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The Organic Carbon in the Water, the Particulate Matter, and the Upper Layer of the Bottom Sediments of the West Kara Sea

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Abstract—In three sections in the Kara Sea, the contents of the dissolved and particulate organic carbon (the DOC and POC, respectively), as well as of the organic carbon of the bottom sediments (C_{org}) were determined. The contents of varied from 6.3 to 2400 μg/l for the DOC and from 0.84 to 12.2 mg of C/l for the POC. The average concentrations for all the samples tested amounted to 200 μg/l for the DOC (n = 78, σ = 368) and 2.7 mg/l for the POC (n = 92, σ = 2.7). The concentrations of C_{org} in the samples of the upper layer of the bottom sediments of the area treated varied from 0.13 to 2.10% of the dry substance at an average value of 0.9% (n = 21, σ= 0.49%). It is shown that the distribution of the different forms of organic matter (OM) is an indicator of the supply and spreading of the particulate matter in the Kara Sea and that the DOC and POC of the Kara Sea are formed under the impact of the runoff of the Ob and Yenisei river waters. It is found that the distribution of the OM of the bottom sediments in the surveyed area of the Kara Sea is closely related to their grain-size composition and to the structure of the currents in the area studied. The variations in the C_{org} content in the bottom sediment cores from the zone of riverine and marine water mixing represent the variability of the OM burial.

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INTRODUCTION

The distribution of the organic carbon in terms of the geological and hydrological parameters is an important characteristic allowing one to estimate the fluxes of the organic matter and to reveal its origin and transformations in marine ecosystems. In view of this, the expeditions to the Kara Sea performed studies of the organic carbon (C_{org}) in the water, particulate matter, and bottom sediments. The treatment of the data collected allowed us to obtain a view of the distribution of the organic matter in the southwest part of the Kara Sea during the summer–autumn period of 2007.

Compared to other Arctic seas, the Kara Sea is much studied. The research performed by Russian and foreign expeditions enabled us to find the main trends in the distribution and burial of the organic matter (e.g., [10, 16]). However, simultaneous studies of the organic matter in the water, particulate matter, and bottom sediments, in combination with detailed hydrological and geological surveys, were only occasional (e.g., cruise 49 of the R/V *Dmitrii Mendeleev* in 1993 [5]).

The route of cruise 54 of the R/V *Akademik Mstislav Keldysh* in the Kara Sea was planned to obtain integrated oceanographic information on three entirely different regions. The Yamal section traverses the area of the minimum impact of the riverine runoff. The section across the St. Anna Trench and the Ob section included the zone from the freshwater inner part of the Ob Bay to the deep-water areas of the Arctic basin and allowed one to reveal the features of the organic matter transformation in the zone of the riverine and marine water mixing, as well as in the continental slope area. The location of the sections and the sampling sites are given on map [13].

THE METHODS

The seawater was sampled using Niskin bottle samplers of 30 l volume from the layers selected by the data of the hydrological probing. The near-bottom water over the layer of bottom sediments collected with a Niemisto tube was also sampled. The water samples were filtered through previously calcined at 430°C GF/F filters with 0.5–0.7 μm conventional pore diameters. The average volume of the filtered water from a single layer amounted to ~10 l; that of the near-bottom water collected with a Niemisto tube was ~0.5 l. The filtrate used to determine the dissolved organic carbon (DOC) was placed into glass flasks of 22 ml volume, acidified to pH 2, and kept in a refrigerator. The filter containing the substance collected was frozen and kept at –20°C until the further analyzing.

The bottom sediments were sampled with an Okean grab sampler and Niemisto tubes. The latter were preferred because the upper layer of the bottom sediments remained intact in the tube. The surface 0–1 cm layer was taken from the grab sampler immediately after its raising aboard the vessel, and the samples of the bottom sediments collected with the Niemisto tubes were preliminarily settled for 1–2 hours until the sedimentation of the roiled upper layer. Later, the near-bottom water layer was filtered through a filter of the above-mentioned type for the subsequent determination of the C_{org} content and the composition of the organic matter (OM). Within the sample of the bottom sediments, the upper semiliquid layer was separated (a watered layer of ~1 cm thickness). Later, the core was divided into roughly equal layers of 5 cm thickness, and the points of the dividing were selected using the lithological characteristics. The samples of the sediments were kept frozen until the analyses for the carbon content. Just before the analyzing, the thawed filters were dried in a dessicator at 60°C. The samples of the bottom sediments were dried to the air-dry state and powdered.

The contents of the C_{org} and C_{carb} (carbonate carbon) were determined using a TOC Veph analyzer manufactured by the Shimadzu co. and equipped with an SSM 5000A attachment. For the dissolved organic carbon, the range of the measurable concentrations was from 0.05–25000 mg of C/l in a sample of 100 μl volume. For the bottom sediments, the measurable concentrations of the carbon were within 0.05–30 mass % (of the dry mass) in a sample of 100 μg mass. For the particulate matter, the range of the measurable concentrations of carbon was 5–1000 μg of C/l. The measuring device's error was 1%. The reproducibility of the results of the analyses amounted to ±5%. Before starting a series of analyses, the device was calibrated with three tubes of standards of bottom sediments (SDO2, SDO1, and SDO3).

