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MARINE CHEMISTRY

Hydrochemical Characteristics of the Waters in the Western Part of the Kara Sea

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Abstract—Hydrochemical study in the Kara Sea was part of the program of the integrated expedition of the 59th cruise of the RV *Akademik Mstislav Keldysh*. Primary hydrochemical surveys were performed on the sections in the Yenisei Gulf, along the eastern and western branches of the St. Anna Trough, and across the Novozemel'skii Trough. Moreover, a flow-through system throughout, in which pH values of the surface waters were measured and samples for hydrochemical analyses were collected, was operated during vessel movement. A wide set of hydrochemical analyses was carried out, including tests for key nutrients (silicon and different forms of nitrogen and phosphorus), dissolved oxygen, and values of pH and total alkalinity. The report describes the hydrochemical conditions in the southwestern part of the Kara Sea. The basic results are presented and compared to those of the preceding integrated expeditions (49th cruise of the RV *Dmitrii Mendeleev* in 1993 and 54th cruise of the RV *Akademik Mstislav Keldysh* in 2007).

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INTRODUCTION

Observations of hydrochemical conditions in the Kara Sea began in the 1930s. Most hydrochemical data from 1964 until 1980 were obtained by the expeditions of the Arctic and Antarctic Research Institute [12]. However, the expeditions that the Institute of Oceanology (IO RAS) performed in the late 20th and early 21th centuries may be considered the most informative, both for the set of measured parameters and for the general scope of surveys [3, 14]. Hydrochemical surveys during the 59th cruise continued with the studies of the hydrochemical structure of the Kara Sea performed by the integrated expeditions of the IO RAS in 1993 and 2007.

The features of the hydrochemical conditions in the Kara Sea are determined by numerous factors, mainly by the openness of the sea to the waters of the Central Arctic Basin, along with a relative isolation from the ingress of the warm Atlantic waters from the west. The Kara Sea is subjected evidently to the greatest impact of the continental runoff compared to other Arctic seas. The Kara Sea receives 41% of the total runoff from land to the Arctic Ocean, or 56% of the riverine runoff in the Siberian sector of the Arctic [2, 8].

The hydrochemical structure of the Kara Sea waters is characterized by wide variability, both over time and over the aquatic area of the sea. This is caused by the changeability and contrasts of the weather conditions and by the involvement of waters of various origins into the formation of the seawaters, mainly of those from the Central Arctic Basin and the voluminous continental runoff. The relative contributions of the sources are greatly variable both with time and over the aquatic area of the sea [6].

Hydrochemical studies in 2011 were characterized by a much wider variety of the measurements than those of 1993. Compared to 2007, measurements with a flow-through cell while the vessel was moving were in wider use (300 h), which allowed us to characterize more completely the surface waters of the sea. Considerable attention was also given to the testing of interstitial and near-bottom waters.

Hydrochemical studies were intended mainly to provide biological research with the characteristics of abiotic components of the ecosystems (dissolved oxygen, key nutrients, and inorganic compounds of carbon); to examine the hydrochemical structure of waters (including the near-bottom and interstitial waters); and to research the distribution of tracer elements in waters (silicon and inorganic carbon) for the characterization of the diffusion of the waters of the Ob and Yenisei riverine runoff over the marine aquatic area and their role in the formation of surface waters.

MATERIALS AND METHODS

The samples were collected by means of 5-L plastic Niskin bottle samplers of a Rosette set, according to

GOST 51592–2000, "General requirements for sampling." The samples for dissolved oxygen and ammonium nitrogen were fixed immediately after sampling. The samples for nutrients (silicates, phosphates, and nitrogen forms), pH value, and alkalinity were placed into plastic 0.5-L flasks with no conservation. For waters with high content of particulate matter (the water in bays and gulfs, as well as in the mixing zones of riverine and marine waters), samples for nutrients were previously filtered through the filters of a 0.45-μm pore size [16]. Colorimetry for mineral phosphorus and silicates in the samples of visible water coloration was carried out by means of the appropriate procedure [10, 13].

Values for pH were measured during vessel movement using a flow-through system mounted by the group of the studies of surface seawaters. The measurements carried out in the flow-through cell contained a temperature sensor and a pH-measuring electrode. The measured parameters and coordinates of the vessel were registered each 30–60 s. Hydrochemical parameters were registered during the vessel's movement using an Ekoniks Ekspert 001 four-channel ionometers manufactured by the Ekoniks Ekspert Co (Russia, Moscow). Water was sampled from the flow-through cell to determine in the laboratory the values of total alkalinity and the concentrations of dissolved oxygen and silicon.

The Neimisto tubes of a 5-cm diameter were used for the sampling to determine the concentration gradients of oxygen and dissolved carbon within the water layer above the sediments. The sampling was carried out using a silicon tube from 2–4 levels of the 1–20 cm layer above the sediment. For these reasons, flasks of small volume (about 30 mL) were prepared for the sampling of oxygen.

The content of oxygen in seawater was determined by titration using Winkler's procedure [13]. Values for pH were determined using an Ekoniks Ekspert 001.4 ionometer calibrated with standard bugger solutions (GOST 8.135-74). The total titratable alkalinity (Alk) was determined using direct titration by Bruevich, with a visual registration of the end of titration [13]. Concentrations of dissolved inorganic and total phosphorus (phosphates), dissolved inorganic silicon (silicates), nitrite nitrogen (nitrites), nitrate nitrogen (nitrates), and ammonium nitrogen (ammonium ions) were determined by means of colorimetry according to [9, 10, 13]. Total nitrogen and phosphorus were determined using wet combustion [10]. Concentrations of dissolved carbon dioxide and of various forms of dissolved inorganic carbon were calculated using the pH–Alk method with thermodynamic equations of carbonate equilibrium, including concentration constants of the dissociation of carbonic acid by Roy [16] corrected from waters differing from seawater in their properties [1, 15]. An SBE 43 sensor was used to examine the fine structure of the oxygen distribution.

RESULTS

As basic stages of the surveys in 2011, one may distinguish the section in the Yenisei Gulf, the sections along the eastern and western branches of the St. Anna Trough, and the section across the Novozemel'skii Trough. All the sections characterized the areas of the west of the Kara Sea as being much different from each other.

