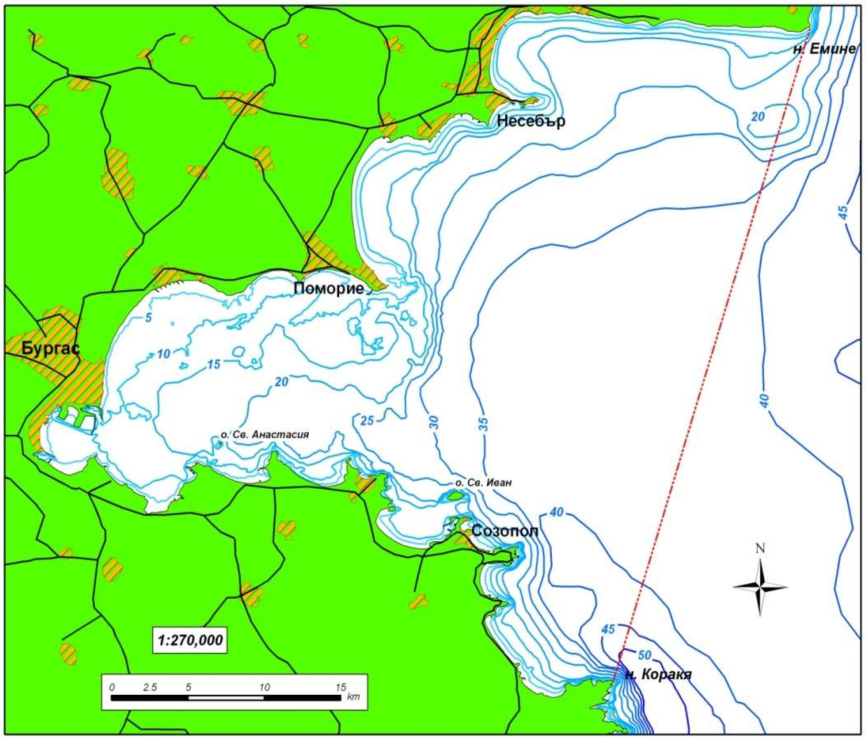


Fig. 1 5. The water area of the Bourgas Bay and relief of the seabed

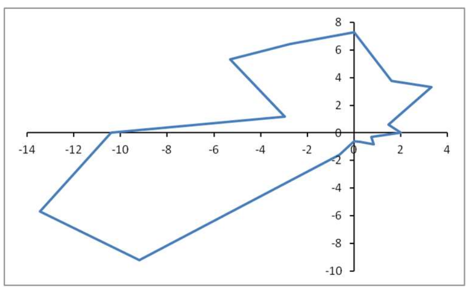
<u>Characteristics of the wind field in the Bourgas Bay area.</u> Wind is a significant dynamic factor under the influence of which he system of water circulation in the bay is formed and which directly transfers part of the litter examined in this project along the coastal line and the adjacent water area. Therefore, although there is no requirement in the assignment for its description, its basic qualitative and quantitative features, which are useful in interpreting the results for dynamics and water and waste will be shown below.

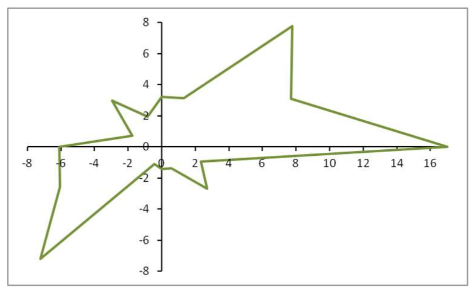
The dynamics of the atmosphere in the region and over the sea has a well-marked annual movement. In the winter, the prevailing influence of the Northeast Ridge of High Pressure in the system of powerful Siberian anticyclones and / or Mediterranean Cyclones, whose trajectories pass over the Black Sea, north or south of it. Anticyclonal circulation is dominated by strong E and NE winds, with the cyclonic one the force of the wind blowing from S and SW increases, the latter becoming Northwesterly . In the summer, the weather over the Balkan Peninsula and the Black Sea is steady and calm, and the influence of local winds, orographic features (i.e. connected with the relief) and coastline geometry as well as breeze circulation are growing. During the warm half-year from March to October, the coastal wind direction is characterized by well-marked 24-hour movement, mainly due to the difference in heating of the sea and land (breeze), as well as for orthographic reasons (slope winds). The change of the sea breeze with on-shore one and vice versa is done respectively in the evening and shortly before noon. In the morning when the on-shore breeze ends, there is a period of calm.

The maximum total duration of wind speed action at a certain speed is observed in the autumn and winter, the minimum - in the spring / summer season. Especially well, this is expressed for the open and deeply projecting parts into the sea of the land of cape Emine. The average continuous wind retention rate over a certain value is similar to the total duration of the winds with a certain speed - the Black Sea region is different from that of the other regions of Bulgaria and these two indicators are comparable to the high mountain regions.

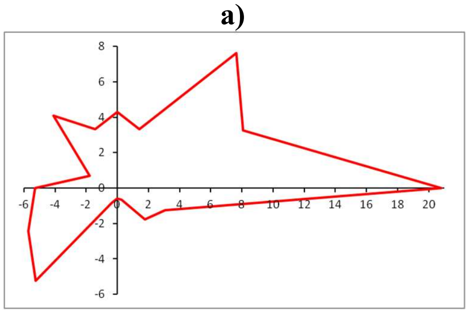
The climatic characteristics of wind speed and direction in the bay area are shown in table. 1-2 and tab. 1-3, and for four characteristic months during the different seasons are shown in Fig. 1-6. They are built on publicly available data from the Internet site https://rp5.ru/ with the results of 14-year observation in the meteorological periods at meteo station № 15655 in Bourgas (42.48 ° N, 27.48 ° E, 28 meters above sea level) and cover the period from 01.02.2005 to 31.05.2019. The presented wind data are topical, as opposed to the data from the official

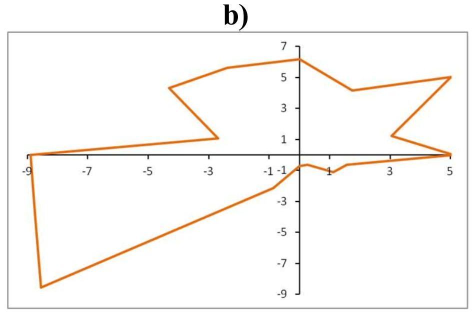
Climate Guide of Bulgaria which are over 40 years old. Mid-Range Speed Module data does not have a well-marked annual movement and the rate of change is around 4-5 m / s throughout the year. The wind roses in Fig. 1-6 and from the data in tab. 1-2 and tab. 1-3 clearly show three main features of the mid-multi-year distribution of wind in Bourgas: a) prevailing winds from the east, west and north quarters, and those from the south have less distinctive character; (b) breeze circulation has an important contribution to the formation of the wind field; (c) the presence of period of calm is clearly expressed.



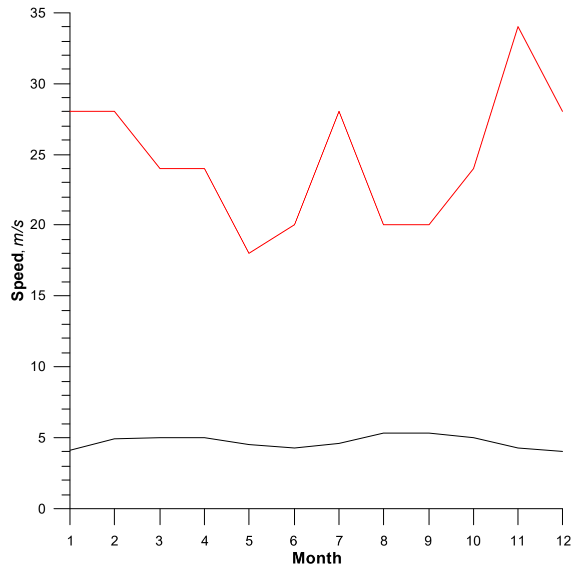


a) **b)**





c) **d)**



e)

Fig. 1 6. Climatic characteristics of the wind in Bourgas station:

(a) wind rose [%] in February (a), May (b), August (c) and November (e);

(b) an annual movement of the average module of the wind speed vector [m / s] and maximum (red) wind pulse [m / s]

Tab. 1 2. Average monthly speed [m / s] and maximum wind pulses [m / s] in Bourgas

WIND	MONTH											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
speed	4.1	4.9	5	5	4.5	4.3	4.6	5.3	5.3	5	4.3	4
pulse	28	28	24	24	18	20	28	20	20	24	34	28

Tab. 1 3. Monthly frequency (%) of wind manifestation in Bourgas in the direction of (rhumb) and wind (Calm)

DIRECTION	MONTH											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
N	7.3	9	5.5	2.9	3.2	3.1	3.2	4.3	5.9	7.1	6.2	6.2
NNE	4.1	6	5.4	4.5	3.4	2.8	3.1	3.6	4.2	5.4	4.5	3.4
NE	4.7	10.1	11.4	12.5	11	9.7	8.8	10.8	11	9.5	7.1	4.4
ENE	1.6	2.7	5.3	7.9	8.3	6.4	7.5	8.7	6.9	4.1	3.3	1.5

E	2	6.9	10.7	15.4	17	18.8	20.4	20.8	15.3	9.5	5.1	2.3
ESE	0.8	1.8	2.6	2.7	2.5	3.1	3.1	3.3	2.7	1.9	1.7	0.6
SE	1.2	1.8	2	2.9	3.8	3.8	3.2	2.5	2.5	2.7	1.6	1.2
SSE	0.7	0.7	0.6	0.8	1.5	1	1	0.7	0.7	0.9	0.7	0.7
S	0.6	0.6	0.9	1.2	1.4	1.6	0.6	0.6	0.9	0.9	0.7	0.7
SSW	1.7	1.7	2	1.5	1.2	1	1.2	0.9	0.6	1.3	2.3	1.7
SW	13	10	9.7	9.6	10.2	10.9	10	7.4	8.3	9.2	12.1	12.3
WSW	14.6	10	10.8	8.1	6.6	6.6	5.9	6.2	6.7	7.3	9.5	15.4
W	10.4	6.4	7.8	5.9	6.1	7	6.1	5.3	6.8	7.4	8.9	10.8
WNW	3.2	2.3	2.7	2.6	1.9	2	2	1.9	2.9	2.8	2.9	4.1
NW	7.5	6.6	4.6	4	4.2	4.5	5.3	5.8	7.4	6.7	6.1	8.9
NNW	7	6.4	3.9	3.2	2.1	2.5	2.2	3.6	4.4	5.3	6.1	6.4
Calm	19.7	17.1	14.1	14.1	3.2	15.2	16.2	13.6	12.9	18	21.1	19.4

Features of sea currents on archive data from direct measurements.