RESULTS AND DISCUSSIONS

The dissolved and particulate organic carbon. The data of the analyses for the contents of the dissolved and particulate organic carbon (the DOC and POC, respectively) in the seawater are presented in Tables 1–3. Based on these data, the features of the DOC and POC distribution were revealed within the water mass in the three sections (Fig. 1).

The concentrations of the dissolved organic carbon in the area considered varied within a wide range: from 0.84 mg of C/l in the deep-water part of the St. Anna Trench (station 4983) to 12.2 mg of C/l in the freshwater part of Ob Bay (station 4993). The concentration of the particulate organic carbon in the area considered varied from 2400 μg/l in the near-bottom waters of the zone of the beginning of the riverine and marine water mixing (station 4994) to 6.3 μg/l in the near-bottom waters of the central part of the Yamal section (station 4958). The average DOC content for all the samples tested amounted to 2.7 mg/l (the number of analyses was $n = 92$, and the standard deviation was $\sigma = 2.7$); the content of the POC was 200 μg/l ($n = 78$, $\sigma = 368$). The average contents for all the samples of the water's surface layer amounted 4.2 mg/l for the DOC ($n = 18$, $\sigma = 3$) and 266 μg/l for the POC ($n = 18$, $\sigma = 388$).

In the Yamal section (Fig. 1a), the increased and maximum DOC concentrations (station 4950, 0 m layer, 3.15 mg of C/l, Table 1) were found in the western part in the surface layer of the waters where the desalinating effect on the marine waters was pronounced [8].

In the coastal zone of the Yamal section, the DOC maximum was registered at stations 4954–4958 (50–435 μg/l), where the POC content increase was also noted. The minimum values of the DOC concentrations were found in the layers of 70 m at station 4946 and of 60 m at station 4960 (1.14 and 1.13 mg of C/l, respectively), and the minimum of the particulate carbon was in the layer of 110 m at station 4958 (6.3 μg/l). In the surface layer, the concentrations of the DOC and POC somewhat exceeded the average values and amounted to 2.1 mg of C/l and 82 μg/l. The average contents for the section amounted to 1.55 mg of C/l for the DOC ($n = 32$, $\sigma = 0.42$) and 65 μg/l for the POC (n=25, $\sigma = 99$).

The observed enrichment of the coastal waters in particulate matter is probably caused by the processes of the coastal abrasion and of the bottom sediments' rewashing at the coastal slope by the Yamal current (stations 4956 and 4957), as well as by the impact of the inner tide that is generated here [9]. At that, a degree of the DOC content's increase is also seen, which may be caused by a partial transition from the particulate into the dissolved form. The waters poorest in the POC content are situated in the mixing zone of the coastal waters of the Yamal current and the upper desalinated water layer (station 4960) occupying the central part of the section. In the deep layers of the western part of the section, the POC concentration exceeds 25 μg/l at low DOC concentrations (1.4–1.1 mg/l), probably marking the Barents Sea waters [2].

The POC concentrations in the water sampled with Niemisto tubes vary within a wide range (157–1000 μg/l) and are determined by the various types of the underlying bottom sediments. No significant increase of the DOC concentrations was found in this water; they amounted to 2.2–1.6 mg/l.

The average OM contents in the section across the St. Anna Trench (1.58 mg of C/l of DOC at $n = 31$ and $\sigma = 0.64$; 61.1 μg/l of POC at $n = 27$ and $\sigma = 30.7$; Table 2) are comparable, in general, to the OM content in the Yamal section (Fig. 1b). In the northern part of the section, at station 4983 at the depths of 61 and 200 m, the studied seawater samples contained the minimum DOC concentrations over the entire area considered (0.94 and 0.84 mg of C/l, respectively). At the same station, in the layer of 200 m, the minimum POC concentration –17.2 mg of C/l was registered. These waters are considerably poorer in C_{org} than those of the southern part of the sea. The decreased

Table 1. The content of the dissolved and particulate organic matter in the Yamal section

Station no. Date	Depth, m	Layer, m	Salinity, psu	DOC		Particulate matter			C_{org}
				mg of C/l	μM of C/l	mg/l	μg of C/l	% of the C_{par}/particulate matter	dis/par
4946 Sept. 9, 2007	160	0	28.0	2.17	181	0.34	23.1	6.9	94
		20	32.1	1.99	166	0.18			
		30	33.2	1.38	115	0.17	29.2	17.4	47
		70	34.2	1.14	95	0.34	32.0	9.4	36
		138	34.5	1.13	94		27.5		41
4950 Sept. 10, 2007	115	0	22.4	3.15	262	0.27	15.8	5.8	200
		30	33.4	1.45	121	0.12	28.3	24.3	51
		50	33.8	1.35	112	0.18	22.3	12.1	61
		71	34.1	1.31	109	0.28	15.5	5.5	84
		113	34.5	1.23	103	0.27	7.1	2.6	173
		115 TH	34.5	2.25	187		830.4		3
4952 Sept. 10, 2007	100	100 ÒÍ	34.4	1.86	155		314.1		6
4960 Sept. 11, 2007	116	0	27.8	2.47	206	0.60	14.5	2.4	170
		18	33.3	1.29	107	0.20	17.0	8.6	76
		29	33.5	1.32	110	0.13	16.1	11.9	82
		60	34.2	1.13	94	0.09	16.1	17.9	70
		109	34.5	1.22	102	0.30	29.3	9.7	42
		116 TH	34.5	1.62	135		959.7		2
4958 Sept. 11, 2007	118	0	28.9	1.21	101	0.42	117.8	28.0	10
		15	33.1	1.24	104	0.30	51.2	16.9	24
		26	33.7	1.36	113	0.21	53.5	25.4	25
		55	34.0	1.16	97	0.57	49.8	8.7	23
		110	34.4	1.25	104	0.92	6.3	0.7	198
		118 TH	34.4	1.63	136		1007.8		2
4957 Sept. 11, 2007	46	46 TH	33.7	1.58	131		157.4		10
4956 Sept. 11, 2007	35	0	30.9	1.27	105	0.64	71.9	11.2	18
		14	32.3	1.34	112	0.32	58.3	18.5	23
		21.4	32.9	1.59	133	0.25	237.7	96.8	7
		25.3	33.1	2.26	188	1.67			
		31.5	33.2	1.23	102	1.92	9.9	0.5	124
4954 Sept. 11, 2007	15	1.5	33.4	1.59	133	9.77	249.9	2.6	6
		13.5	33.4	1.62	135	15.95	435.0	2.7	4