The Yenisei section was executed on September 18–22 (stations 5010–5026). The initial southernmost station of the section was executed at a site where no effect of saline waters was traced over the entire vertical profile. However, it is difficult to say whether this station might characterize chemical features of riverine runoff because the Yenisei River, like other large rivers, is characterized by a pronounced irregularity of its runoff over the riverbed alignment [4]. The variability range of the hydrochemical parameters in this section was the widest in the entire considered area, which is common for the contact zones of riverine and marine waters (Table 1). The zone of mixing (contact) of riverine and marine waters is well pronounced in the section, according to hydrochemical parameters. This zone, as in many large rivers, shows a complicated structure and consists of two parts: the vertical frontal zone between the stations 5012 and 5013 and the horizontal zone with showings traced just to the end of the section. The boundaries of the frontal zone are the best seen by the distribution of total alkalinity and dissolved silicon (Figs. 1 and 2).

Unfortunately, the "normal" dynamics of the hydrochemical parameters were disturbed in the transient zone from riverine to marine waters. The section near station 5018 was crossed by a "tongue" of desalinated water in which the salinity of surface waters decreased almost to 5 PSU. This crossing is the most pronounced in the distribution of total alkalinity (Fig. 1). The two main areas of the bulk sedimentation and oxidation of organic matter in the upper layer of sediments are distinguished in the section. First, station 5015 is characterized by a growth of all nutrients and a decrease of the content of dissolved oxygen to 4.68 mL/L, i.e., below 60%. A considerable increase of the content of total phosphorus (over 10 μg-atom/kg), as well as of ammonium and total nitrogen (to 6.8 and 45.6 μg/L, respectively), testifies to the high intensity of the destruction processes and to the "youth" of the organic matter of the sediments.

The other area of the decomposition of organic matter is located downstream (stations 5020 and 5021) where 54 bottom relief forms a depression separated from the seaward part by an area of shallow depth. The increase of nutrient content is less pronounced here than upstream. The increase of the content of nitrate nitrogen (Fig. 4) and decrease of relative oxygen content to 70–80% are the most pronounced. The prevalence of completely oxidized nitrogen and a moderate increase of phosphates show that organic matter in the

Table 1. Average values and ranges of the registered hydrological and hydrochemical parameters in the section at the Yenisei Gulf on September 18–22, 2011

Parameter	Riverine waters	Transitional area	Seawaters
Layer, m	12 0–32	7 0–16	30 0–63
Temperature	9.36 8.66–9.63	4.63 0.53–7.96	–0.86 –1.56–2.01
Mineralization, g/L	0.136 0.063–0.518	21.237 1.415–29.972	32.307 31.000–34.000
Oxygen, mL/L	7.84 7.73–8.04	7.48 4.69–8.58	7.48 5.74–10.95
Oxygen, %	97.9 97.1–99.0	95.4 59.6–108.6	85.7 67.3–105.5
pH value, NBS units	7.94 7.79–8.11	7.85 7.32–7.99	7.81 7.65–7.99
Alkalinity, mg-equiv/L	1.008 0.934–1.069	1.837 0.974–2.258	2.304 2.204–2.405
Phosphorus, μg-atom/L	0.18 0.02–0.23	0.45 0.12–2.34	0.77 0.18–1.40
Total phosphorus, μg-atom/L	1.70 0.18–2.19	1.23 0.40–10.39	1.19 0.91–2.34
Silicon, μg-atom/L	107.93 103.10–113.59	26.14 1.71–112.5	10.81 1.47–20.64
Ammonium nitrogen, μg-atom/L	1.52 0.00–3.46	1.47 0.48–8.04	1.21 0.51–1.91
Nitrate nitrogen, μg-atom/L	0.26 0.19–0.36	0.80 0.00–7.30	3.91 0.11–6.77
Nitrite nitrogen, μg-atom/L	0.23 0.09–0.27	0.06 0.01–0.13	0.13 0.04–0.20
Total nitrogen, μg-atom/L	18.93 9.44–24.46	15.76 3.74–45.62	14.13 6.45–21.11
Inorganic carbon, mg/L	12.52 11.71–13.34	21.83 12.22–26.89	27.38 26.25–28.91

upper layer of sediments and in the near-bottom water has already gone through the main stages of oxidation.

One may suppose that the upstream oxidation area (station 5014) is related to the bulk precipitation of dissolved and particulate matter at the geochemical barrier, which is also confirmed by the distribution of water mineralization. The other area associated with the oxidation of organic matter most probably appeared at the "orographic" barrier [8], where changes in dynamic characteristics of the flux and the features of the bottom relief in the gulf result in conditions for the precipitation of water-borne particulate matter.

In view of the distribution of dissolved oxygen and its degree of saturation, the biological activity of the gulf waters was not high. Oxygen content was close to saturation (usually from 98 to 101%), exclusively in the surface waters (Table 1). On the other hand, the content of nutrients did not limit photosynthetic activity. The distribution as such of the hydrochemical parameters may testify not only to the seasonal decrease of photosynthetic activity but also to a high content of organic matter in riverine waters. Similarly to most high-latitudinal rivers, the section was characterized by a relatively low nitrate nitrogen content, often either close to that of nitrite nitrogen or not exceeding it. This is caused by low rates of biochemical processes owing to low temperature, and/or to the initial stages of the decomposi-

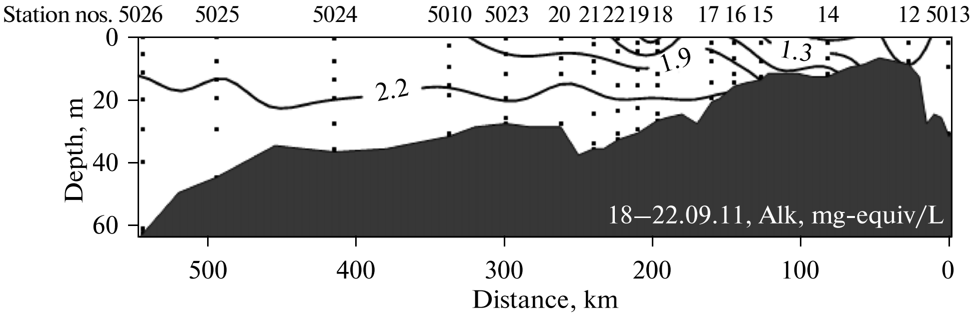

Fig. 1. Distribution of total alkalinity values (mg-equiv/L) in the Yenisei section.

