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WATER QUALITY AND PROTECTION: ENVIRONMENTAL ASPECTS

Hydrocarbons of Bottom Sediments at the Shtokman Field in the Barents Sea

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Abstract—Hydrocarbon samples taken from bottom sediments of the Barents Sea in summer 2010 in two grounds near the Shtokman Gas Condensate Field were studied. The concentration of hydrocarbons was found to increase with sampling depth along with a decrease in C_{org} concentration. The composition of alkanes had mixed genesis: autochthonous homologues (n-C_{16}–C_{17}) dominated in the low-molecular domain, while oil ones dominated in the high-molecular domain; light polyarenes dominated in the composition of polycyclic aromatic hydrocarbons. The seepage of hydrocarbons from the sedimentary stratum and their transformation in the surface layer of bottom sediments are considered as their major source. The relatively low hydrocarbon concentrations converted to dry mass and in the composition of C_{org} are supposed to be due to a decrease in the intensity of fluid flows, since the hydrocarbon reservoirs of the Shtokman Field are firmly capped by an impermeable stratum of mostly clay rocks.

Keywords: aliphatic hydrocarbons, polycyclic aromatic hydrocarbons, alkanes, bottom sediments, field, pockmarks, fluid flows

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INTRODUCTION

The keen interest to studying hydrocarbons (HC) in Arctic seas is largely due to the huge oil-and-gas potential of the shelf and the development perspectives of its fields. Eleven oil and gas fields have been discovered in the water area of the Barents Sea alone. The resources of the Barents Sea are estimated at 998.1 million t of liquid HC and 23540.8 billion m^3 of gas, accounting for 28.1 and 90.4% of Arctic shelf resources [3]. The increasing volumes of extraction, production, and transportation of oil products increases the anthropogenic load onto the environment. Therefore, the commissioning of the *Prirazlomnaya* ice-resistant offshore platform and the accompanying oil transportation routes can affect the ecology of the shelf area in the Barents Sea.

A major source of anthropogenic HC in the Barents Sea is Atlantic water arriving from industrial regions of Europe, the United States, and water areas with oil production and active navigation [16], i.e., various anthropogenic compounds are "discharged" into the sea [6]. However, the available survey data show no considerable pollution of the sea, and extremely high HC concentration were recorded at a few sites in local coastal zones [3]. The mosaic character of HC distribution is largely determined by hydrological processes—the redistribution of Atlantic waters over the water area.

To determine the levels and composition of HC in the bottom sediments (BS) of the southeastern Barents Sea, samples were taken in August 2010 (the 57th voyage of r/v *Akademik Mstislav Keldysh*) in the area of the Shtokman gas-condensate field (ShGCF) (Fig. 1). Test ground 1 is situated in the water area where funnel-like cavities were found on the seabed (Fig. 1a). Their formation can be attributed to either the melting of buried ice (potholes) or seepage of gas from sediments (pockmarks) [18, 27]. Test ground 2 is situated within the water area of the field (Fig. 1b).

METHODS OF STUDIES

BS were sampled by a boxcorer and frozen at –18°C. In the laboratory, the samples were defrozen, dried at 50°C, after which the fraction of 0.25 mm was sieved out. HC were extracted by methylene chloride in a "Sapfir" ultrasonic bath at 30°C. HC concentration was determined by IR-spectrophotometry by "IRAffinity-1" (Shimadzu). GSO 7554-99 was used as a standard (oil product composition in CCl_4). This method, in the equivalent of the standard used, was accepted as arbitration one in the analysis of oil HC (OH) [8]. HC concentrations were converted into C_{org} concentrations with the use of coefficient 0.86 [9]. The concentration and composition of polycyclic aromatic hydrocarbons (PAH) were determined by high-performance liquid chromatography on a chromatograph (Lab Alliance), equipped with Diasfer column