Note: The data on the mass concentrations of the particulate matter were provided by Kravchishina [1].

DOC content probably marks an inflow of Atlantic waters into the Kara Sea in 2007 [2]. In the southern part of the sea, in the surface layer, the increase of the OM concentrations caused by the influence of the riverine runoff was observed (station 5004). The increase of the particulate matter concentration in the near-bottom layer of station 4983 to 106 μg of C/l assumes the existence of a nepheloid layer in the St. Anna Trench.

The distribution of C_{org} in the Ob section points to the OM supply with the riverine waters and its transformation at the area of the river—sea barrier (Fig. 1c). In the southern part of the Ob section, abnormally high concentrations of the DOC (12 mg of C/l, station 4993) and POC (2400 μg/l, station 4994) were registered in the near-bottom waters collected with bottle samplers at salinities from 0 to 1 psu (Table 3). Seaward along the section, the concentration of organic carbon (OC) decreases gradually, remaining the maximum in the riverine waters spreading in the upper part of the water mass over the underlying seawaters [6]. In

Table 2. The content of the dissolved and particulate organic matter in the section across the St. Anna Trench

Station no. Date	Depth, m	Layer, m	Salinity, psu	DOC		Particulate matter			C_{org}
				mg of C/l	μM of C/l	mg/l	μg of C/l	% of the C_{par}/particulate matter	dis/par
4983 Sept. 23, 2007	555	0	34.2	1.59	132	0.23	99	43.9	16
		10	34.3	1.13	94		91.3		12
		20	34.3	1.04	86		62.6		17
		40	34.4	1.03	86	0.35	62.3	17.6	17
		62	34.6	0.94	78	0.33	62.7	19.2	15
		200	34.8	0.84	70	0.18	17.2	9.4	49
		528	34.9	1.1	91	4.3	106.1	2.5	10
		555 TH	34.9	1.51	126		88.2		17
4984 Sept. 23, 2007	564	0	34.1	1.15	96		59.6		19
		17	34.4	1.21	101		76.6		16
		73	34.6	1.25	104		47.8		26
4988 Sept. 24, 2007	183	0	33.9	1.54	129	0.32	70.9	22.3	22
		20	34	1.31	109	0.27	72.4	26.5	18
		30	34	1.78	148		67.3		26
		37	34.1	1.49	124	0.25	42.2	17.1	35
		60	34.4	1.4	116	0.25			
		102	34.6	1.46	121	0.3	59.6	19.8	24
		178	34.8	1.49	125	0.34	21.5	6.4	70
		183 TH	34.8	1.54	128		550.3		2.8
4990 Sept. 24, 2007	129	0	26.2	3.03	253	0.48	115.5	24.2	26
		12	32.6	2.48	206	0.27	52.8	19.4	47
		10	31.7	1.66	138		41		40
		24	33.4	2	166	0.23	30.6	13.2	65
		55	34.1	2.04	170	0.29	49.6	17.1	41
		78	34.2	1.47	123	0.24	17.7	7.4	83
		111	34.3	1.44	120	0.53	43.3	8.1	33
		129 TH	34.3	1.74	145		670		2.6
5004 Sept. 30, 2007	110	0	18.6	4.03	336	0.43	150.2	35.1	27
		15	32	1.25	105	0.2	39.2	19.9	32
		40	33.6	1.91	159	0.27	45.9	17.1	42
		103	34.1	1.05	88	0.37	46.4	12.4	23

Note: The data on the mass concentrations of the particulate matter were provided by Kravchishina [1].

the area of well-pronounced vertical stratification, the processes of the DOC coagulation and flocculation develop in the layers of the salinity gradient, which causes the changes in the particulate matter content [3, 7]. The excess of the DOC and POC concentrations in the surface and near-bottom layers, respectively, probably testifies to the horizontal disposition of the zone of the riverine and marine water mixing and to the enlargement of the area of the supply of the particulate matter to the bottom. The formation of the particulate matter and its supply to the bottom may also proceed under the activation of the mixing of the layers by the tidal and pile-up currents. A pronounced effect of the freshwater runoff is traced in the surface

Table 3. The content of the dissolved and particulate organic matter in the Ob section