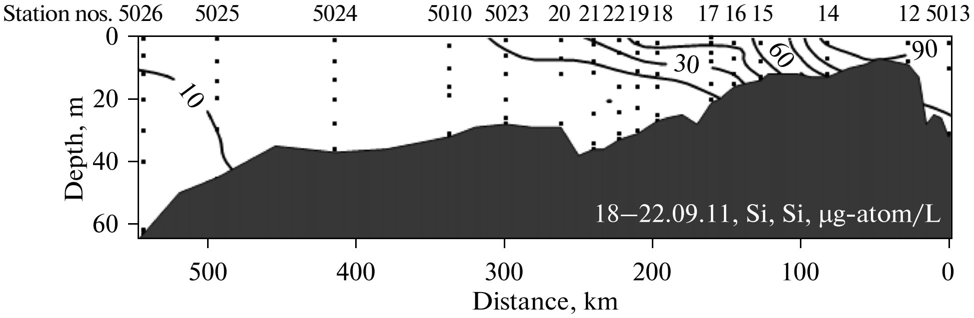

Fig. 2. Distribution of dissolved silicon (μg-atom/L) in the Yenisei section.

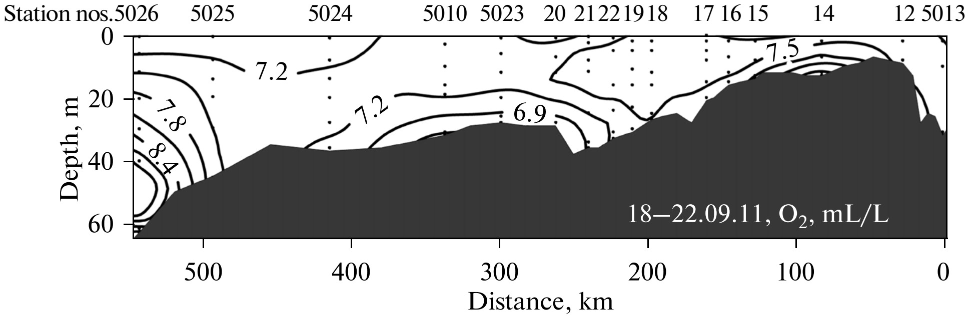

Fig. 3. Distribution of dissolved oxygen (mL/L) in the Yenisei section.

tion process of organic matter when the oxidation of nitrogen is not completed.

The hydrochemical analyses at most of the stations were carried out in near-bottom water (at 2–4 levels from the bottom) and in interstitial water of the upper layer of the sediment. As a rule, the concentration gradients of silicon and phosphorus were small in near-bottom water. The quite high current velocities may have resulted in leveling of the hydrochemical characteristics. The oxygen content, as a more dynamic parameter, was not as affected by the current, and most of stations showed a decrease in oxygen content by 0.5–0.8 mL/L in the immediate vicinity of the sediment surface (1 cm).

Sections in the St. Anna Trough. During the cruise, two sections were executed along the western and eastern branches of the St. Anna Trough through which sea waters exchange with the waters of the Central Arctic Basin. The eastern (stations 5032–5042) and the western (stations 5043–5050) sections were executed on September 24–26 and 29–29, respectively (Table 2).

These sections are different from one another in the distribution of hydrochemical parameters. This is reflected in the fact of water slippage down the slope, which may be supposed for the eastern section. Deep-water layers at stations 5036–5038 showed an increased content of dissolved oxygen (Fig. 5); however, it did not affect the degree of saturation. The con-

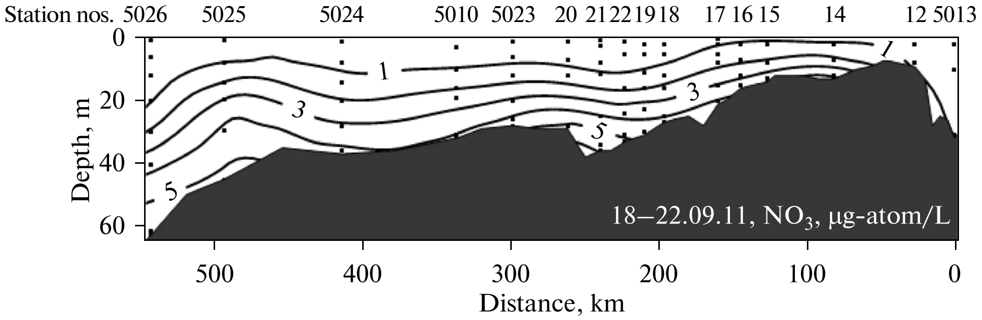

Fig. 4. Distribution of nitrate nitrogen (μg-atom/L) in the Yenisei section.