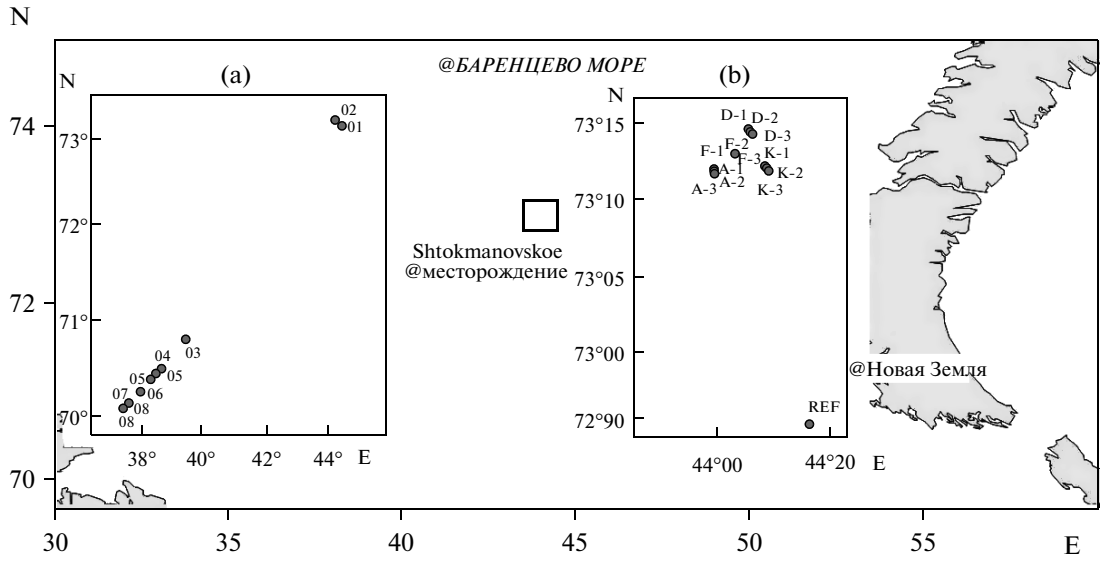

Fig. 1. Layout of stations in the southeastern Barents Sea: (a) Test ground 1 with funnel-like caverns on the bed; (b) Test ground 2 near the ShGCF.

(BioKhimMak). The standards were mixtures of individual PAH (Supelco). The composition of alkanes was determined on a gas–liquid chromatograph with a 30-m column and liquid phase ZB-5 (Intersmat GC 121-2), equipped with a flame-ionization detector with temperature programmed from 100 to 320°C at a rate of 8 deg/min. The methodological procedures are described in detail in [10, 11]/

RESULTS AND DISCUSSION

BS at Test ground 1 consisted of brown-gray pelite–aleurite or sand-containing silts on the surface, passing, with the burial depth, into greenish-gray silt with no hydrogen sulfide smell (except for St. 6) (Table 1). BS mass was found to contain black lumps, sometimes containing hydrotroilite. BS section shows tubular-worm channels and remains. At some stations (St. 7), debris of various metamorphic rocks were found (from fine gravel to gravel, from light to dark) with different roundness.

Visually, the BS could be divided into three layers, which reflect three main stages of postglacial sedimentogenesis [15]. At the early stage, Holocene BS formed, showing the predominance of pelite fraction formed due to fine products of glacier melting supplied to the basin. The second stage corresponds to the time of Atlantic climatic optimum with its maximal transgression level, active shore abrasion, and increasing role of sand–aleurite fraction. The third stage—the deposition of modern Late Holocene BS—falls on the subboreal–subatlantic period of basin regression, corresponding to an increase in the amount of pelite particles because of the stabilization of the rate of shore abrasion, supplying coarse-grained material.