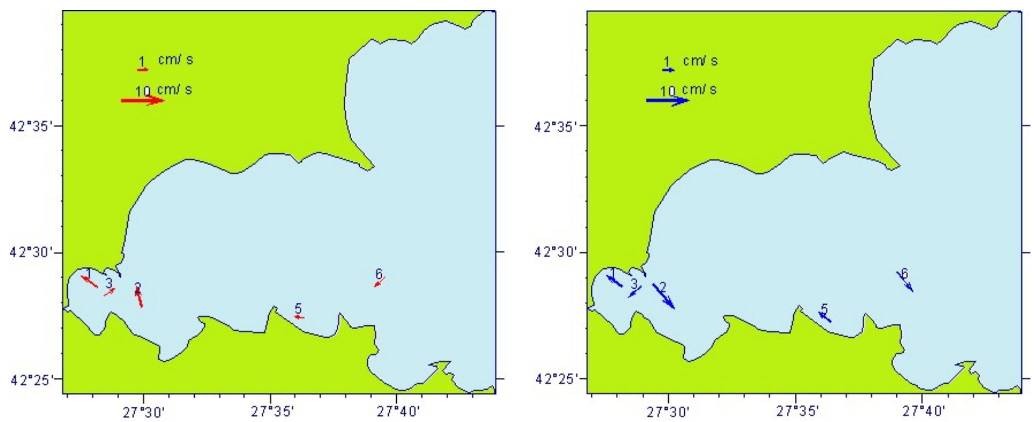
The nature of the sea currents is determined essentially by the wind field and the local features of coastline geometry and underwater shoreline slope. The existing sporadic historical data from direct current measurements as well as the results of the mathematical models of the wind circulation in the small bay of Bourgas (without taking into account the density stratification) show that, depending on the direction of the wind, cyclone or anticyclone type of circulation can be generated, and on the periphery of the main whirlpool in the small bays there is usually a whirlpool with a sign opposite of the main movements. Currents have relatively low speed vector modules - the surface current's rate does not exceed 10-15 cm/s in calm conditions: The movements in the north part are more intense than in the south one. These results are consistent with the flow patterns drawn up by remote observations.

More systematic experimental studies of the dynamics of the waters in the Big Bourgas Bay were carried out on board of the research ship (rv) "Prof. Al. Valkanov "in the late 90's together with the Institute of Oceanology (BAS) and the

Institute of Fish Resources in Varna. The results of these measurements confirm the above-mentioned features of the currents and their wind characteristics. Those with the range of ten centimeters per second prevail in the distribution of the measured rates. Higher modules of the rate vector (about 20 cm/s) were recorded at the hourly measurements in the most eastern water areas off the island of St. Ivan, Bank Koketrais and cape Emine, as well as with stronger winds.

From Table. 1-4 and Fig. 1-7 with the results of the expeditionary observation in September 1999 in the southern and western parts of the Great Gulf is a clear opportunity for the presence of two-layered, oppositely directed movements at average rate of about 10 cm/s. Surface current may reach 15-16 cm/s during a period of calm, up to 20 cm/s - with strong winds, and separate pulses in strong winds - up to 40-50 cm/s. The nature of the currents is mainly controlled by the wind field and by the local orographic factors - in particular this can be seen in Fig. 1-8 progressive vector diagrams built on measurements abreast of Vramos Bay. Obviously, deep-sea movements close to the shore may have a compensatory character and have opposite direction to the surface ones. The co-analysis with data from the parallel measurement of sea water temperature and salinity shows the presence of the phenomenon of upwelling circulatory cell with flow of deep waters from the open parts of the bay towards the land and their coming out on the surface near the shore.

Most of the current fluctuation energy is concentrated in the uncorrelated high-frequency movements, which is reflected in the very low level of the spectral amplitudes of the fluctuations - substantially smaller than the amplitudes in the waters of other more open Bulgarian bays and coastal shelf areas. The characteristic periods of fluctuations in the Bourgas Bay recorded on the currents data are the breeze (24 hour) and the 10-11 hour one related to the orographic features of the bay. Characteristic fluctuations were also observed with other periods: 36, 18, 6, 3.6, 1.5 and 2/3 hours, with different amplitudes for each period. Spectral amplitudes in the bay are about twice smaller than those for analogous offshore waters. Such fluctuations decrease in depth - on a horizon of ~20 m there is a distinct maximum with a period of ~17 hours, which is in fact an inertial fluctuation with characteristic anti-cyclone rotation. In the surface layer the inertial fluctuations are very smooth and deformed, with a small amplitude and a smaller (compared to the bottom layer) period.



a) б)

Fig. 1-7. Current measurement results in September 1999: Average rates in the surface (a) and bottom layer (b).

Designations: station numbers according to table 1-4.

The sea currents, especially in the surface layer of the coastal area, feature not only seasonal changes (relatively smooth), but also a strong variation in the frequency range from several minutes to several days. Hence comes, in particular, the relatively unreliable data from short-term measurements results. The parameter R (see table 1-4), which represents the percentage ratio between the medium vector module and the average current module, is used as an indicator of the current variability.

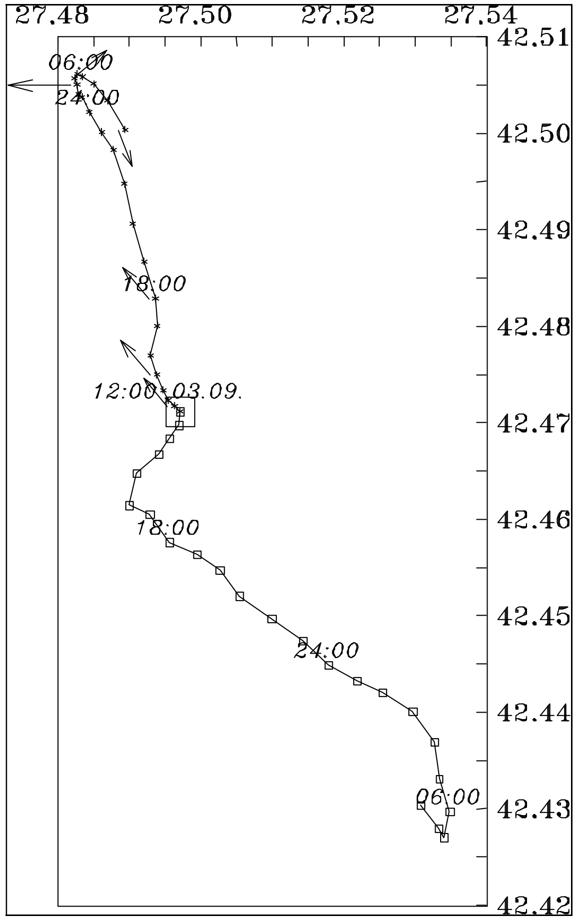


Fig. 1-8. Progressive vector diagrams in the surface (*) and bottom (□) layer of the western part of the Bourgas Bay.

Time [in hours] and date of commencement of the measurements are shown (3.IX.); the arrows indicate the direction of the wind; □ marks the beginning of the measurements

Table 1-4. Basic statistical assessments of sea currents according to data from long-term measurements in September 1999

u, v, $\sigma_{\upsilon}, \sigma_{v}$ - components, cm/ s of the mean vector along the parallel and the meridian their standard deviations; R - resistance parameter, %

Station		Horizon	U	v	σu	σv	R
№	Coordinates	m	cm/s	cm/s	cm/s	cm/s	%
1	42°28.868'N 27°27.883'E	4	-2.7	2.0	5.92	5.76	0.39
3		3	1.3	0.8	2.81	2.26	0.44

	42°28.438'N 27°28.681'E	7	-2.0	-1.7	4.00	3.09	0.48
2	42°28.271'N 27°29.827'E	3	-1.0	3.9	7.80	8.66	0.37
		9	4.5	-5.4	9.94	8.27	0.53
5	42°27.449'N 27°36.158E	3	-0.7	0.0	15.55	13.26	0.34
		9	-1.8	1.5	15.33	12.90	0.18
6	42°28.830'N 27°39.336'E	3	-1.4	-1.3	9.51	8.50	0.17
		22	3.2	-4.1	9.87	8.71	0.40

Characteristics of sea currents according to direct measurements data in May 2019

For the purposes of this study observations of the currents in the surface layer of 17 points in the water area of the Big Bourgas Bay were made on board the motor-sailing yacht "Orpheus" from 14.05.2019 to 17.05.2019. The measurements were made with the "Nobska MAVS 5" current meter. The measurements at each point were made at 6 m depth, with the exception of station 14 (where the instrument was immersed at 5.5 m horizon) - thus mitigating the impact on the measured wind drift rate and the wave effects. In order to avoid the impact of the yacht drift on the observed rates, the measurements of the current rate were not made on board - the instrument was immersed in the water with an autonomous buoy away from the vessel. The discretion of each measurement was 1 minute except at station 17 where the measurements were made at a half a minute interval. The conversion of the primary codes received by the meter into actual direction and current rate data was done by using the company software of the device itself. Parallel to the measurement of the components of the current rate vector, information about the temperature of the seawater that was not subject to this study was also reported by the meter and it had control functions. The coordinates of the hydrological stations were fixed by a high-frequency GPS receiver "SAMYUNG ENC" model "DSPR-

1400”, and the depths - by means of an on-board echo sounder. Observations on board also included standard meteorological observations of the direction (by compass) and wind rate (by hand anemometer) and visual ones of the sea, visibility and cloudiness. Table 1-5 includes information about each station - coordinates by space and time, depth and horizon of measurement, wind data, and Fig. 1-9a shows the location of all measuring points. The main part of the observations is concentrated in the coastal parts of the Big Bourgas Bay while those with numbers 15 - 17 give an idea of the dynamics of the water in its open eastern part. The depth of the stations varies between 10 and 42 m.