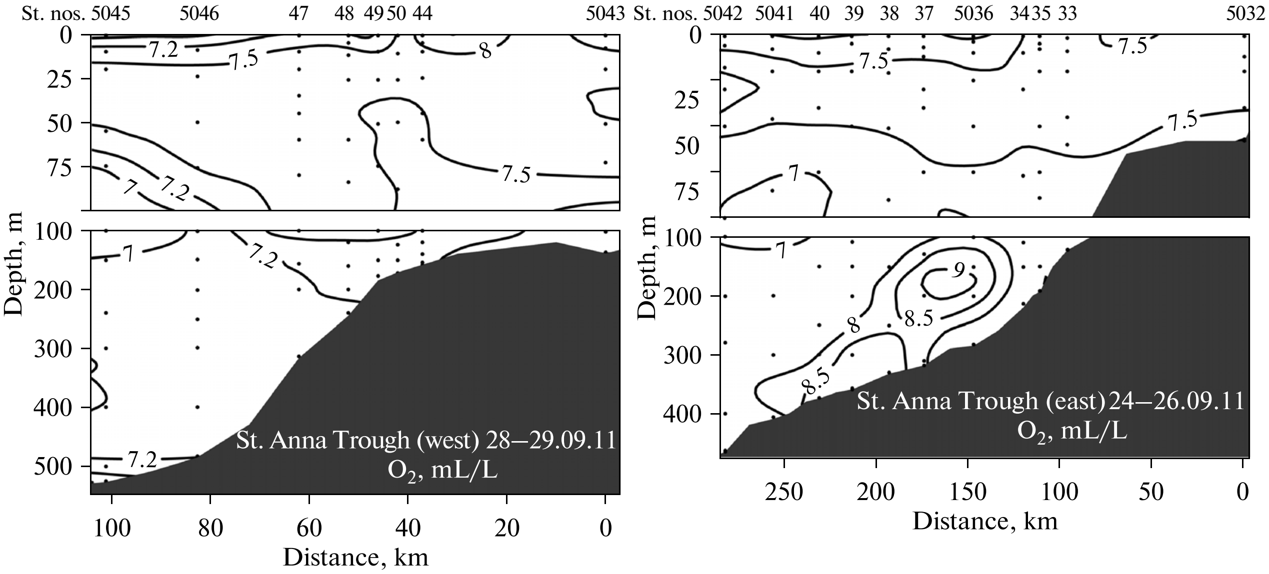

Fig. 5. Distribution of dissolved oxygen (mL/L) in the sections along the western and eastern branches of the St. Anna Trough.

centrations of dissolved phosphorus and silicon increased as well (Figs. 6 and 7). Conversely, the content of nitrate nitrogen decreased in surface waters at these stations (Fig. 8). The influence on the hydrochemical structure of waters by those flowing down from shallow areas is quite typical for the waters of the Arctic Basin, especially during the season of the beginning of the water cooling at the shelf. In low-gradient waters, this has resulted in the formation of a specific layered structure of the distribution of hydrochemical parameters.

The influence of continental runoff in surface waters was traced in the southern part of the both sections (stations 5032 in the eastern and 5043 in the western section). However, whereas the eastern section was characterized by waters of a relatively low silicon content, as well as of minute pH values and small amounts of dissolved inorganic carbon, surface waters in the western section showed high concentrations of dissolved silicon along with a moderate decrease of total alkalinity value and of the content of total dissolved inorganic carbon. The values of other hydrochemical parameters in the western section were nearly unaffected by the continental runoff. It is probable that the different carbon–silicon ratios in these waters result from their formation, involving continental waters of various origins.

At the same time, both sections showed many similar features. First, here is an interesting peculiarity of the distribution of oxygen. The layer of 20–30 m is characterized by the water supersaturation in oxygen at nearly all the stations of both sections. Whereas the saturation degree on the surface amounted to about 90%, the mentioned layer shows a relative oxygen content of 100–105% and over (109% maximum value). This layer was located a little deeper than the halocline. The appearance of this layer is most probably related to the fact that the considerable water masses supplied with the flood in spring overlapped the surface seawaters in which intense spring bloom occurred that time. The contact of these waters and the atmosphere had ceased and the contained oxygen was, as it

Table 2. Average values and ranges of registered hydrological and hydrochemical parameters in the sections at the western and eastern branches of the St. Anna Trough on September 24–29, 2011

Parameter	Surface layer	Layer of temperature minimum	Intermediate waters	Deep waters
St. Anna Trough, eastern branch				
Layer, m	6 0–20	150 40–280	100–200	200–466
Temperature	3.68 −1.35–4.81	−0.85 −1.68º–0.39	−0.34 −1.12–1.55	−0.33 −0.8–0.49
Salinity	31.290 27.270–33.575	34.643 33.744–34.850	34.784 34.408–34.895	34.919 34.849–34.950
Oxygen, mL/L	7.45 6.54–10.78	7.58 7.20–10.56	7.59 6.71–10.56	7.73 6.94–10.30
Oxygen, %	97.5 86.9–105.2	88.5 86.5–89.8	88.2 82.1–91.0	88.9 84.9–92.1
pH value, NBS units	8.06 7.90–8.14	7.98 7.93–8.06	7.99 7.92–8.06	7.96 7.92–8.02
Alkalinity, mg-equiv/L	2.181 0.539–2.338	2.389 2.354–2.410	2.394 2.378–2.410	2.397 2.386–2.410
Phosphorus, μg-atom/L	0.10 0.03–0.29	0.69 0.47–1.03	0.70 0.54–1.03	0.81 0.71–1.01
Total phosphorus, μg-atom/L	0.36 0.16–0.75	0.92 0.77–1.16	0.92 0.75–1.16	0.94 0.82–1.07
Silicon, μg-atom/L	1.92 0.09–8.21	4.53 2.80–6.97	3.97 2.04–6.97	5.48 3.56–6.69
Ammonium nitrogen, μg-atom/L	0.66 0.36–1.46	0.82 0.36–2.48	1.21 0.42–2.48	0.75 0.36–1.67
Nitrate nitrogen, μg-atom/L	0.15 0.00–0.69	9.62 5.76–12.48	9.94 6.57–12.95	12.77 10.94–14.06
Nitrite nitrogen, μg-atom/L	0.03 0.00–0.06	0.08 0.02–0.15	0.11 0.07–0.20	0.04 0.01–0.11
Total nitrogen, μg-atom/L	12.03 9.59–19.08	17.64 15.49–19.21	20.33 18.23–23.86	28.75
Inorganic carbon, mg/L	24.80 5.92–26.69	27.64 27.19–27.92	27.63 27.19–28.02	27.78 27.39–28.02
St. Anna Trough, western branch				
Layer, m	6 0–20	152 73–240	100–200	200–528
Temperature	3.88 2.59–6.55	−0.70 −1.46º–0.15	0.11 −1.19–2.52	−0.25 −0.63–0.06
Salinity	30.950 19.850–33.855	34.608 34.250–34.894	34.702 34.386–34.894	34.924 34.828–34.966
Oxygen, mL/L	7.50 6.67–9.40	7.31 7.14–7.71	7.22 6.86–7.71	7.21 7.04–7.79
Oxygen, %	98.1 87.6–107.1	88.9 87.1–91.6	89.6 83.9–99.8	88.9 87.5–95.4

Table 2. (Contd.)