The concentration of C_{org} in BS varied from 0.38 to 1.938% (Table 1). Its mean concentration was 1.135 in the surface layer and 0.845% in the bottom layer. At nearly all stations (except for St. 2), its concentration, as well as BS moisture content, as usually, decreased with burying depth. A dependence with a high correlation coefficient was found to exist between C_{org} distribution and BS moisture content: $r(MC–C_{org}) = 0.89$ ($n = 27$). Conversely, HC concentrations, which varied from 4.4 to 88.6 μg/g, increased with burying depth (Table 1). In the surface horizon, their concentration averaged 11.2 μg/g (with standard deviation $\sigma = 7.4$, $n = 13$), while in the bottom horizon, it was 34.1 μg/g ($\sigma = 25.6$ μg/g, $n = 14$). At stations 1 and 5, their concentrations differed almost 9 times. The share of HC in C_{org} in the bottom horizon was, on the average, 4.4 times greater than that in the top horizon (0.1 and 0.44%, respectively). The maximal value (1.62% of C_{org}) was recorded at St. 3 (Fig. 3). This sediment showed the presence of caverns from which supposedly, gas was released. Test ground 1 featured a complete absence of correlation between HC distribution, BS moisture content, and C_{org}: $r(MC–HC) = –0.30$, $r(C_{org}–HC) = –0.09$.

The origin of HC determines the composition of alkanes. The alkanes in oils have a uniform distribution of homologues and the ratio of odd to even compounds in the high-molecular domain—the oddnes index CPI ≈ 1 [11, 19, 31]. Autochthonous alkanes typically have peaks in low-molecular domain. Dominating in the composition of alkanes of phytoplankton and phytobenthos are mostly n-C_{17}, and sometimes, homologues n-C_{15} and n-C_{19}, which account for more than 90% of all alkanes [20]. Bacterial transformation of OM in the low-molecular part of chromatograms of

Table 1. Organic matter content of BS at Test ground 1 (the samples were taken in caverns, asterisks (*) mean nearby background area)

Station	Horizon, cm	Moisture content, %	C_{org}, %	HC, μg/g	HC, % C_{org}
1	0–5	49.92	1.938	7.14	0.03
	12–17	45.22	1.748	63.53	0.31
2	0–5	43.14	1.524	17.87	0.10
	12–17	43.40	1.749	32.86	0.16
3	0–5	33.80	1.357	32.84	0.20
	20–25	25.01	0.453	79.76	1.62
3*	0–5	45.44	1.404	9.10	0.05
	20–25	27.17	0.544	58.83	0.93
4	0–5	35.98	1.165	8.41	0.06
	15–20	32.82	0.843	22.94	0.24
4*	0–5	43.52	1.182	10.85	0.08
	15–20	34.45	0.953	16.60	0.14
5	0–5	41.02	1.259	9.47	0.06
	14–19	30.87	0.807	84.62	0.90
5*	0–5	38.35	1.221	13.17	0.09
	15–20	31.15	0.849	24.59	0.24
6	0–5	43.55	1.195	4.56	0.06
	14–19	32.50	0.880	7.78	0.04
6*	0–5	41.13	1.105	7.58	0.06
	14–19	35.79	1.006	8.91	0.08
7	0–5	30.09	0.548	18.58	0.25
	9–14	31.45	0.389	11.51	0.28
7*	9–14	23.58	0.654	21.12	0.30
8	0–5	34.33	0.544	4.44	0.07
	10–15	24.01	0.415	25.92	0.52
8*	0–5	31.12	0.456	5.55	0.10
	10–15	24.56	0.380	14.78	0.32

alkanes results in the formation of even alkanes n-C_{16}–C_{18} with concentration comparable with odd alkanes [26]. Therefore, the ratio of odd to even alkanes with chain length $<C_{22}$ (in the low-molecular domain CPI<1) can serve as an indicator of the rate of HC transformation by microorganisms. Terrestrial vegetation shows the predominance of high-molecular odd alkanes (n-C_{25}–C_{31}) [11, 31], and for allochthonous organic matter (OM) in the high-molecular domain, CPI > 1. This type of alkanes is most widespread in marine BS [11], since odd homologues are more stable than even ones, and, in the case of OM transformation, their role increases.