Table 1-5. Data on the stations from the hydrologic picture in May 2019

Station	*Commence ment*	*Coordinates*		*Depth*	*Horizon*	*Wind*	
№	*hour*	*φ, °N*	*λ, °E*	*m*	*m*	*azimuth, °*	*rate, m/s*
DATE	***14.05.***						
1 Emine	*17:00*	*42.66283*	*27.86383*	*26*	*6*	*90*	*4-5.5*
2 Vramos	*21:31*	*42.44667*	*27.61333*	*10*	*6*	*40-90*	*1-11*
DATE	***15.05.***						
3 p. Akin	*08:31*	*42.46600*	*27.62300*	*21*	*6*	*80-90*	*1-3.5*
4 p. Atiya	*10:31*	*42.46833*	*27.59300*	*27.5*	*6*	*90*	*3*
5 Rosenets	*12:42*	*42.46167*	*27.52333*	*19*	*6*	*90-95*	*3-4*
6 Kraymorie _1	*14:16*	*42.44517*	*27.50300*	*11*	*6*	*90*	*4-6*
7 Kraymorie _2	*16:11*	*42.46533*	*27.48117*	*14.7*	*6*	*70-90*	*5-6.5*
8 Poda	*17:42*	*42.45917*	*27.46883*	*10.1*	*6*	*90*	*2-5.5*
DATE	***16.05.***						
9 Speedfire	*07:37*	*42.50500*	*27.58400*	*26.5*	*6*	*0-340*	*1-5*

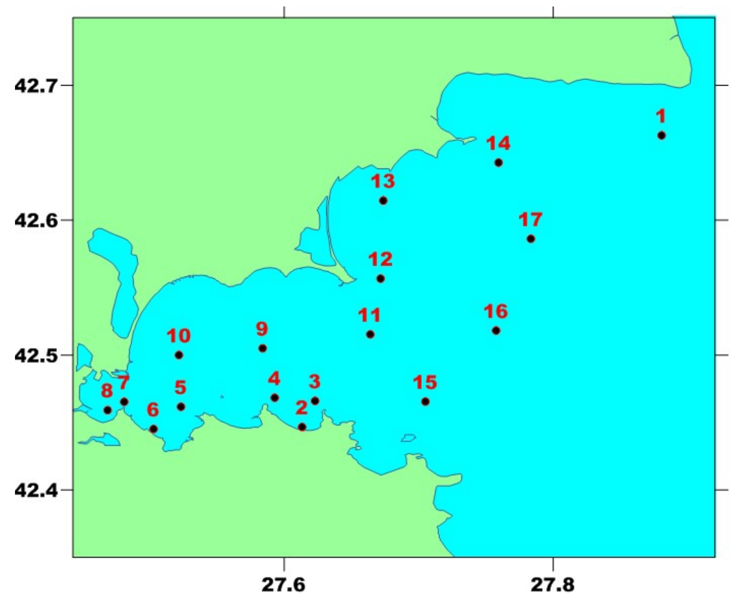
10 Bourgas	*09:11*	*42.50 000*	*27.52183*	*17.5*	*6*	*70*	*3-8*
11 Stavrova bank	*11:34*	*42.51 533*	*27.66400*	*24*	*6*	*70-80*	*4.5-6.5*
12 Pomorie 2	*14:06*	*42.55 667*	*27.67167*	*22*	*6*	*320*	*5.5*
13 Pomorie 3	*16:21*	*42.61 450*	*27.67367*	*28*	*6*	*100*	*5-6*
14 Nessebar	*18:21*	*42.64 267*	*27.75933*	*31*	*5.5*	*150-160*	*2*
DATE	***17.05.***						
15 Sozopol	*07:41*	*42.46 550*	*27.70500*	*41*	*6*	*0-310*	*1-2.5*
16 Big Bourgas Bay 1	*09:40*	*42.51 817*	*27.75750*	*42*	*6*	*270*	*2-5*
17 Big Bourgas Bay 2	*11:31*	*42.58 617*	*27.78333*	*40*	*6*	*30-180*	*5-9*

Table 1-6. Statistical characteristics of the current:

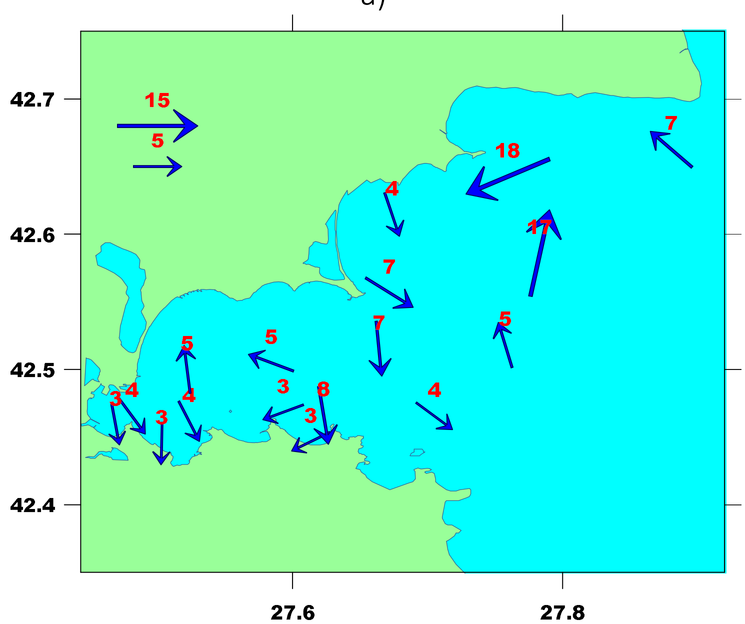
minimum and maximum components *[cm/s] of the current rate vector on parallel umin and umax and on meridian vmin and vmax, standard deviation σu and σu; of the components, azimuth [°] and rate module [cm/s] of the mean rate vector, mean module [cm/s] of the current, resistance R [%], number of measurements n*

Station №	umin	umax	vmin	vmax	σu	σv	Mean current		Mean module	R	n
							azimuth	rate			
1	-7.2	-1.3	3.7	6.1	1.70	0.74	312	6.5	6.6	0.98	25
2	-2.8	4.3	-1.4	6.4	0.96	1.41	244	2.3	2.6	0.90	543
3	3.6	11.9	-3.2	4.6	2.47	0.95	170	7.9	7.9	0.99	28
4	-1.7	3.2	1.1	-0.5	1.03	0.99	250	2.8	2.9	0.95	25
5	1.9	4.6	-2.7	-0.5	0.70	0.68	153	3.6	3.7	0.98	15
6	0	4.4	-1.1	1.2	1.10	0.74	181	2.2	2.4	0.93	27
7	-2.8	6.4	-4.0	0.0	2.38	1.00	144	2.5	3.0	0.85	23
8	-1.2	5.7	-2.1	1.3	1.92	1.08	169	1.8	2.5	0.73	22
9	-2.7	-0.6	2.7	6.9	0.69	1.13	290	4.4	4.4	0.99	15
10	-7.1	-2.2	-1.1	2.0	1.16	0.80	353	4.3	4.4	0.98	26
11	0.3	41.2	-2.7	2.5	9.29	0.81	174	6.3	6.4	0.99	65
12	2.1	5.4	-8.3	-3.2	0.85	1.10	122	6.9	6.9	0.99	52
13	1.3	3.8	-3.8	1.7	0.76	1.28	161	2.8	4.4	0.63	20
14	4.2	9.6	10.9	22.5	1.36	3.75	247	18.0	18.1	0.995	27
15	0.7	3.2	-4.7	-1.1	0.68	0.84	127	3.4	3.5	0.98	24

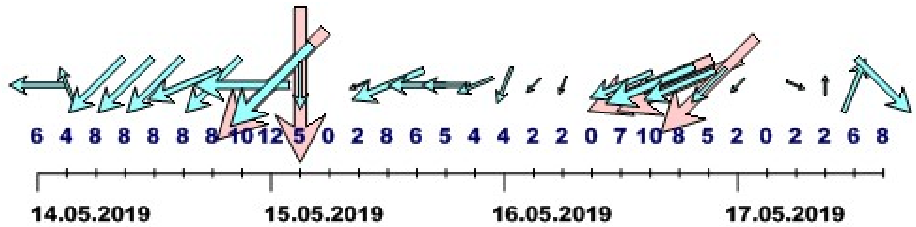
16	*-5.9*	*1.0*	*-3.9*	*3.6*	*1.39*	*1.56*	*5*	*2.1*	*2.7*	*0.76*	*82*
17	*-22.7*	*-11.4*	*-8.5*	*0.4*	*2.29*	*1.32*	*17*	*17.3*	*17.4*	*0.997*	*132*



a)



b)



c)

Fig. 1-9. Hydrologic picture in May 2019 in May 2019: (a) location of the stations; (b) mean current vectors; c) wind vectors (blue) and its pulsations (pink), measured in meteorological terms at the meteorological station Bourgas.