Parameter	Surface layer	Layer of temperature minimum	Intermediate waters	Deep waters
pH value, NBS units	8.09 7.97–8.16	8.01 7.95–8.08	8.02 7.95–8.12	8.00 7.96–8.04
Alkalinity, mg-equiv/L	2.207 1.720–2.374	2.386 2.354–2.402	2.392 2.378–2.410	2.399 2.378–2.410
Phosphorus, μg-atom/L	0.13 0.05–0.23	0.63 0.27–0.79	0.64 0.20–0.83	0.81 0.68–0.90
Total phosphorus, μg-atom/L	0.37 0.23–0.45	0.97 0.91–1.00	0.86 0.50–1.00	0.99 0.84–1.09
Silicon, μg-atom/L	6.68 0.95–30.6	4.25 1.04–5.98	4.20 1.23–7.78	5.51 3.89–7.07
Ammonium nitrogen, μg-atom/L	1.03 0.57–2.00	1.24 0.69–2.15	1.26 0.57–2.30	0.73 0.48–1.79
Nitrate nitrogen, μg-atom/L	0.27 0.00–0.83	7.43 2.59–10.62	8.21 2.08–13.99	12.10 9.43–15.23
Nitrite nitrogen, μg-atom/L	0.05 0.02–0.08	0.09 0.04–0.20	0.09 0.03–0.17	0.05 0.02–0.14
Total nitrogen, μg-atom/L	15.69 6.11–51.56	21.96 20.90–23.02	20.26 5.99–27.42	22.28 14.21–31.68
Inorganic carbon, mg/L	25.45 23.33–26.67	27.48 26.87–27.84	27.44 26.68–27.85	27.64 27.36–27.87

were, conserved. A similar effect was registered at several stations during the 54th cruise of the RV *Akademik Mstislav Keldysh*; this effect was described and explained by Stunzhas [5]. However, whereas this effect took place at individual stations in 2007, the occurrence of the subsurface layer of increased oxygen content was registered in 2011 at most of the stations in the open part of the sea.

Another similar feature of the both sections is the occurrence of the nitrite maximum in the layer of 50–

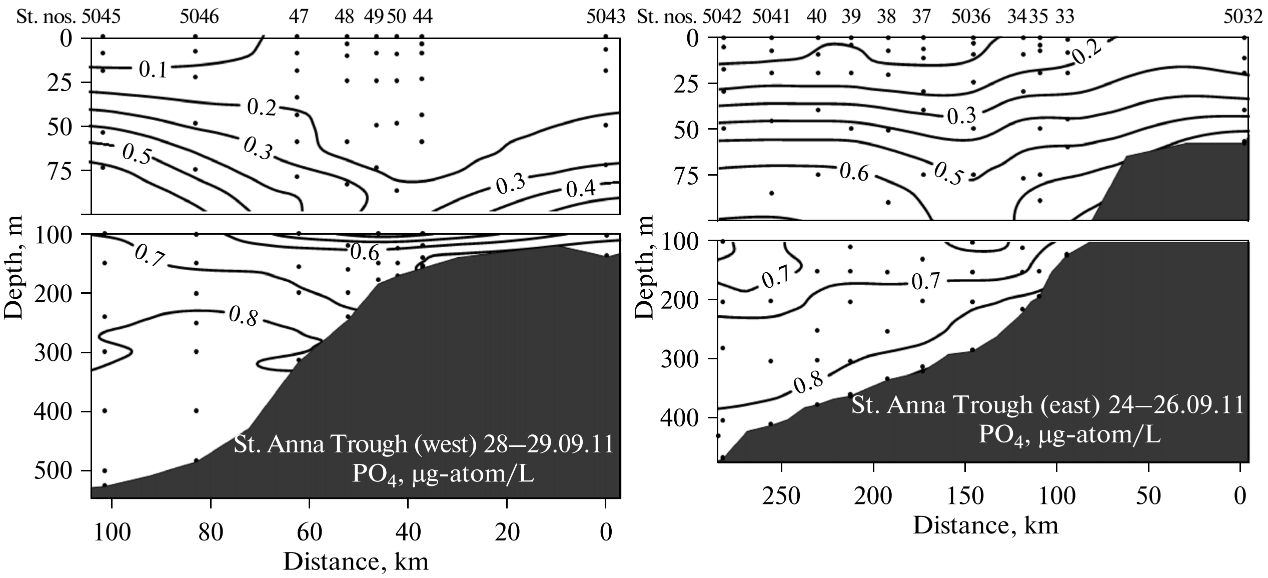

Fig. 6. Distribution of dissolved inorganic phosphorus (μg-atom/L) in the sections along the western and eastern branches of the St. Anna Trough.

Table 3. Average values and ranges of the registered hydrological and hydrochemical parameters in the section across the Novozemel'skii Trough on November 3, 2011

Parameter	Surface layer	Layer of temperature minimum	Intermediate waters	Deep waters
Layer, m	0–20	70–100	100–200	200–311
Temperature	7.06 5.57–8.39	−1.40 −1.55º–1.19	−0.99 −1.34º–0.03	−1.44 −1.62º–1.34
Salinity	31.897 30.117–33.550	34.397 34.328–34.478	34.544 34.476–34.614	34.645 34.601–34.708
Oxygen, mL/L	6.94 6.76–7.27	7.42 7.26–7.53	7.06 6.85–7.51	6.64 6.46–6.97
Oxygen, %	100.6 97.6–104.7	88.4 86.8–89.7	85.2 82.0–92.8	79.1 77.0–83.3
pH value, NBS units	8.02 8.01–8.04	7.94 7.93–7.96	7.93 7.89–7.99	7.89 7.87–7.93
Alkalinity, mg-equiv/L	2.245 2.147–2.346	2.392 2.386–2.402	2.398 2.378–2.410	2.404 2.394–2.410
Phosphorus, μg-atom/L	0.15 0.04–0.68	0.78 0.61–1.03	0.78 0.55–0.94	0.93 0.91–0.94
Silicon, μg-atom/L	2.12 0.33–5.17	4.04 3.27–4.64	5.85 2.32–7.16	9.75 7.16–12.33
Ammonium nitrogen, μg-atom/L	1.05 0.49–2.15	0.97 0.62–1.34	1.41 0.80–2.18	0.93 0.80–1.10
Nitrate nitrogen, μg-atom/L	0.05 0.00–0.19	8.45 7.89–9.09	8.75 4.17–11.8	8.72 7.86–9.74
Nitrite nitrogen, μg-atom/L	0.03 0.02–0.05	0.04 0.02–0.07	0.08 0.03–0.20	0.06 0.03–0.13
Inorganic carbon, mg/L	25.48 24.45–26.66	27.89 27.81–28.05	27.97 27.53–28.13	28.23 28.13–28.38

100 m (Fig. 9). This layer showed also an increased content of ammonium nitrogen. Deeper in the layer of 100–200 m in the seaward parts of the sections, the content of nitrate nitrogen increased. Such a distribution of the forms of dissolved nitrogen may be caused by the intense processes of oxidation of organic matter supplied from the surface layer during spring–summer bloom in the layer of 50–100 m.