The distribution of alkanes in Test ground 1 in the bottom and top BS layers showed some difference. Almost all examined samples showed no "hump" of naphtheno-aromatic compounds (Fig. 3), i.e., the transformation of HC (especially high-molecular) was not significant. The concentrations of n-alkanes were higher than those of their iso-homologues (pristane and phytane); since the rations n-C_{17}/i-C_{19} and, in the majority of cases, n -C_{18}/i-C_{20}>1, pristane dominated over phytane (i-C_{19}/i-C_{20} > 1) (Table 2), as is typical of biogenic HC [11, 31]. Moreover, in most BO samples, the share of low-molecular HC is higher than that of high-molecular (ΣC_{12}–24/ΣC_{25-35} > 1), suggesting the intensity of autochthonous processes. Dominating in the low-molecular domain, were n-C_{15}–C_{17}, while the maximum in high-molecular domain corresponded to n-C_{24}–C_{26}. Studying the isotopic composition of C_{org} showed that the values of $\delta^{13}C$–C_{carb} in the layer 0–25 cm vary from –1.13 to –6.02‰, as is typical of marine sedimentation and early diagenetic carbonates [7]. At the same time, the uniform distribution of high-molecular homologues (the values of $CPI_{C25-C33}$ were below or slightly above unit) suggested their origin from oil (Fig. 4a). in the surface BS layer, the share of allochthonous homo-

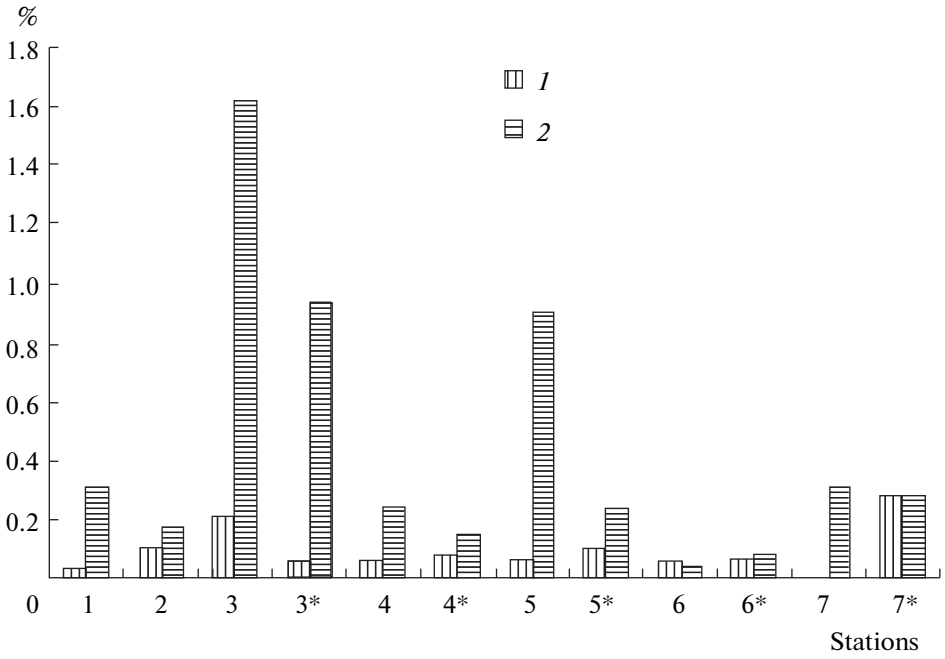

Fig. 2. Variations of HC share in the composition of C_{org} at Test ground 1. (*1*) Top and (*2*) bottom layers in BS column.

logues is higher than that in the bottom layer. In particular, at St. 1, $CPI_{C25-C33}$ was 1.58, while in the bottom layer, it was as little as 0.72 (Table 2).