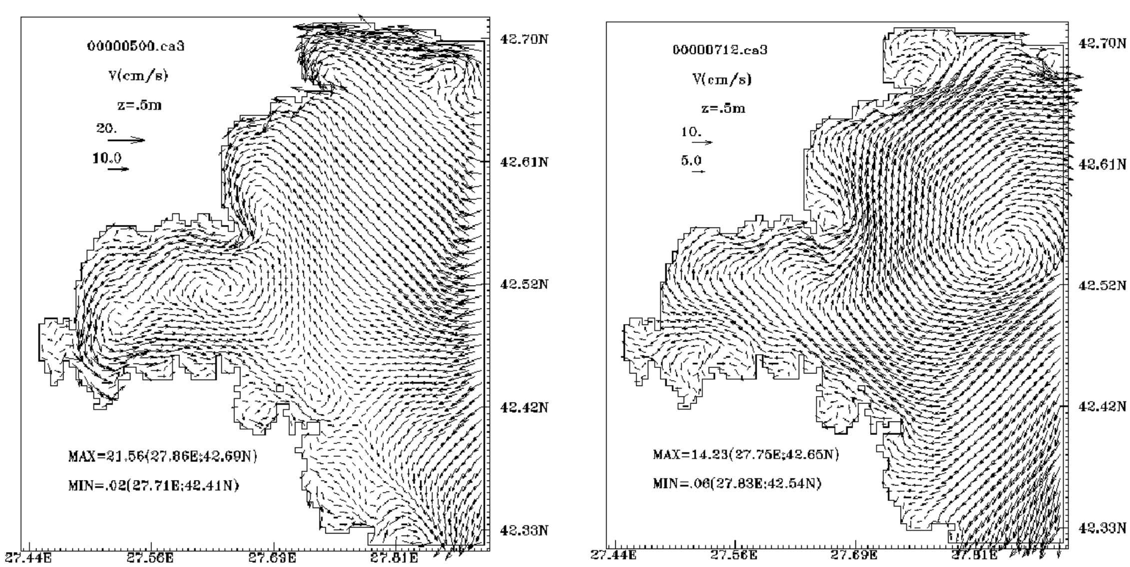
Markings: station numbers (a); rate of the mean current, cm/s (b) and of the wind, m/s (c)

Table 1-6 includes results with statistical characteristics of the measured currents, and the diagram of Fig. 1-9b shows the mean vectors of the rate. Figure 1-9b also shows the wind rate vectors measured in meteorological terms at the meteorological station Bourgas, as well as its pulsations (data taken from https://rp5.ru/). The winds from the eastern quarter prevail (as a whole this was recorded in the background observations on board the "Orpheus" yacht) - moderate to strong, reaching 10-12 m/s on the evening of May 14 and the night of May 15. Strong wind gusts in the range of 14 to 16 m/s were recorded on the night of May 15, the afternoon and the evening of May 16 (Fig. 1-9b). The mean rate and the rate of the mean current are close, resulting in high current resistance, but the latter is rather a consequence of a relatively short period of measurement at individual points (most often up to and less than 30 minutes). The rate module as a rule was a few centimeters per second, which corresponded to the previous measurements. The movements at stations 14 and 17 at the end of the expedition had more intense rates of 17-18 cm/s found in the open eastern part of the bay, where there is generally possibility for more developed dynamics, especially after the active circulation of the atmosphere in the evening of May 16th. There is a good correlation between the direction of the current and the wind at individual stations, but there are also those in which the connection is not expressed, which is normal considering the coastline features and the orography of the coastal area of the bay. However, there is a good quality relation and good coincidence at individual stations with the cyclonic diagram of Fig. 1-10a formed in this type of wind pattern according to the numerical model reconstructions described below.

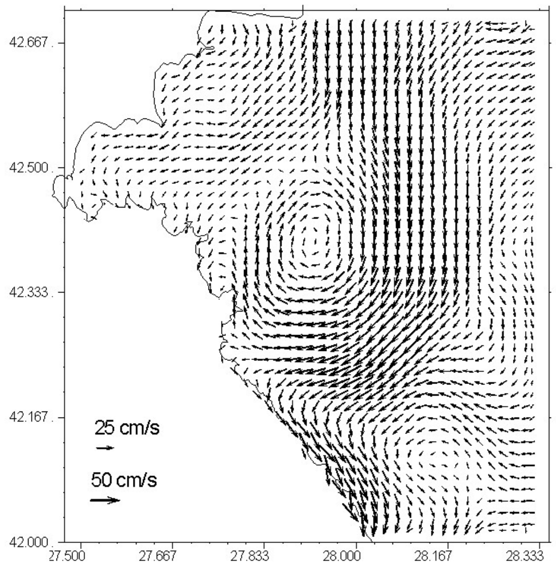
Results from numerical reconstructions of the field of the sea currents. There are three-dimensional numerical reconstructions of the motions in the inland waters of the bay and the shelf water area to the east, obtained by using three-dimensional, non-stationary mathematical patterns of currents based on the complete system of primitive equations of oceanic thermo-hydrodynamics. Fig. 1-10a, b shows the current patterns in the whole bay of Bourgas in typical winds on a net with division of 500 m. The results show the existence of a swirling structure of the currents and the existence of a rapid adjustment (within several hours) of the movements to the changes in the wind field. As a rule, a major whirlpool is observed in the Small Bourgas bay: in northerly, northeasterly and easterly winds the current system is cyclonic (Figure 1-10a), and in westerly, southwesterly and southerly winds – anti-cyclonal (Figures 1-10b). Cyclonic type movements are usually dominant. Inland flows and small-scale whirlpools form in coastal waters.

Data on the spatial distribution of the sea water temperature and salinity fields measured at 66 stations at a quasi-synchronic hydrological picture by the Research vessel “Academic” in July 1986 were used for the reconstruction of the current field of Fig. 1-10c. The wind field (from the northern quarter and rates of 5-10 m/s) was reproduced by the ship’s meteorological observations. The spatial division of the numerical network is 1' in 17 levels and a maximum depth of 100 m. The major dynamic formations are mesoscale: anticyclone of regular shape and a diameter of 15-20 miles and a less pronounced cyclone to the south. The southern flow prevails in the surface layer of the open shelf, the maximum surface rates reaching ~40 cm/s. It disappears in the area of the thermocline (~20 m) and below, the southern flow being weakened as the movement in some regions is opposite to the surface direction.

Other types of motion are shown in Fig. 1-11 - averaged monthly climatic movements in the bay. They are obviously weaker than the meteorological ones but retain their vortex structure. These diagrams can serve to assess long-term trends in coastal litter flows, especially if potential sources of such pollutants have already been familiar.



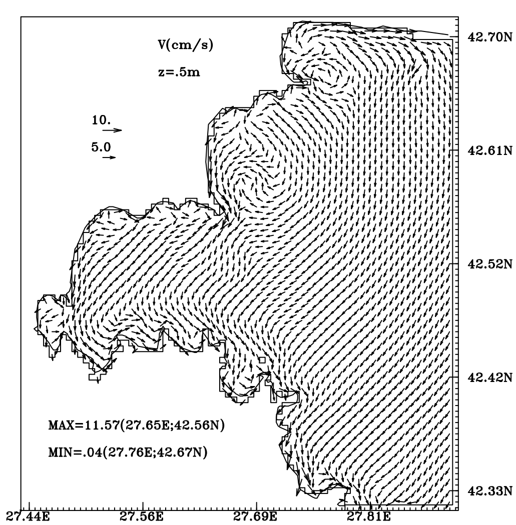
a) b)



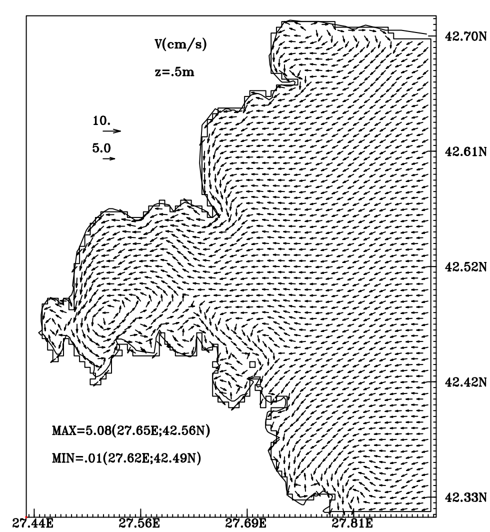
c)

Fig. 1 10. Modal reconstructions of meteorological diagrams of surface circulation in Bourgas Bay.

Cyclonic (a) and anti-cyclonic (b) type of circulation in September 1999, swirl structure in July 1986



a)



b)

Fig. 1-11. Horizontal diagrams of the climate surface circulation [cm/s] in January (a) and July (b)

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3. Identification of main streams of solid (non-liquid) waste and potential waste concentration points in surface water

3.1. Introduction

Excessive pollution of oceans and seas with floating marine waste and its growing accumulation along the coast is one of the major environmental issues worldwide. It is recognized that these waste have a negative impact on marine and coastal ecosystems, the health status of the population and seafarers, the normal development of sea-oriented economies, including the tourism industry, fishing and shipping.

Floating marine waste play an important role in the marine waste cycle because they represent their mobile fraction as well as the path to the various environmental components.

Understanding the dynamics of floating waste is critical to developing appropriate marine waste management strategies both globally and locally.

Sources of waste in the sea are numerous and heterogeneous and therefore measures to reduce them and to prevent them from entering the marine environment must be applied across broad geographical boundaries and social spheres.

The main sources of marine waste can be divided into two main groups - sea and coastal.

Marine sources of waste include:

- merchant shipping, ferries, passenger and tourist vessels;
- fishing boats;
- military fleets and research vessels;
- pleasure boats;
-petrol and gas platforms;

- aquaculture.

Major coastal sources include:

- municipal landfills (waste disposal sites) located along the coast or inland;

- river flow of waste, that fell into the river with the current from the landfills or other sources and other inland waterways (canals);

-disposal of untreated household sewage;

-industrial installations;

-Tourism.