The distribution of hydrochemical parameters in near-bottom waters of the sections along the trough branches is different from that in the Yenisei section. Whereas the near-bottom layer of the riverine section was characterized by the leveling of hydrochemical parameters by the current, and no vertical gradients were seen for the concentrations of dissolved silicon and phosphorus, as well as for the total alkalinity value, the stations in the trough showed quite a regular increase of these parameters in the near-bottom layer. Among five stations at which the surveys in the near-bottom layer were carried out, the oxygen content in the 10-cm layer over the sediment increased by 0.1–0.2 mL/L at two stations (nos. 5033 and 5039). Other stations showed in this layer a decrease of oxygen content by 0.2–0.5 mL/L.

Novozemel'skii section. Surveys at the section were carried out on November 3, 2011 at stations 5055–5060 (Table 3). Similarly to the sections along the branches of the St. Anna Trough, a water layer of increased content of dissolved oxygen was registered. The most probable origin of this layer is considered above. Below this layer, the content of dissolved oxygen and the degree of its saturation decrease uniformly with depth (Fig. 10). The value of total alkalinity and the content of dissolved inorganic phosphorus (Figs. 11 and 12) increase uniformly from the surface to the bottom. As for the content of dissolved oxygen, isolines were inclined to the eastern part of the section.

The content of dissolved silicon in the upper layer of the waters was low. The concentrations amounted to 0.3–3 μg-atom/L in the 50-m surface layer (Fig. 13).

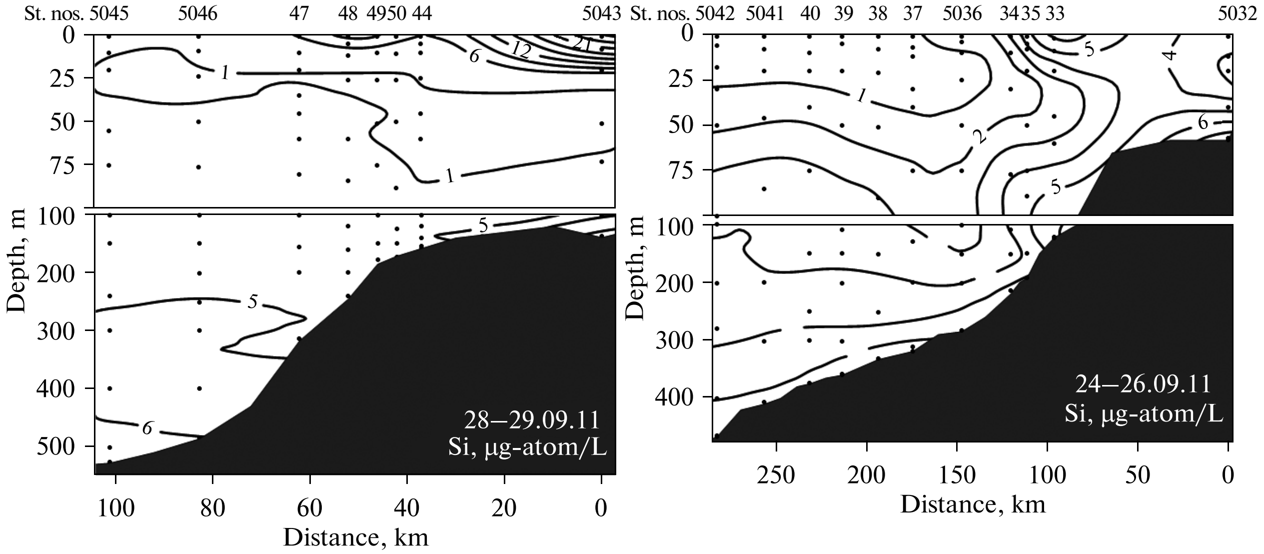

Fig. 7. Distribution of dissolved silicon (μg-atom/L) in the sections along the western and eastern branches of the St. Anna Trough.

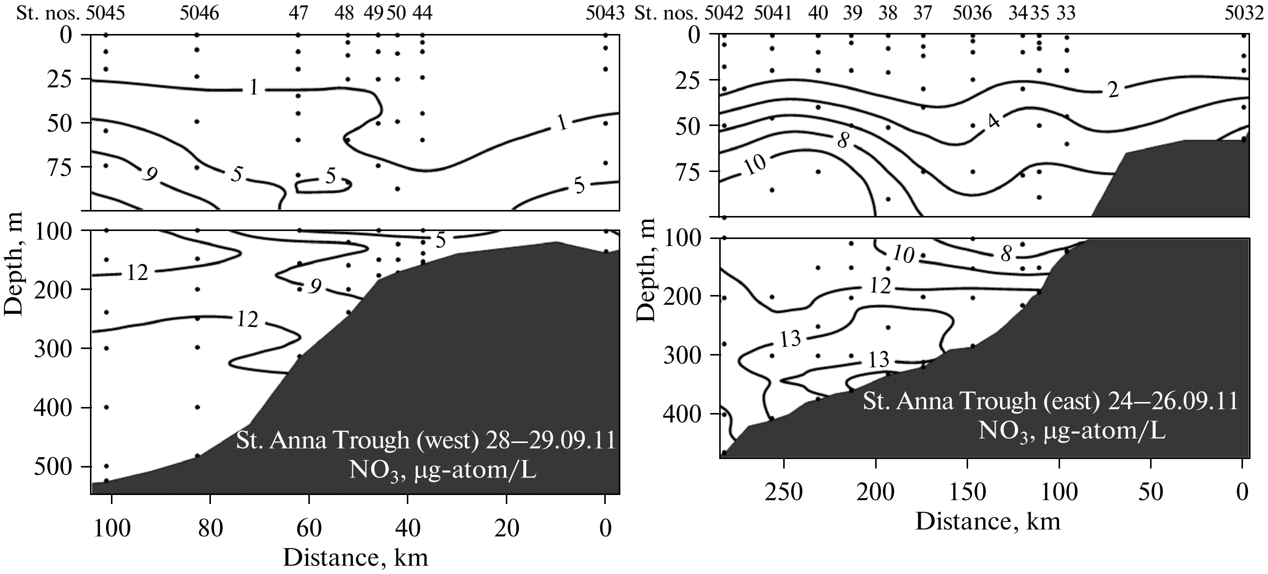

Fig. 8. Distribution of nitrate nitrogen (μg-atom/L) in the sections along the western and eastern branches of the St. Anna Trough.