Station no. Date	Depth, m	Layer, m	Salinity, psu	DOC		Particulate matter			C_{org}
				mg of C/l	μM of C/l	mg/l	μg of C/l	% of the C_{par}/particulate matter	dis/par
4993 Sept. 27, 2007	21	0	0.2	11.94	995	23.13	920.3	4	13
		21	0	12.03	1003	20.07	892.7	4.4	13
		21 TH	0	12.14	1012		1050.3		12
4994 Sept. 27, 2007	16	0	0.6	9.09	758	34.37	1489.1	4.3	6.1
		15	0.7	9.35	780	80.8	2404.7	3	3.9
		16 TH	0.9	9.39	783		1608.6		5.8
4996 Sept. 28, 2007	17	0	6	6.92	577	19.57	650	3.3	11
		2	13.5	3.88	324	3.82	177.9	4.7	22
		15	24.4	3.52	293	14.65	643.6	4.4	5.5
		17 TH	24.4	3.36	280		1241.5		2.7
4999 Sept. 28, 2007	27	0	9.3	7.46	621	6.47	447.8	6.9	17
		6	21.2	3.79	315	1.97	277	14.1	14
		24	29.5	2.65	221	26.58	767.1	2.9	3.4
		27 TH	29.5	2.64	220		2734.7		1.0
5000 Sept. 29, 2007	24	0	19.8	4.05	338	0.4	198	49.5	20
		16	30.9	2.13	178	6.08	321.8	5.3	6.6
		22	32.1	2.7	225	8.09	428	5.3	6.3
		24 TH	32.1	2.33	194		1253.5		1.9
5001 Sept. 29, 2007	25	0	20.6	4.99	416	0.32	117.7	37.3	42
		12	27.7	4.18	349	0.19	57.1	30.8	73
		23	31.9	2.96	247	8.4	217	2.6	14
		25 TH	32.7	2.16	180		967.3		2.2
5002 Sept. 29, 2007	29	0	19	4.97	414	0.56	110.4	19.7	45
		14	29.5	2.85	237	0.44	46.8	10.7	61
		25 TH	32.3	2.94	245	3.83	111.5	2.9	26
5003 Sept. 30, 2007	60	0	19.1	4.71	392	0.55	121.2	22.2	39
		10	29	3.68	306	0.3	70.1	23.5	52
		14	32.5	1.88	156	0.7	70.5	10.1	27
		58	33.9			0.78	59.7	7.7	
		60 ÒÍ	33.9	1.35	113		440.8		3.13

Note: The data on the mass concentrations of the particulate matter were provided by Kravchishina [1].

waters along the entire Ob section and the southern part of the section across the St. Anna Trench [3]. At that, the increase of the POC concentration in the northern part of this section may be partly caused by the influence of the terrigenous runoff from the Novaya Zemlya Islands. In the northern deep-water part of the water mass in the section across the St. Anna Trench, the water is much poorer in the OM content. The concentrations of the organic matter here are close to the average values for the Arctic seas of Russia [11].

The study of the regularities in the DOC distribution over the Kara Sea was the most detailed in [14, 15]. The new data supplement the view obtained well.