The distribution of marine waste in the water column is consistent with the water density and the floating ability of the waste. The heaviest objects sink and accumulate at the bottom of the sea, and the lighter ones float on the surface and after certain time they are thrown to the shore. The third group remains in a neutral position and stays in the water column between the surface and the bottom.

The items, defined as waste, that flow in sea waters may be ship or container sizes, fishing nets, cans, boxes, bottles, plastic bags, small consumer goods, pieces of objects, and micro-waste particles with nano and molecular size.

It is estimated that almost 90% of floating waste in sea waters are objects made from polymers of anthropogenic origin.

The potential damage caused by floating waste is very high. The living part of the ecosystem, incl. seabirds, fish, turtles and marine mammals can entangle or engulf different objects and this is just one of the effects of the floating waste.

It can be assumed that floating marine macro-waste is a precursor to floating marine micro-waste.

Floating waste is also a potential vector for transferring extraneous (invasive) species.

Floating waste fall into the marine environment from river waters that flow into the sea, from coastal runoff, from airborne masses carrying low density particles or from sources at sea, such as disposed or lost materials and objects from ships and installations.

Objects with positive flow can be kept above the water due to the properties of the material they are made of (positive-buoyancy polymer) or shape (bottles, containers, float nets, etc.).

They float on the water surface along with surface currents, although the wind can also have a significant impact on the distribution of objects floating on the surface.

The spatial distribution of floating marine waste, combined with currents, tides, and inflowing rivers, gives an indication of the physical source, i. the entry point of the waste and its distribution path which is very valuable information about the size of the source and can help to take appropriate measures to prevent and reduce marine pollution and to check their effectiveness.

Within the EU, the sources and impacts of marine waste are subject to a large number of policies and measures. These include statutory acts on waste management, urban sewage and ship-source pollution. Since 80% of marine waste comes from land-based sources, proper disposal of waste and better implementation of legislative measures can make a significant contribution to improving the quality of our seas. The same applies to changes in the packaging of goods where a large amount of plastic material is used.

On 21 May 2019, the Council of Europe adopted a directive introducing new restrictions on certain disposable plastic products. The Single Use Plastics Directive is based on existing EU waste legislation but goes further by laying down stricter rules for those products and packaging that are among the ten most polluting European beaches. The new rules prohibit the use of certain disposable plastic products for which alternatives exist. In addition, specific measures are introduced to reduce the use of the most discarded plastic products. Under the new rules until 2021 plastic dishes, cutlery, straws, balloon handles and earmuffs will be banned. Member States agreed to achieve by 2029 a 90% separate collection of plastic bottles and a recycled content of plastic bottles of at least 25% by 2025 and 30% by 2030.

In the EU Marine Strategy Framework Directive adopted in 2008, waste at sea is identified as one of the issues to be addressed in order to achieve good environmental status in the European seas by 2020. Marine waste is one of Descriptors (D10) related to the types of pressures on the marine environment.

In the currently applicable Decision 2010/477/EC on Criteria and Methodological Standards for Good Environmental Condition of sea waters, the Defined Criteria and Descriptor Indicators 10 - Marine Waste Defined Criteria and Indicators are as follows:

10.1 Features of waste in the marine and coastal environment

10.1.1. Trends in the quantity of waste dumped and / or deposited on the beach, including composition analysis, spatial distribution and, where possible, source;

10.1.2 Trends in the amount of waste in the water column (including floating on the water surface) and seabed, including compositional analysis, spatial distribution and, where possible, the source;

10.1.3. Trends in the amount, distribution, and, where possible, microparticle composition (in particular microplastics).

A process to update the Decision and Annex III of MSFD 2008/56 / EC started in 2015 (Marine Strategy Framework Directive). The changes related to Descriptor 10 are referring to the merging of Criteria 10.1.1 and 10.1.2, as well as the dropping out of the monitoring and evaluation of waste in the water column. The obligatory numbering (10.1.1, 10.1.2, etc.) of indicators is also dropped out, and states may themselves define national or regional indicators.

The following writing has been adopted in the monitoring program on Descriptor 10 – Marine waste: Descriptor 10, Criterion 1, Indicator 2 (Surface floating waste > 2.5 cm), proposed and developed within the MARLEN project.

In order to reduce the anthropogenic pressure on coastal and territorial waters and to ensure consistency with the MSFD, additional measures are planned within the scope of the second river basin management plan of the Bulgarian Red Cross for the period 2016-2021, mainly aimed at reducing the introduction of waste from land-based sources.

3.2. Results of Surface Floating Marine Waste Monitoring under WFD (Water Framework Directive) 2008/56 / EC

In 2016, a pilot monitoring of marine waste floating on the sea surface > 2.5 cm was carried out in the framework of the MARLEN project, using the Marine Waste Monitoring Manual in the European Seas: https://ec.europa.eu/ jrc / sites / default / files / lb-na-26113-en-n.pdf containing recommendations and guidance on how to conduct monitoring to compare data with other Black Sea and European countries and complying with the MSFD (Marine Strategy Framework Directive) .

The monitoring of the quantity, type, size and spatial distribution of surface floating marine waste> 2.5 cm was conducted in the period 01 - 20.07.2016, covering the coastal (0-30m) and shelf (30-200m) areas of the region between cape Kaliakra and the town of Sozopol and includes visual observations of waste on the sea surface of 46 transects distributed equally to coastal and shelf areas (Figure 1). The total area surveyed is 2.34 km2, and the total length of the transects in which visual observations are made is 325.2 km.

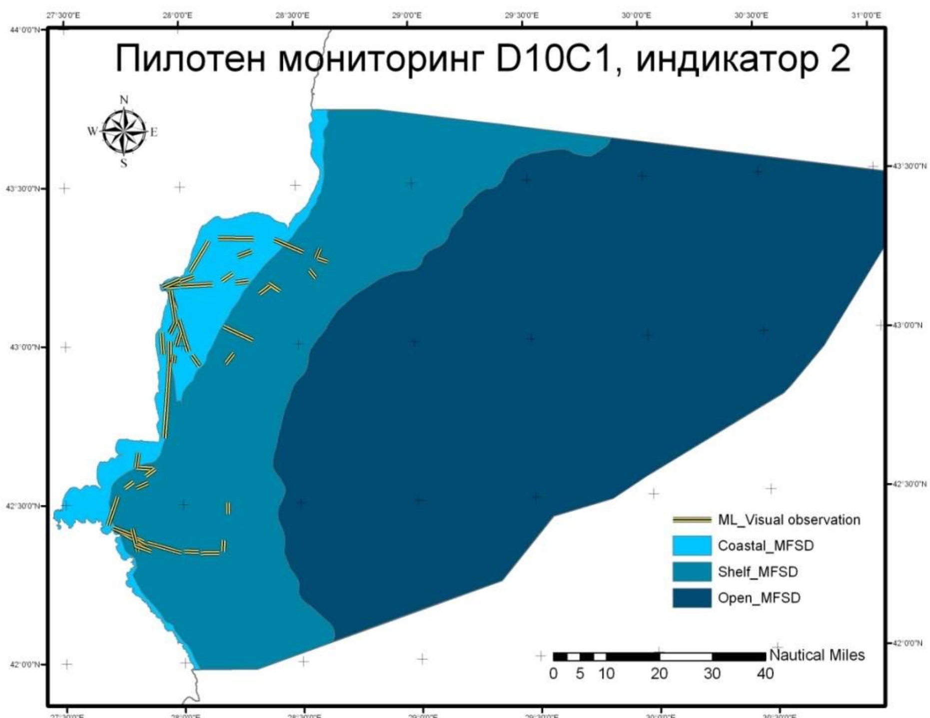

Figure 1. Surface Floating Marine Waste Survey Area > 2.5 cm.

The quantity of registered wastes on the sea surface during the pilot monitoring in the water area surveyed is 1252, of which 558 were found in the coastal zone, and 695 in the shelf zone. No waste was found in four transects (V001, V022, V023 and V024). The density of waste on the sea surface varies from 0 to 8441 pcs/km2, with an average value of 690 pcs/km2. For the shelf the average concentration of waste is higher (796 pcs/km2) than that for the coast (585 pcs/km2). A minimum (11pcs/km2) and maximum (8441pcs/km2) sea level waste concentration values are reported in the coastal zone, respectively in the area of Galata (transect V039) and in the zone between Kamchia River and the village of Shkorpilovtsi (transect V012). For the shelf, the minimum density is more than 1.5 times (28 pcs/km2 - V020) higher than that for the coast, unlike the maximum that is almost half (4857 pcs/km2 - V018). The spatial distribution of waste floating on the sea surface expressed as number of objects per km2 is shown in Figure 2.