The content of dissolved silicon increased to 5 μg-atom/L just at the surface in the east of the section under the impact of the runoff from the Novaya Zemlya Islands. This is caused by the fact that the silicon resource was quite completely utilized by phytoplankton during the spring–summer bloom. The influence of continental runoff (the main source of silicon) was minor in this section, and the supply of silicon from deep-seated layers under the autumn intensification of mixing had not yet begun.

The distribution of various forms of dissolved nitrogen (nitrite, nitrate, and ammonium) is more complicated than that of other hydrochemical parameters. The maxima of nitrite and ammonium nitrogen were found in the layer about 50 m depth. This was most pronounced at the eastern and western peripheries of the section. The highest concentrations of these forms of nitrogen were registered in this layer at the eastern part of the section. The distribution of nitrate nitrogen over the section was characterized by a maximum in the layer of about 150 m depth. This maximum was more pronounced in the western part of the section (Fig. 14). Considering the distribution of hydrochemical parameters in the upper layer of waters (from the surface to the halocline) in the Novozemel'skii section, one may see that the concentrations of dissolved nitrogen and phos-

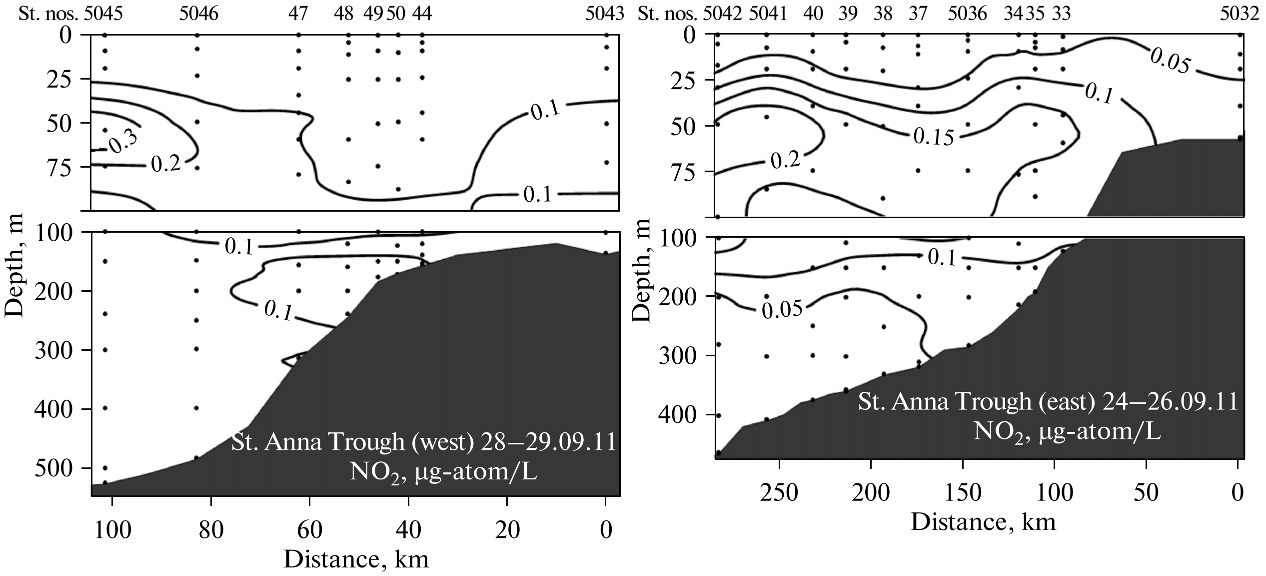

Fig. 9. Distribution of nitrite nitrogen (μg-atom/L) in the sections along the western and eastern branches of the St. Anna Trough.

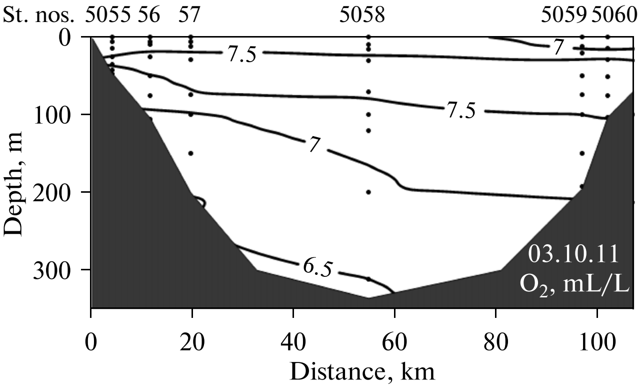

Fig. 10. Distribution of dissolved oxygen (mL/L) in the Novozemel'skii section.

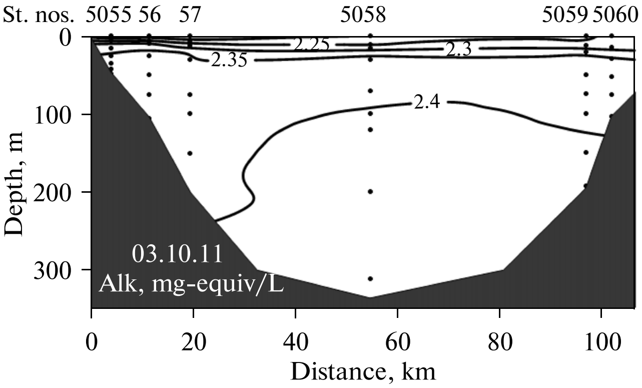

Fig. 11. Distribution of total alkalinity values (mg-equiv/L) in the Novozemel'skii section.