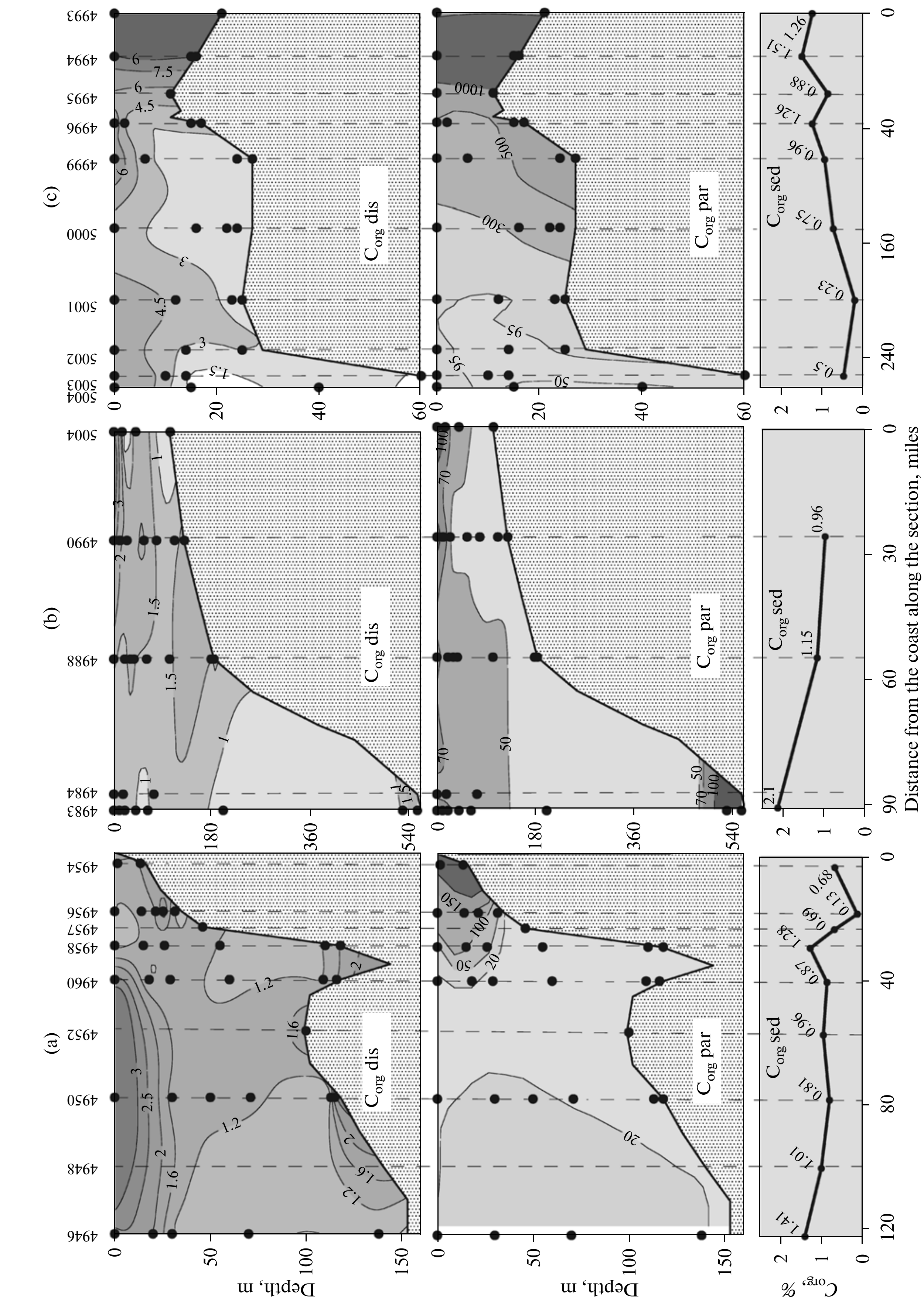

Fig. 1. The distribution of the dissolved (C_{org} dis, mg/l), particulate (C_{org} par, μg/l), and C_{org} of the upper layer of the bottom sediments (C_{org} sed, % of the dry mass) in the Yamal section (a), the section across the St. Anna Trench (b), and the Ob section (c).

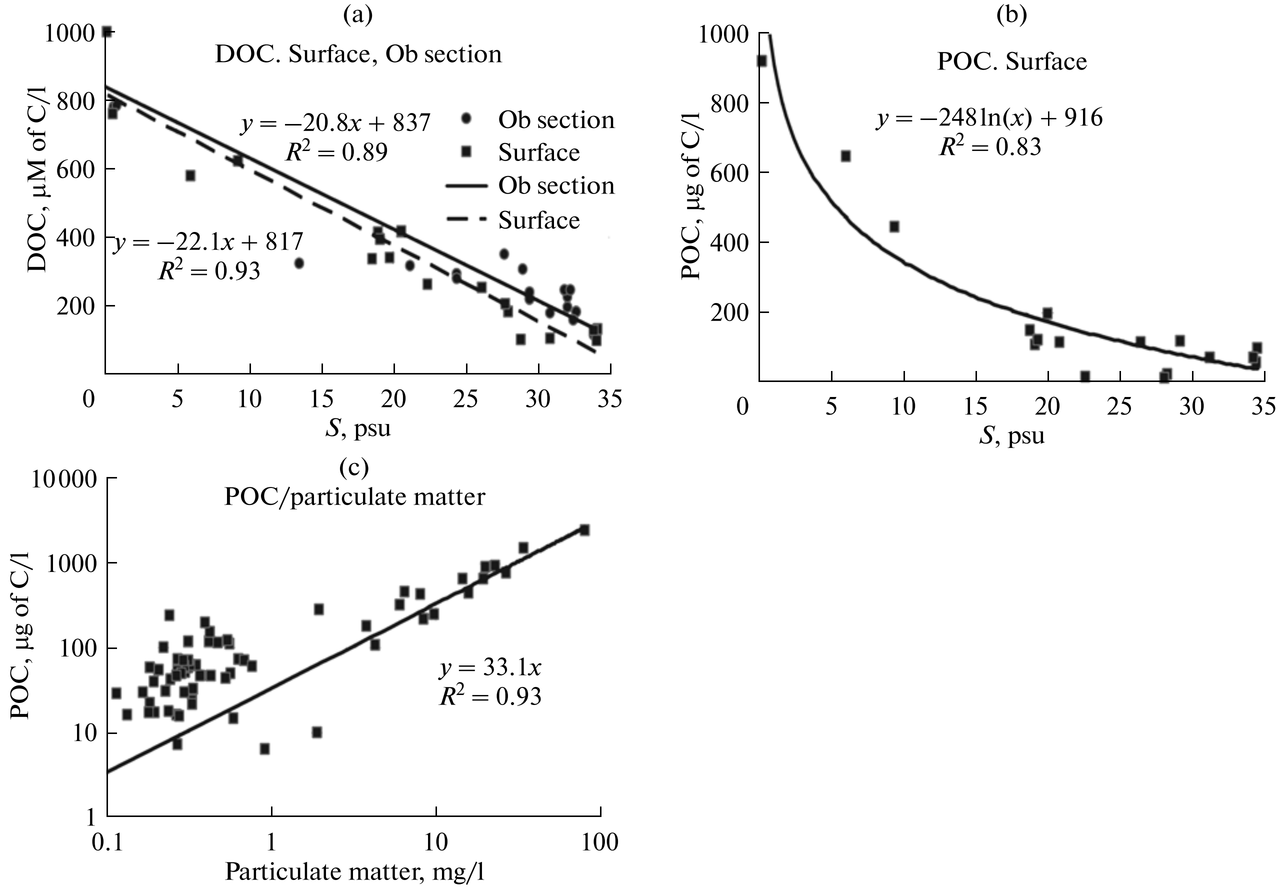

Fig. 2. The salinity dependence of the dissolved (a) and particulate (b) carbon content and the ratios of the dissolved organic carbon and the total particulate matter (c) for all the samples tested.