BS in Test ground 2 are also represented by pelite silt, sometimes, with a small amount of aleurite fractions. Various forms of macrobenthos (worms and their remains) were found on the surface. Visually, the BS column, as well as in Test ground 1, could be divided into 3 parts: a top (0–1 cm) oxidized brown layer, a middle (1–5 cm) dark gray layer with a greenish hue, and a bottom (5–23 cm) layer. The bottom layer differed from the overlying one by a large number of spots with a color varying from dark gray to black and brown, which originate most likely from plant remains. The concentration of C_{org} in BS was higher than that in Test ground 1, varying within 1.61–4.02% (on the average, 2.41%), $\sigma = 0.54$, $n = 13$; the mean in the surface layer was 2.39%, $\sigma = 0.59$. The scatter of data as small as that can suggest the homogeneity of OM in BS. Unlike C_{org}, HC concentration were low, varying in layer 0–1 cm within 6–51 (on the average, 15) μg/kg, $\sigma = 7$, $n = 13$; in layer 1–5 cm, within 4–81 (on the average, 21) μg/g, $\sigma = 14.7$; and in layer 19–23 cm, within 12–83 (on the average, 44) μg/g, $\sigma = 27$. Therefore, HC concentration increased with the burying depth, as was the case with Test ground 1, while the concentrations of C_{org} either remained unchanged or decreased. Therefore, the proportion of HC in the composition of C_{org} increased in BS strata (Fig. 5), as was the case in Test ground 1, and an inverse relationship was found to exist between the HC and C_{org} distributions: $r(C_{org}–HC) = –0.48$. The composition of alkanes also suggests a mixed genesis of HC: autochthonous in the low-molecular domain, and oil in the high-molecular domain (Fig. 4b).

The total PAH concentrations in BS varied within 55–402 ng/g at Test ground 1 and within 4.9–150 ng/g at Test ground 2. Based on these data, we can suppose that BS are weakly polluted by polyarenes, since the sum of 3–6-ringed homologues was mostly <100 ng/g. At permanent input of pollutants, PAH concentrations in BS are commonly in excess of 1000 ng/g, while at concentrations >4000 ng/g, the sediments become toxic [31]. PAH are microcomponents of OM in BS. Their concentrations in oil is also much lower than that of aliphatic HC [24]. The main source of PAH is atmospheric aerosol fallouts [14, 17, 19, 23, 31]. PAH cannot be directly referred to biopaleomarkers, because their direct analogues have not been detected in biota [14, 19]. However, unsubstituted PAH were determined in the marine environment in regions. where the possibility of pollution is excluded [17], i.e., they can also be referred to geochemical background compounds.

In BS of Test ground 2, the mean concentrations of individual polyarenes decreased in the following order, ng/g: fluorene (12.6) > naphthalene (11.7) > phenanthrene (10.3) > chrysene (3.5) > pyrene (3.2) > methylnaphthalene (1.9) > benzperylene (1.7) > benz(a)anthracene (1.6) > indopyrene (1.4) ≈ perylene (1.4) > anthracene (1.2) > benz(a)pyrene (0.8) > dibenz(a)anthracene (0.7) > fluoranthene (0.5) > benz(k) fluoranthene (0.4) > benz(e)pyrene (0.1) (Fig. 6). Their concentrations in BS were almost constant, because the values of σ averaged 7.2% of homologue concentration. PAH are most stable compounds

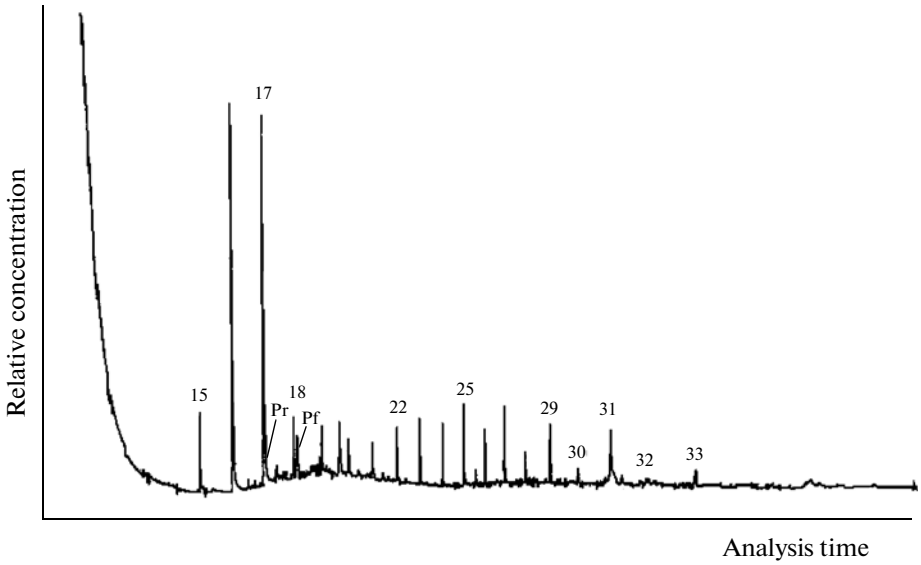

Fig. 3. Typical chromatogram of alkanes isolated from BS (Test ground 1, St. 5).