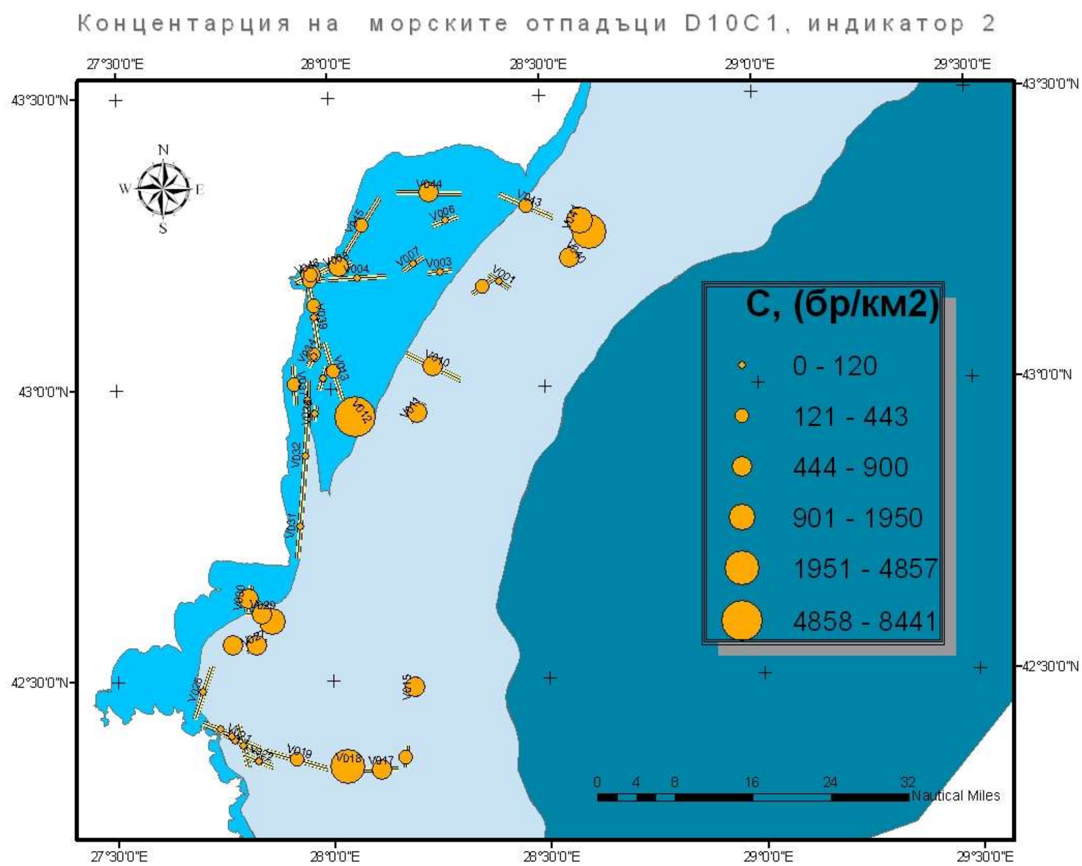

Figure 2. Spatial distribution of the concentration of macro-waste on the sea surface, expressed as number of objects per km2.

Pilot monitoring has revealed waste of all categories valid for D10C1, indicator 2 (“artificial polymer materials”, “rubber”), “clothing and textiles”, “paper and cardboard”, “processed timber”, “metal”). 95% of the total waste fall into the category of “artificial polymer materials” and the remaining 5% were allocated to the sub-categories of the main categories of waste - rubber, paper, metal, textiles and processed timber.

In the category “artificial polymer materials”, the largest percentage shares were recorded for the sub-categories (G38) “Packaging” - 57% and (G79) “Plastic pieces with size between 2,5> <50 cm” - 26%.

Maximum concentrations of plastic waste of sub-category (G38) “Packaging” are registered in the coastal waters in the area between the Kamchiya River and the village of Shkorpilovtsi (transect V012) (5543 pcs/km2) and in the shelf zone in front of the town of Sozopol (V018) (2998 pcs/km2). For the shelf the average density of waste from the category “Artificial polymeric materials” on the sea surface is 805 pcs/km2, while in the coastal waters it is considerably smaller - 549 pcs/ km2.

88% of the objects of all categories registered during the monitoring are between 2.5 cm and 20 cm, 51% (636 pcs) being of Class A (2.5 cm - 5 cm), 24% (301 items) fall into category “B” (5 cm - 10 cm), 13% (168 objects) are between 10 cm and 20 cm (group “C”) (Figure 3). Objects with size > 20 cm fall in the remaining 12%, as waste with size of more than 50 cm being only 26 pcs. (2%), of which 24 were found in the shelf zone (Figure 4).

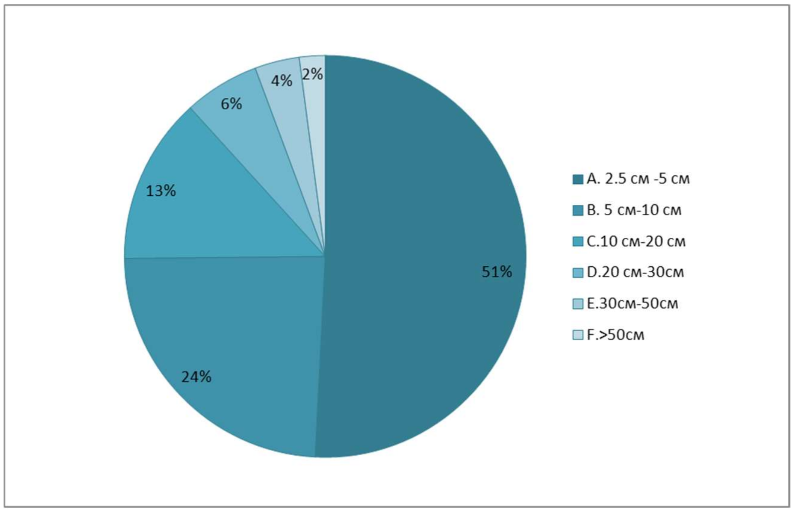

Figure 3. Percentage distribution of the quantities of macro-waste by size categories (A: 2.5-5 cm, B: 5-10 cm, C: 10-20 cm, D: 20-30 cm, E: 30-50 cm and F > 50 cm).

Plastic waste falls into all dimensional groups “A-F”. More than 70% of the total number corresponds to the low-size groups “A” and “B”, and only 2% are over 50 cm. For the other categories of waste, such as rubber, paper, metal, textiles, and processed timber most objects have size between 5 cm and 20 cm (group “B” -59% and “C” -13%).

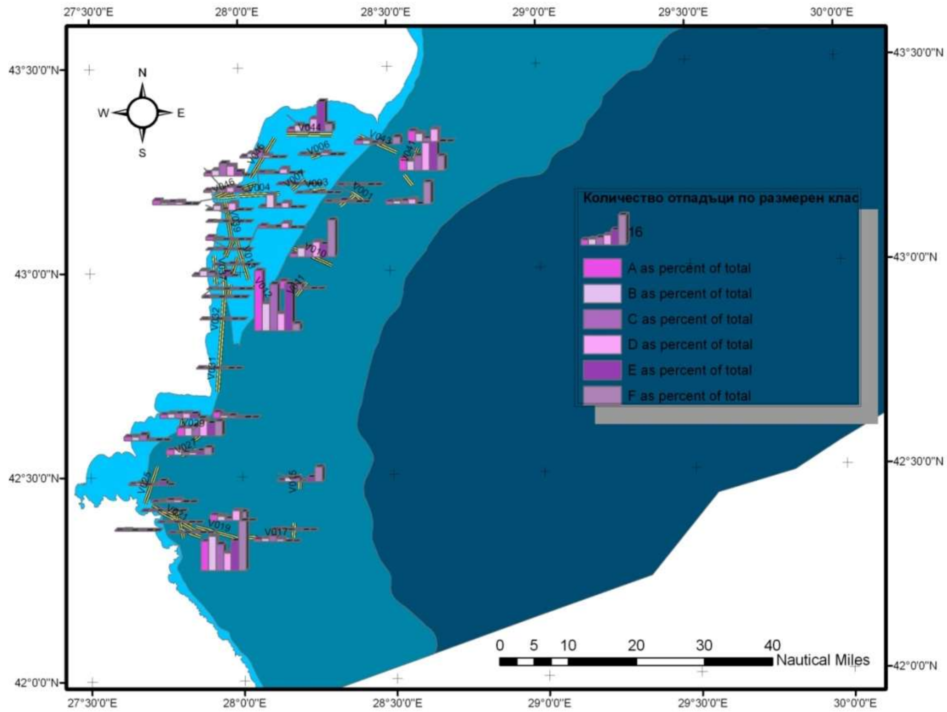

Figure 4. Distribution of the amount of macro-waste by size categories

The data provided by the Black Sea Basin Directorate from the monitoring of waste floating on the sea surface in the autumn season of 2017, conducted by a team of IO-BAS in two periods: 09.10.2017 - 16.10. 2017 and 22.11.2017 - 30.11.2017 by the Research vessel "Academic" are analyzed covering a total of 117 transects.

The quantity of registered waste on the sea surface in the researched water area is 582 pcs. No waste was established in 25 transects (V002-X, V005-X, V008-X, V020-X, V025-X, V027-X, V032-X, V033-X, V051- X, V017-XI, V025-XI, V027-XI, V030-XI, V032-XI, V033-XI, V035-XI, V039-XI, V047-XI, V048-XI V056-XI).

Waste from the following categories: "artificial polymer materials", "fabric and textiles", "paper and cardboard", "processed timber" and "metal" has been identified. 87% of the total waste falls into the category of "artificial polymer materials" and the remaining percentages are distributed as follows: 9% in the paper and cardboard category, 2% in the "processed timber" category, 1% in the "textiles" and 1% in the "metal" category (Figure 5).

86% of the objects of all categories registered during the monitoring are between 2.5 cm and 50 cm, 45% being in class "A" (2.5 cm - 5 cm), 19% fall in category "B" (5 cm - 10 cm), 12% are between 10 cm and 20 cm (group "C"), 7% fall in category "D" (20 - 30 cm), 3% are between 30 cm and 50 cm (group "E"). There are 49 pcs. with size over 50 cm.

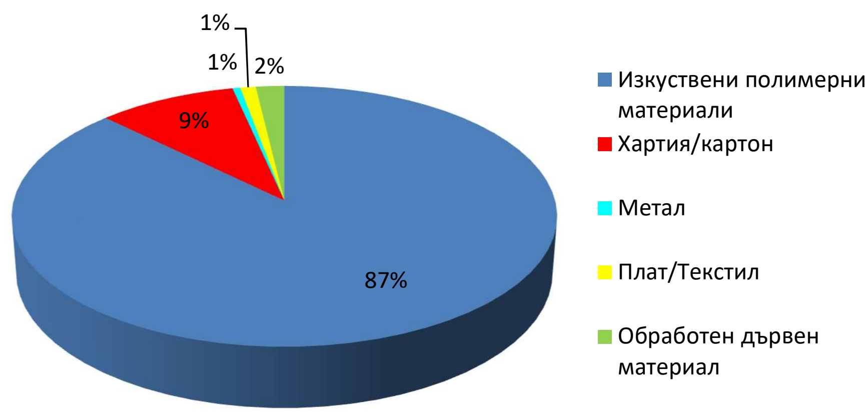

Figure 5. Percentage distribution of the quantities of waste by categories.