The diagrams of the salinity dependence of the DOC content (μM of C/l) plotted for the surface waters and the Ob section (Fig. 2a) point to the inverse linear relationship of these parameters. The comparison of the equation $Y = -22.1X + 817$ for the entire surface waters and that of $Y = -20.8X + 837$ for the entire waters of the Ob section allows one to reach a conclusion concerning the stability of the composition of the bulk of the DOC and concerning its genetic relationship to the riverine runoff waters. The calculated value of the DOC content in the freshwaters amounts to 820–830 μM of C/l by the data of the present study. This value exceeds the calculated parameters of 1997–2000 (552, 597, and 617 μM of C/l in 1997, 1999, and 2000, respectively) [15] and represents an increased DOC content in the Ob freshwaters compared to the preceding seasons. One must note that the annual runoff volume in 2007 (522 km^3) exceeded those of 1997, 1999, and 2000 (426, 475, and 388 km^3, respectively) [18]. For the section across the St. Anna Trench, the salinity dependence of the DOC content is less pronounced, and no regular salinity dependence is revealed for the Yamal section. In general, the dissolved organic carbon in the surveyed part of the Kara Sea shows a quasi-stable behavior; the variations in the DOC concentrations are mainly caused by the mixing of the freshwaters supplied to the sea with the seawater (Fig. 2a). The few exceptions mentioned may be explained by the supply of waters of another genesis (the Barents Sea or Atlantic) to the Kara Sea [2].

Comparing the concentrations of the dissolved and particulate organic matter, the relative enrichment in the DOC is seen at the coastal stations of the Yamal section. In the desalinated part of the Ob section, the dissolved : particulate OM ratio changes in favor of the particulate matter, which points to the intense processes of coagulation and flocculation [6].

The correlation analysis of the POC concentrations and the salinity (Fig. 2b) shows a logarithmic relationship, which points to the processes of the particulate matter precipitation onto the bottom in the zone of the changes in the salinity. This relationship is also characteristic for the particulate matter as a whole [4]. The comparison of the total particulate matter concentration and that of its organic component (Fig. 2c) illustrates the following regularity: at high concentrations of particulate matter, a linear dependence is traced between its mass and that of the OC; at low

Table 4. The content of organic carbon (C_{org}, % of the dry mass) in the upper layer of the bottom sediments

Station no.	Layer, cm	C_{org}, %	Sand, %	Siltstone, %	Claystone, %	Lithological description of the sediment
Yamal section						
4946	surf.	1.41	0	10	90	Clayey–silty ooze
4948	surf.	1.01	5	25	70	Clayey–fine-silty ooze with a sand admixture
4950	0–1	0.81	20	20	60	Clayey with sand and siltstone
4952	0–1	0.96	5	20	75	Clayey–fine-silty ooze with inclusions of iron–manganese concretions (IMC)
4960	0–1.5	0.87	35	15	50	Clayey–sandy–silty
4958	0–1	1.28	10	15	75	Calyey–silty grey ooze with a sand admixture
4957	0–1	0.69	85	15	0	Sandy–silty sediment
4956	0–1	0.13	15	60	25	Coarse siltstone with imc inclusions
4954	surf.	0.68				Fine-silty ooze
The section across the St. Anna Trench						
Station no.	Layer, cm	C_{org}, %	Sand, %	Siltstone, %	Claystone, %	Lithological description of the sediment
4990	0–1	0.96	15	15	70	Clayey–sandy–silty
4988	0–1	1.15	15	30	55	Clayey–sandy–silty
4983	0–1.5	2.10	5	10	85	Clayey–silty with a sand admixture
Ob section						
Station no.	Layer, cm	C_{org}, %	Sand, %	Siltstone, %	Claystone, %	Lithological description of the sediment
4993	0–0.5	1.26	0	10	90	Clayey–silty ooze
	0.5–1.5	1.35				
	1.5–5	1.91				
	5–10	1.61				
	10–15	1.52				
	15–20	1.25				
	25–30	1.51				
	35–40	1.59				
	45–50	1.80				
	55–60	1.81				
4994	0–1	1.51	35	30	35	Sandy–clayey–silty ooze
	1–3	0.68				
	3–5	0.89				
	5–10	0.48				
	10–15	0.29				
4995	0–1	0.88	0	10	90	Clayey–silty ooze
4996	0–5	1.26	0	20	80	Clayey–silty ooze
	5–10	1.58				
	10–15	1.48				
	15–20	1.63				
4999	0–1	0.96	5	20	75	Clayey–silty ooze
5000	0–1	0.75	25	35	40	Clayey–silty ooze with sand
5001	0–1	0.23	65	20	15	Sandy–silty–clayey
5003	0.1–1	0.50	55	20	25	Sandy–clayey-silty

concentrations, the enrichment of the particulate matter in the organic component is observed.