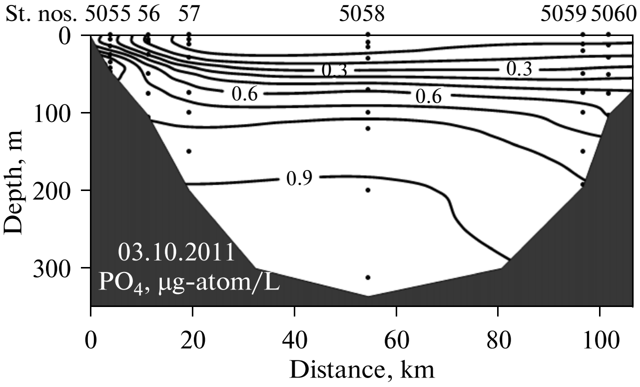

Fig. 12. Distribution of dissolved inorganic phosphorus (μg-atom/L) in the Novozemel'skii section.

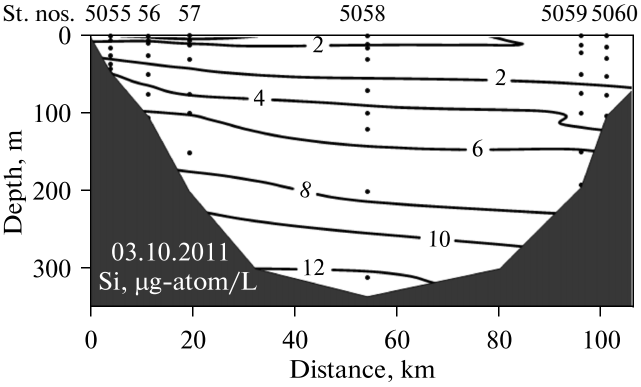

Fig. 13. Distribution of dissolved silicon (μg-atom/L) in the Novozemel'skii section.

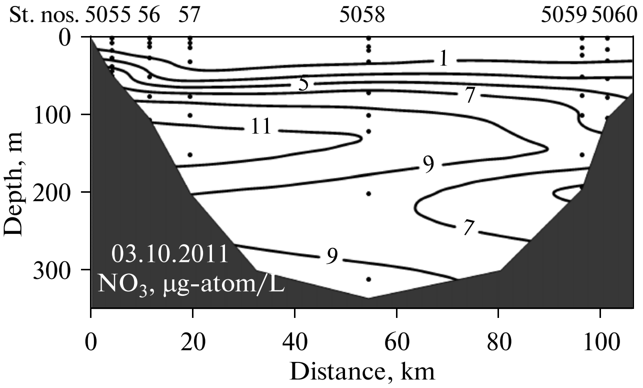

Fig. 14. Distribution of nitrate nitrogen (µg-atom/L) in the Novozemel'skii section.

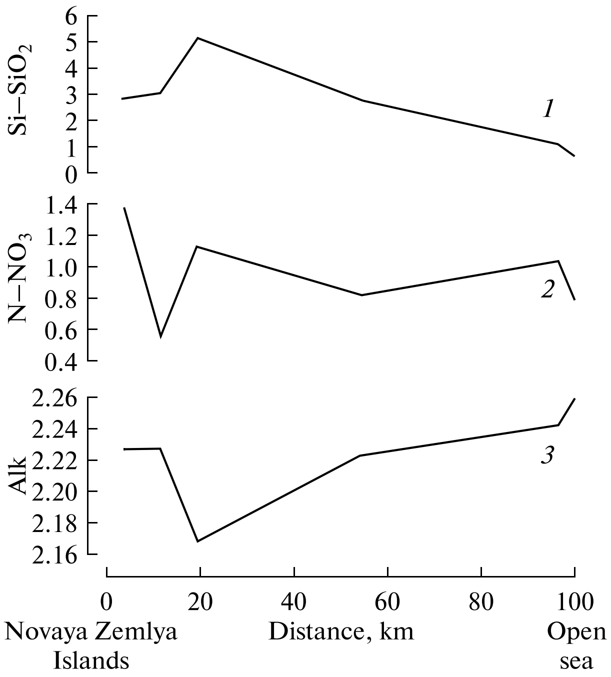

Fig. 15. Variability of concentrations in the upper 10-m water layer of the Novozemel'skii section: *1*—dissolved inorganic silicon (µg-atom/L); *2*—sum of nitrate and nitrite nitrogen (µg-atom/L); *3*—total alkalinity value (mg-equiv/L).

phorus, as well as the value of total alkalinity increase and the content of dissolved silicon decreases notably near the coasts of the Novaya Zemlya Islands (Fig. 15). The same view was seen in the surface waters in the section across the Novozemel'skii Trough in 2007. Study [7] has shown that the aleuropelite schists constituting the coasts might be the sources of nitrogen and phosphorus. Similar to 2007, the impact of the runoff from the Novaya Zemlya Islands on the hydrochemical structure of the upper layer of seawaters was traced for over 10 km from the coast.

CONCLUSIONS

The distribution of hydrochemical parameters in the central part of the Kara Sea and in the north of the Yenisei Gulf (the content of oxygen and basic nutrients) was within the long-term average values for a given season. The amount of nutrients (mainly of phosphates and nitrate nitrogen) in the surface waters decreased during the surveys almost to analytical zero. The content of phosphates was not as low as the value limiting the development of phytoplankton. However, the concentrations of nitrate nitrogen in the upper water layers of the marine sections were often below the detection limit. Evidently, nitrogen for the development of phytoplankton was produced by the recycling of nutrients and/or by the utilization of other forms of nitrogen (e.g. of nitrites or ammonium), which is quite typical for the high-latitudinal seas. As would be expected, seawater was well aerated and the oxygen content, as well as pH values, remained quite high even in the deepwater parts of the troughs.

Comparing the results obtained in this expedition to former studies, one may note an interesting feature. Relatively to preceding years, the influence of continental runoff on the hydrochemical conditions of the region increased. This is also resulted in the fact that quite a stable northward displacement of the contact (mixing) zone of marine and riverine waters almost for 100 km has been registered since 1993 both in the Ob Bay and in the Yenisei Gulf. Saline water recedes every year to the north, replaced by riverine water. The annual runoff of Siberian rivers has shown a pronounced trend to increase from the 1930s to the early 1990s against the background of wide interannual variations [11].

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