compared to aliphatic HC. However, their composition is also governed not only by emission sources (pyrogenic compounds form largely in combustion processes [22, 23]), but also by transformation in the marine environment [14, 17, 32]. The high concentrations of naphthalene were surprising, because this arene is most volatile and readily decays in water. In the composition of PAH in BS, naphthalene is commonly a minor component [31]. The ratio naphthalene/methylnaphthalene > 1 (on the average, 6.2) suggested insignificant input of arenes during BS pollution by oil products, since the concentration of methylated homologues in oils is higher [17, 24]. Naphthalene concentration may be determined by its input with fluid flows from BS stratum. As the Shtokman field is gas–condensate, low-molecular polyarenes mostly seep here. Phenanthrene is mostly of natural origin; in relatively clean regions, it forms at OM transformation in the course of diagenesis in BS, rich in humus (a reference point of humus-accumulation process), or during dehydration of steroids by microorganisms [23, 32].

Table 2. Distribution of markers in the composition of BS alkanes at Test ground 1 (dash means none of isomers detected)

Station	Horizon, cm	HC, μg/g	Alkane composition						
			$C_{17}/i\text{-}C_{19}$	$C_{18}/i\text{-}C_{20}$	$i\text{-}C_{19}/i\text{-}C_{20}$	$\Sigma C_{12-24}/\Sigma C_{25-35}$	$CPIC_{13-C24}$	$CPI_{C25-C33}$	dominating peaks
1	0–5	7.14	7.8	1.9	1.1	2.84	1.00	1.58	C_{17}
	12–17	63.53	1.9	2.8	1.4	3.52	0.88	0.72	C_{15}, C_{16}
2	0–5	17.87	2.7	–	–	1.60	0.92	1.31	C_{16}, C_{24}
	12–17	32.06	2.0	0.7	1.3	1.21	0.94	1.19	C_{16}, $C_{24\text{-}26}$
3	0–5	32.84	1.9	0.6	1.2	1.79	0.83	0.73	C_{16}, $C_{24\text{-}26}$
	20–25	79.76	2.6	0.7	1.0	1.78	0.71	0.74	C_{16}, $C_{24\text{-}26}$
4	0–5	8.41	1.9	0.9	0.3	1.69	0.81	0.94	C_{20}, $C_{24\text{-}25}$
	15–20	22.94	2.80	1.0	1.3	1.00	0.84	0.88	C_{20}, $C_{24\text{-}25}$
5	0–5	9.47	3.75	1.75	3.0	13.67	1.23	1.00	C_{16}
	14–19	84.62	4.75	1.50	1.0	1.61	0.82	1.43	C_{16}, C_{24}
7	0–5	18.58	6.18	1.40	1.7	2.23	0.90	1.48	C_{16}, C_{24}
	9–14	11.51	0.90	1.50	5.0	0.98	0.69	1.33	C_{16}, C_{24}
8	0–5	4.44	10.50	1.67	0.7	2.53	1.10	1.83	C_{17}, C_{22}
	10–15	25.92	3.36	1.00	1.6	1.60	0.98	1.26	C_{16}, C_{24}