The increased OM content in the particulate matter composition is registered in the surface layers of all the stations in the section across the St. Anna Trench (nos. 4983, 4988, 4990, 5004, 5001, and 5003), as well as at several stations of the Yamal section (stations 4950 and 4958). All the stations mentioned are relatively far from the areas of the particulate matter supply, which allows one to ascribe this enrichment to the autochthonous component. The particulate matter of the near-bottom waters is the most depleted in the organic component. A similar view is also seen in the surveyed mouth area of the Ob River. Here, despite the higher volumes of the particulate matter supplied by the river [7, 12], the OM content within the particulate matter composition is relatively low.

The Organic carbon content in the upper layer of the bottom sediments. The concentrations of C_{org} in the samples from the upper layer of the bottom sediments in the area treated varied from 0.13 to 2.10% of the dry substance with an average value of 0.9% ($n = 21$, $\sigma = 0.49\%$, Table 4). The highest value of 2.10% was registered at station 4983 in the oozes of the deep-water St. Anna Trench. The minimum of 0.13% was found in the coarse-silty sediments at station 4956 near the coasts of the Yamal Peninsula. The OM contents measured in the bottom sediments are in good agreement with the published data on the Kara Sea and closely related to the grain-size composition of the sediments [17, 11, 10]. The low content of biogenic $CaCO_3$ in the Kara Sea sediments is caused by the undersaturation of the cold seawaters in carbonates and by the low amounts of their biosynthesis, which is characteristic for all the Arctic seas [10].

In the section from the Yamal Peninsula to the open part of the Kara Sea (Fig. 1a), the maximum C_{org} concentration in the upper layer of the bottom sediments is registered in the clayey–silty oozes at station 4946, being the farthest from the Yamal coast (1.4%), and the minimum was equal to 0.13 % in thecoarse siltstone of the coastal slope (station 4956). The variations of the carbon concentrations from 0.13 to 1.28% at stations 4954–4958 may point to the process of the transition of the upper layer of the bottom sediments owing to the transverse circulation in the near-slope Yamal current and to the accumulation of silty oozes enriched in organic matter in the deep-water part of the section [17]. Among the treated samples of the section, the most C_{org}-depleted sediments ($C_{org} = 0.13\%$) are represented by the well rewashed coarse-silty sediments of station 4956. The bottom sediments of coastal station 4954 are enriched in organic carbon compared to the seaward stations. This may be caused by the supply of fine-grained matter enriched in OM under the coastal abrasion. In the clayey–silty oozes lying on the local bottom (stations 4957, 4958, and 4960), the C_{org} content is increased compared to the coarser sediments of the slope. This is caused by the fact that, at high rates of the coastal Yamal current, the considerably fine-grained sediment is not precipitated on the slope but transferred to be buried in the local bottom lowerings where the clayey and silty–clayey oozes are accumulated. At stations 4948–4952, the C_{org} is distributed uniformly (0.81–0.96%), and the increase of its concentration to 1.4% at station 4946 is related to the growth of the clayey fraction in the ooze.

The section across the St. Anna Trench traversing the continental slope is a prolongation of the Ob section passing from the southern area of Ob Bay, where the waters of zero salinity were registered, via the area of the shallow-water shelf to the continental slope boundary (Figs. 1b, 1c). In these sections, the maximum C_{org} concentration in the surface layer was found at station 4938 (2.1%) with the minimum of 0.23% at station 5001; the average value for the stations of both sections was equal to 1.03% ($n = 11$, $\sigma = 0.52\%$). The section across the St. Anna Trench is characterized by the higher C_{org} concentration ($n = 6$, $\sigma = 0.35\%$) for the Ob section ($n = 11$, $\sigma = 0.35\%$). For the Ob section, it was lower (0.99% at $n = 5$ and $\sigma = 0.72\%$). This is caused by the fact that the sediments in the Ob section are lithologically less uniform and vary from sands to fine oozes.

In the surface layer of the bottom sediments in the Ob section, two stations with quite a high C_{org} content may be distinguished (1.3 and 1.26% at stations 4993 and 4996, respectively). The former station is associated with the black sapropel-like oozes of Ob Bay (S‰ ~ 0.1 psu) and the latter is related to the area of riverine and marine water mixing (S‰ ~ 5–8 psu). Towards the northern part of the Ob section, in the sandy–silty–clayey sediments of station 5001, the content of C_{org} in the surface layer of the bottom sediments decreases to 0.23%. In the section across the St. Anna Trench, the maximum C_{org} concentration (2.1%) was registered at station 4983 (the deepest one in the region considered). The sediments are represented here by clayey–silty oozes with a sand admixture, in which the OM is accumulated owing to the sedimentation of the substance from the surface layers, as well as owing to the mixing of the bottom sediments from above the slope.

The analysis of the tests performed showed a small variability in the C_{org} content according to the depth based on the bottom sediment cores collected with the Niemisto tubes, e.g., 1.45% at station 4996 (the average value; $n = 5$, $\sigma = 0.17\%$) or 1.58% at station 4993 ($n = 14$, $\sigma = 0.21\%$). Against this background, station 4996 is drastically distinguished, at which the C_{org} variations according to the core depth were different by a factor of 1.5–2 (the average C_{org} content is 0.77%; $n = 5$, $\sigma = 0.47\%$). The variations in the C_{org} content as such may be caused by the pronounced seasonal and interannual variability of the hydrological conditions in the mouth zone and represent the displacement of the river–sea barrier [3].

CONCLUSIONS

The distribution of the different forms of OM is the indicator of the supply and spreading of the particulate matter in the Kara Sea, which shows its sources and the OM transformations under these processes.