The analysis of the data provided by the Black Sea Basin Directorate from the monitoring of floating waste on the sea surface carried out by an IO-BAS team under the PUDOOS Program in 2018, is based on a total of 116 transects, 36 of which are in the shelf zone observed in the period 21.07.2018 - 26.08.2018 and 80 in the coastal area - 40 observed in the period 07.08.2018 - 10.9.2018 and 40 in the period 08.10.2018 - 31.10.2108

The total quantity of registered waste on the sea surface in the researched water area is 413 pcs. and no waste was established in 35 transects.

Waste from the categories “synthetic polymer materials”, “rubber”, "fabric and textiles”, “paper and cardboard”, “processed timber” and “metal” has been established. 91% of the total waste fall into the category of “artificial polymer materials”, followed by the category “paper and cardboard” represented by 7%.

The density of waste on the sea surface varies from 0 to 1750 pp/km2, with an average value of 160 pp/km2. For the shelf the average concentration of waste is higher (190 pcs/km2) than that for the coastal waters (148 pcs/km2). Maximum levels of concentration of waste have been established in the coastal zone of Sozopol-Alepu area (transects V025-c1 and V026-c1). Minimum waste concentration values have been established in Shkorpilovtsi-Byala area (transects V001-c and V002-c) in the coastal area and in Durankulak-Kaliakra area (transect V015) in the shelf zone. The spatial distribution of waste floating on the sea surface, expressed as number of objects per km2, is presented in Figure 6.

It is evident from the figure that waste in the surface waters is concentrated in the shelf areas of Kaliakra-Durankulak and Bourgas and the coastal areas of Galata, Kamchiya and Sozopol-Alepu.

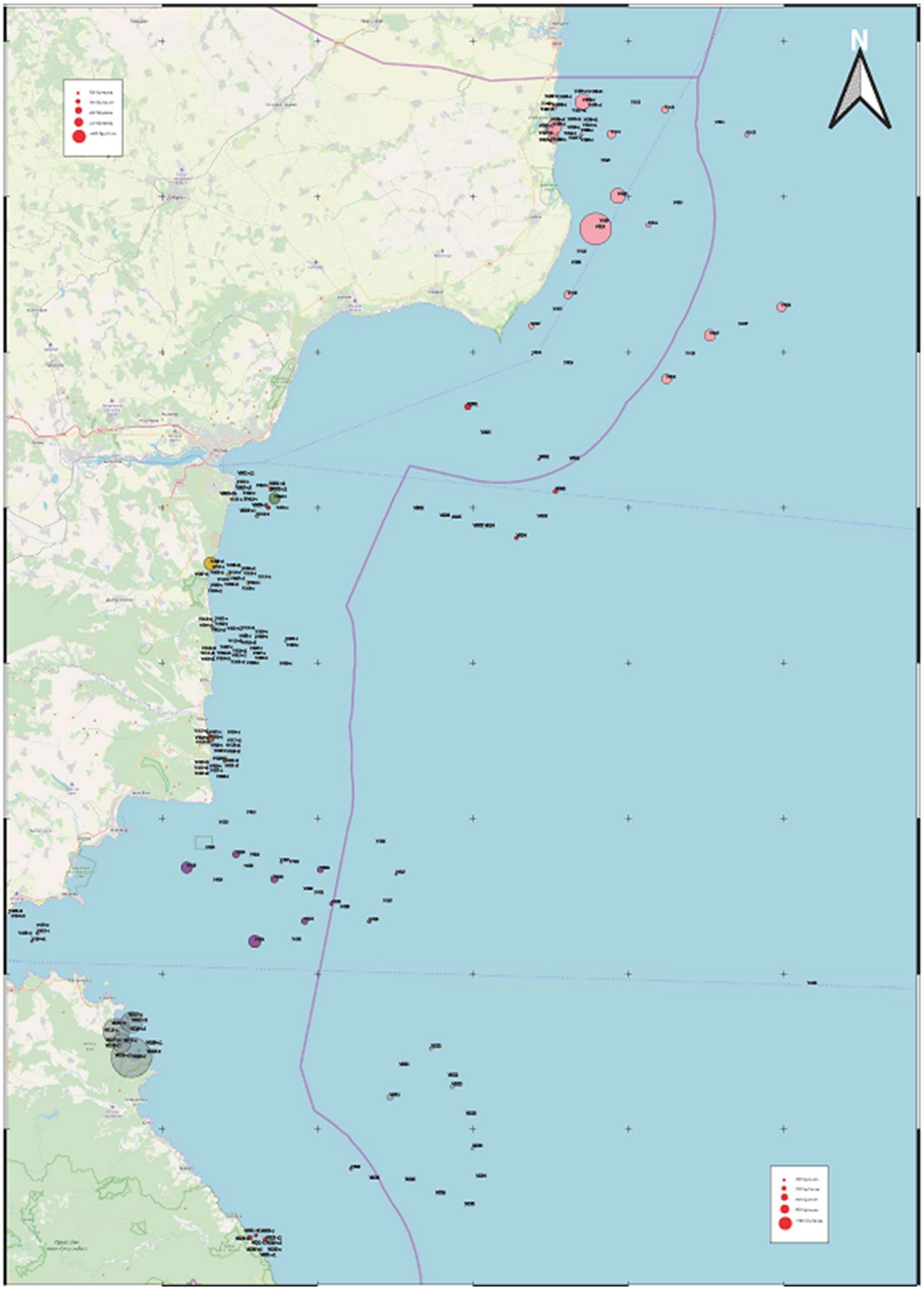

Figure 6. Spatial distribution of the quantities of macro-waste.

During the monitoring of floating waste in the waters off the Bulgarian Black Sea coast during the Wind2Win challenge in the period 18-27.09.2018, a series of 20 observations was carried out as follows: 11 observations in the water area between Durankulak and Varna with a total length of transects of 25 km and a total area of 0.5 km2; 5 observations in the water area between Varna and Byala with a total length of transects of 8 km and a total area of 0.16 km2 and 4 observations in the water area between Sozopol and Bourgas with a total length of transects of 16 km and an area of 0.16 km2.

14 out of all observations established no floating waste in any of the monitored categories. The remaining 6 transects have established different quantities of floating plastic waste (plastic polymer materials) - plastic bags and pieces of plastic polymers with sizes between 2.5 and 50 cm have been observed. The most floating plastic waste was observed in the Sozopol bay on 22.09.2018 in the morning - an average of 558 objects per km2 (transect BG34), while the waste quantities in the remaining five transects (off Tyulenovo, Varna, Kamchiya, Kraimorie and Atia) is significantly lower - between 23 and 50 objects per km2. During re-observation of the transect in the Sozopol bay (BG34) 7 hours later no floating waste (BG37) was observed. In the period between the two observations, a strong SE wind was reported in the area, which probably swept the waste to the shore (the beach of Zlatna Ribka-Gradina, the beach of Chernomorets).

Conclusions and recommendations

The total volume of waste on the sea surface is dominated by “artificial polymer materials” category, with a share of 95% in 2016, 87% in 2017 to 91% in 2018.

There have been no significant differences in the average concentrations of surface waste for the coastal and shelf areas.

The size fraction of the waste is dominated by small fractions of category “A” (2.5 cm - 5 cm) and category “B” (5 cm - 10 cm).

The maximum concentrations of waste on the sea surface in 2016 are registered in the area of the Kamchiya River (8441 sq/km2) for the coastal waters and in the shelf area off the town of Sozopol (4857 sq/km2) and Kaliakra (3115 km2), characterized by the presence of intense shipping traffic.

The shelf areas of Kaliakra-Durankulak and Bourgas and the coastal areas of Galata, Kamchia and Sozopol-Alepu have been established as concentration points of waste in surface water in 2018.

The presence of floating waste is highly variable and depends on the strength and direction of the prevailing winds and currents. The deposition of large quantities of plastic waste on the beaches on the southern Black Sea coast (Alepou beach) was reported after strong winds, sea and currents directed towards the Bulgarian coast in September 2018.

The typical autumn storm winds “meltems” with wind direction ESE, heavy sea and surface currents with direction WSW have the ability to “clean” the coastal waters from floating waste and to deposit it on the beach and the rocky shores of the Bulgarian Black Sea coast.

One-time surveys of waste floating on the sea surface provide information about the moment state, therefore it is advisable to combine them with monitoring of the movement of water masses in the coastal area and modeling the distribution of different types of plastic waste in the sea.

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- *European Parliament and Council Directive on reducing the environmental impact of certain plastics products, 2019. https://data.consilium.europa.eu/doc/document/PE-11-2019-REV-1/en/pdf*
- *Report on the project "Tools for evaluation of waste, eutrophication and noise in the sea" (MARLEN), Varna, 2017, 290 p.*
- *Koichev M., 2014. The pollution of the sea with solid waste - a current environmental problem, Science and technologies: Volume IV, 2014, Number 2: Nautical and Environmental Studies, 1-5.*
- *The challenge WIND2WIN, 2018. http://wind2win.com/monitoring/*
- *Monitoring programs under Art. 11 of the Marine Strategy Framework Directive https://www.bsbd.org/en/msfd_monitoring.html*

4. ASSESSMENT OF THE MARINE WASTE FLOW IN THE BLACK SEA BASIN

The available data at this stage of the current research do not allow to add quantitative assessments of the processes of the marine waste flow in the whole basin. It is also difficult to add new results from the MARLEN Pilot Project to the current assessments of the processes abreast of the Bulgarian coast and adjoining land - those will be presented after the fulfilment of the foreseen in the assigned task Project monitoring of the Great Bourgas bay beaches and the obtained results are analyzed. Therefore, the following below will outline some key features of the pollution process and, above all, its relationship to environmental dynamics that are, for the reason stated, of a qualitative nature. Critical analysis and indication of the deficiencies of the MARLEN results are made in order to make a more accurate procedure, organization and interpretation of following research.