In the three sections over the Kara Sea, the contents of the POC and DOC varied from 6.3 to 2400 μg/l and from 0.84 to 12.2 mg of C/l, respectively. The average concentrations of all the samples tested amounted to 200 μg/l for the POC ($n = 78$, $\sigma = 368$) and to 2.7 mg/l for the DOC ($n = 92$, $\sigma = 2.7$). The concentrations of the C_{org} in the samples of the upper layer of the bottom sediments varied from 0.13 to 2.1% of the dry substance with an average value of 0.9% ($n = 21$, $\sigma = 0.49\%$).

The particulate and dissolved organic matter in the Kara Sea is formed under the decisive influence of the riverine runoff waters. The POC distribution shows a conservative character; the main changes in its concentrations proceed under the fresh and marine water mixing. The distribution of the DOC points to the changes in the particulate matter sedimentation processes at the river–sea boundary and to the enrichment of the particulate matter in the autochthonous organic component in the well offshore areas.

The supply of terrigenous organic matter with the desalinated waters of the upper layer to the areas distant from the Ob River's mouth is revealed. According to the contents of the OM forms treated, the horizontal boundary of the riverine and marine waters is well registered in the Ob section, along with its role in the formation of the river–sea horizontal boundary.

The distribution of the OM of the bottom sediments in the surveyed part of the Kara Sea is closely related to the grain-size composition of the sediments and the structure of the currents in the area considered. The changes in the C_{org} content in the bottom sediment cores in the zone of the riverine and marine water mixing represent the variability in the OM burial caused by the seasonal and interannual migration of the freshwater runoff and by permanent displacement of the river–sea boundary

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REFERENCES

1. V. I. Burenkov, Yu. A. Gol'din, and M. D. Kravchishina, "Distribution of the Particulate Matter Concentration in the Kara Sea in September 2007 according to Onboard and Satellite Data," Okeanologiya **50** (5), 842–849 (2010).
2. A. G. Zatsepin, E. G. Morozov, V. T. Paka, et al., "Water Circulation in the Southwestern Part of the Kara Sea in September 2007," Okeanologiya **50** (5), 683–697 (2010).
3. A. G. Zatsepin, P. O. Zav'yalov, V. V. Kremenetskii, et al., "Surface Desalinated Layer in the Kara Sea," Okeanologiya **50** (5), 698–708 (2010).
4. V. V. Gordeev, "Russian Arctic Rivers: Flow of Sedimentary Material from the Continent to the Ocean," in *New Ideas in Oceanology,* Vol. 2: *Geology* (Nauka, Moscow, 2004), pp. 113–167 [in Russian].
5. A. P. Lisitsyn, V. P. Shevchenko, M. E. Vinogradov, et al., "Particulate Matter Fluxes in the Kara Sea," Okeanologiya **34** (5), 748–758 (1994).
6. A. P. Lisitsyn, "Marginal Filter of Oceans," Okeanologiya **34** (5), 735–747 (1994).
7. A. P. Lisitsyn, "Marginal Filters and Biofilters of the World Ocean," in *Oceanology at the Start of the XXI Century*, Ed. by A. L. Vereshchaka (Nauka, Moscow, 2008) [in Russian].
8. P. N. Makkaveev, P. A. Stunzhas, Z. G. Mel'nikova, et al., "Hydrochemical Characteristics of Water in the Western Part of the Kara Sea", Okeanologiya **50** (5), 730–739 (2010).
9. E. G. Morozov and V. T. Paka, "Internal Waves in a High-Latitude Basin," Okeanologiya **50** (5), 709–715 (2010).
10. *Organic Matter of Bottom Sediments of Polar Zones of the World Ocean. Ministry of Geology of the USSR, All-Union Research Institute of Geology and Mineral Resources of the World Ocean*, Ed. by A. I. Danyushevskaya (Nedra, Leningrad, 1990) [in Russian].
11. E. A. Romankevich and A. A. Vetrov, *Carbon Cycle in Russian Arctic Seas* (Nauka, Moscow, 2001) [in Russian].
12. E. A. Romankevich, A. I. Danyushevskaya, A. N. Belyaeva, and V. P. Rusanov, *Biogeochemistry of Organic matter of Arctic Seas* (Nauka, Moscow, 1982) [in Russian].
13. M. V. Flint, "Cruise 54 of R/V 'Akademik Mstislav Keldysh' in the Kara Sea," Okeanologiya **50** (5), 677–682 (2010).
14. R. M. W. Amon, *The Organic Carbon Cycle in the Arctic Ocean*, Ed. by R. Stein and R. W. Macdonald (Springler, Berlin, 2004), pp. 83–100.
15. H. Kohler, B. Meon, V. V. Gordeev, et al., *Siberian River Run-Off in the Kara Sea*, Ed. by R. Stein et al. (Elsevier, Amsterdam, 2003), pp. 281–308.
16. *Siberian River Run-Off in the Kara Sea,* Ed. by R. Stein et al. (Elsevier, Amsterdam, 2003).
17. R. Stein and K. Fahl, *The Organic Carbon Cycle in the Arctic Ocean*, Ed. by R. Stein and R. W. Macdonald (Springler, Berlin, 2004), pp. 237–266.
18. http://rims.unh.edu/data/station/station.cgi?station=7142.