In accordance with the way of entering the marine environment, the waste is divided in Part Two (§2.1) into two categories: (a) directly disposed into the sea due to different human activities; (b) blown by the wind and carried by the sea off the continent, or from the latter, the water masses coming through the straits, (from the flowing rivers, gullies, discharged water from sewage treatment plants, sewers, etc.). In particular, the process of waste circulation is closely related to the coastline area, which is in contact with the marine environment, the land and the atmosphere. Particularly sensitive are the beaches where there is active recreational activities, especially during the summer half-year- they are subject to this research. Part of the floating waste Is carried and thrown onto the shore due to the effect of the wind and the sea – these are the so-called external pollutants for the latter. Together with the waste that is directly produced by people in the specified area (internal pollutants), they may re-enter the sea with the change of hydrometeorological conditions. Therefore: (a) the coastal part of the land is in the process of spreading waste, bearing in mind that it is both polluted and, at the same time, a potential source of pollutants for the marine environment; (b) the sea and wind (which generates it) are the main driving force that make part of the pollutants flow from the land into the sea. (In order not to complicate the adoption of the main objective of the research from the very beginning, the scheme excludes those pollutants which are carried by the wind and directly come onto the sea surface). Obviously, for the assessment of such a circulation in a specified region, special case of intention should be provided for the analysis of wind and sea mode – an omission of this study is that in the draft version of it such analysis was not foreseen . The nature of the wind is also decisive for the phenomenon of upwelling and the opposite phenomenon downwelling, in which characteristic circulating cells originate in the water, with coastal waters being drawn to the interior of the sea and compensated for by deep water or vice versa. Such phenomena are often observed along our coastline, in §1.3 a specific example is given from the water area of Bourgas Bay.

Of the physical factors influencing the dynamics of floating pollutants, the currents of the sea are of paramount importance: once they enter the sea, pollutants with positive or neutral buoyancy are taken up by them. Those with a negative buoyancy sink directly and go down to the seabed. From there, some of those in the coastal area, with high sea and storms, are thrown out on land - for our coastal conditions, this process has so far not been quantitatively and qualitatively assessed.

The Black Sea is a semi-closed basin with a very limited water exchange with the World Ocean. The general nature of water circulation, as described in §1.1, along with river flow (mainly concentrated in the Northwest of the sea, i.e. in close proximity to the Bulgarian coast - see Part 1), supports the process of gradual accumulation of waste in the sea. Although we do not have specific information, we can assume with confidence that the water exchange through the Bosphorus and the Kerch Strait also favors such a trend. Although the surface of the Black Sea waters, along with the waste they carry, flows through the Upper Bosphorus current in the Sea of Marmara, the incoming stream of the Lower Bosphorus current must not be disregarded - through it waste water from the Istanbul metropolitan is discharged. In the Kerch Strait, additional quantities of floating waste from the Azov Sea should also be expected. This shallow basin has pronounced ecological problems and is under the strong influence of the river flow (the Don and Kuban River have an annual runoff of 26 km3 and 13 km3 respectively) and therefore its density is lower than that of the Black Sea . That is why his waters penetrate the Black Sea through the surface layer of the Kerch Strait, importing floating debris. As a summary of all this, it follows that the closed scheme of movements with MBC (Main Black Sea Current) and the developed swirl structure at its periphery, described in Part 1 (§1.1 and §1.2), favor the cross-border transfer and the gradual accumulation of floating waste. For this reason, the sea is becoming a major permanent source of pollution of coastal land, including the beaches that are the main subject of a study of this project. Regarding our coast, the impact is particularly pronounced for several reasons:

(a) the existence of a large shelf with sloping underwater descent;

(b) the passage of the intensive flow of the MBC and its hydrodynamic instability, expressed in the originating of vortices of different scale. For this reason, in Fig. 2.2 and Fig. 2.4 The absolute maximum concentrations and quantities of floating macro-waste are recorded in the open shelf southeast of cape Kaliakra and east of cape Maslen, as well as east of the Kamchia estuary, where the Kaliakrian anti-cyclone is periodically located;

c) the coastal river discharge from the shallow Northwestern part - a region with permanently degraded ecological status, which in the observations of the project "EMEPA" (Enterprise for management of environmental protection activities) is reflected with the maximum of floating macro-waste in the region north of Shabla;

(d) extensive beaches with anthropogenic load;

(e) marine activities of a different kind;

(f) unresolved problems with the treatment and the regulated discharge of waste water;

(g) insufficient effective control of the marine environment.

When examining trajectories of floating waste, particular attention must be paid to the impact on them of the meanders of the flow of MBCs and whirlpools. Cycles of cyclonic and anticyclonic vortices are characterized by vertical movements of the rise and fall of the water masses respectively, along the periphery of the vortices the direction of the vertical rate is reversed. All this favors the unfavorable tendency of the waste to penetrate the surface of the sea in depth, and the picture of their dynamic flow is further complicated, because the stratification of sea water should also be taken into account. It is a fact that there are two main water bodies in the Black Sea - surface with lower salinity and deep (Mediterranean) with greater density. Between these two structures there is a abrupt boundary that separates them - this is the constant haloclin (picnocline), it is normal to assume that there will be some (local) maximum amount of floating waste. With stronger vertical movements, they can be lifted near the surface of the sea and engage in the general horizontal circle of water. Therefore, the periodic study of the load of floating waste of intermediate and deep layers should not be excluded from future projects.

The origin or passage of a given whirlpool through a certain water area significantly affects not only the character of the local currents but also the horizontal water exchange. Abreast of the Bulgarian coast, such effects can be expected from the Kaliakrian and Burgas anticyclones, and the presence of the latter, as stated in §1.2, is recorded on an average of 190 days and nights per year. Upon the emergence of a sequential anticyclone to the east of the Bourgas Bay, the waters of the shelf fall first into its southern periphery, where the flows are from the eastern quarter, with its passage the movements are under the influence of the northern periphery and are now directed East. The western part of such a dynamic entity will support southern flow and will limit the exchange between flood waters and those on the open shelf. Therefore, swirl formations of the type shown in §1.3 (with a varying sign depending on the direction and force of the prevailing wind) may be blocked at the entrance of the Big Bourgas Bay, which helps to accumulate floating waste in the internal floodplains water. In the area of Koketrais Bank, there is a possibility to periodically form a zone of convergence and thus to increase the quantities of waste in the marine environment. This assumption is confirmed in particular by the measurement results shown in Fig. 2.2.

Concerning the different types of wastes in the marine environment and on the coastline of the Bulgarian coast, quantitative and qualitative assessment for them is obtained from the results summarized and presented in §2.2 of the pilot project "MARLEN". Unfortunately, the report of this study is of a fact-finding, descriptive nature and its analytical part is weak and almost absent. A significant disadvantage is that despite the fact that floating wastes are being studied, there is no relation to the dynamics of the marine environment. There are no data on the hydrometeorological environment before and during the survey, and it has a significant impact on the registered distributions. There are no explanations (or at least hypothesis) of the recorded high (compared to the shore) open sea quantities in the northern region (and they are obviously coming from the northwest part of the Black Sea, i.e. they have cross-border characteristics) and various parts of the MBC (Figure 2.2, Figure 2.4 and Figure 2.6). It can be assumed that the extreme accumulation of macro-waste in the area between the Bay of Sozopol and Cape

Maslen (an open region subjected to more intense wind impact and hence a more developed water dynamics) is also dynamic and is a consequence of their flow from a slack water area in the southeastern part of the Big Bourgas Bay and their mixing with the incoming quantities from the north, carried by the main southern stream. When performing the cuts, a methodological error is made: in order to achieve (quasi) synchronicity and hence better concordance between the individual observations, the ship routes should be moved sequentially from north to south along with the characteristic Southern flow.

In order to provide a grounded assessment of the floating waste load, an analysis (and not just description!) of the registered spatial distributions of waste on land, their possible origin (internal or external), the reasons for the seasonal differences and their relation to the peculiarities of hydrometeorological conditions (wind and sea) and the total circulation of waters for each specific region. Studies are also needed, with the results of which an indication about the nature of the pollution process in extreme conditions can be obtained, because the latter may lead to substantial redistribution of the studied characteristics.

It is only after overcoming the critical remarks made above and receiving up-to-date information from new monitoring surveys that improved sea load assessments should be carried out.

5. List of applications

- Application 1 – List of information sources;
- Application 2 – Black Sea streams monthly values of 2,50 m depth for the period 2013 – 2017, months: February, May, August and November;
- Application 3 - Black Sea streams monthly values of 101,57 m depth for the period 2013 – 2017, months: February, May, August and November;

- Application 4 - Black Sea streams monthly values of 210,90 m depth for the period 2013 – 2017, months: February, May, August and November;
- Application 5 - Black Sea streams monthly values of 2,50 m depth for the period 2013 – 2017, months: February, May, August and November;
- Application 6 - Black Sea streams monthly values of 33,0 m depth for the period 2013 – 2017, months: February, May, August and November;
- Application 7 - Black Sea streams monthly values of 49,5 m depth for the period 2013 – 2017, months: February, May, August and November;
- Application 8 - Black Sea streams monthly values to 2,5 m depth for the period 2015 to 2017;
- Application 9 – Map with percent distribution of carried marine waste by type (2018);
- Application 10 – Map with marine waste concentration by type (2018);
- Application 11 – Marine waste Information and distribution .