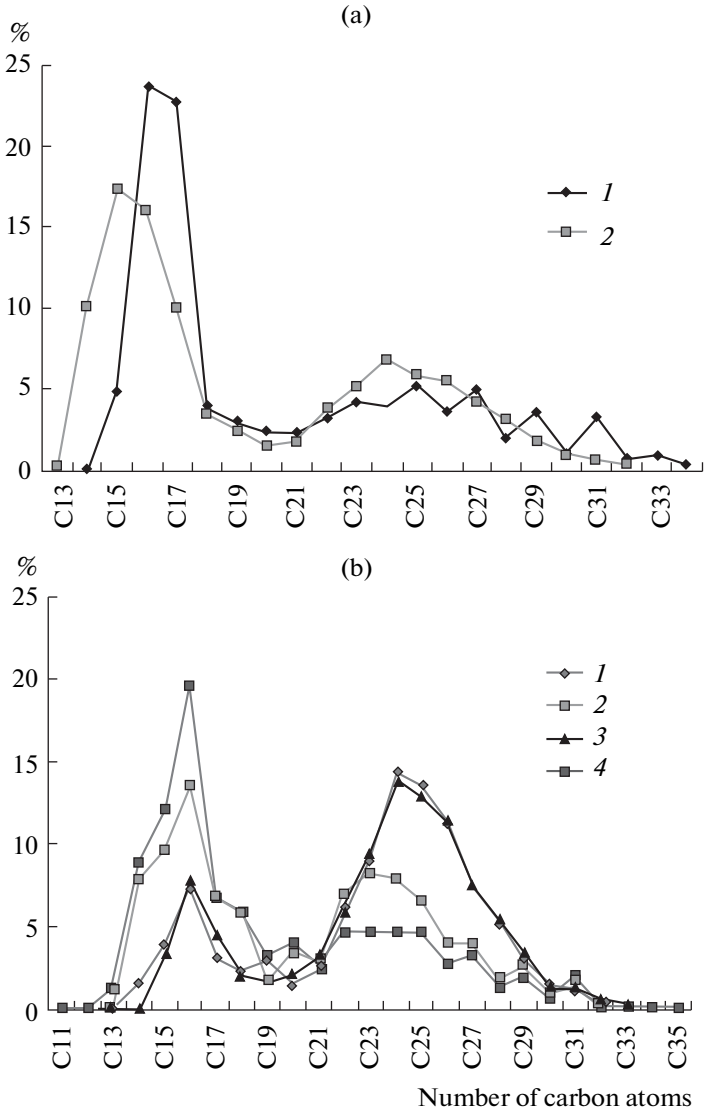

Fig. 4. Distribution of homologues in the composition of alkanes: (a) in (*1*) surface and (*2*) bottom horizons of HS columns at Test ground 1, St. 1; (b) in bottom horizons of BS columns at stations (*1*) A2, (*2*) K-1, (*3*) FPU-1, (*4*) FPU-3.

At direct pyrogenic inputs, the ratio fluoranthene/(fluoranthene + pyrene) < 0.5 [23, 31]. In BS examined by the authors of this article, this ratio averaged 0.67, i.e., the BS can be considered as not polluted by pyrogenic products. This also can be seen from the small value of the anthracene/phenanthrene ratio, which averages 0.12. Those data on PAH composition fit the results of studies of BS in the southeastern Barents Sea, since in 2005, the amount of pyrogenic compounds increased relative to 1991–1998 only in coastal regions [22]. The composition of PAH in pelagic zone showed almost no changes.

A minor component of PAH is benz(a)pyrene (BP), the most carcinogenic among identified polyarenes, its presence may be due to its lower concentration in combustion products compared to pyrene [14]. Moreover, BP readily decomposes in seawater. Model experiments have shown that BP destruction takes place mostly in the surface water layer (53%) of the initial amount per hour) [5]. The microbial destruction of BP in surface seawater amounts to ~400 t/year (~8% of its total input from natural and anthropogenic sources). The increase in PAH concentrations in the subsurface BS layer may be due to their higher emission in the mid-XX century [14, 21].

The obtained results regarding the concentrations of PAH in BS, as well as aliphatic HC, were lower than those obtained before [4m 17, 22]. According to studies of Sevmorgeo, BS in the area of ShGCF in 2000 showed higher PAH concentrations (on the average, 1610 ng/g) compared with other parts of the Barents Sea (on the average, 110 ng/g) [4]. In 2001–2005, PAH concentration in ShGCF area varied within 137–861 ng/g [17, 22]. The increase in PAH concen-

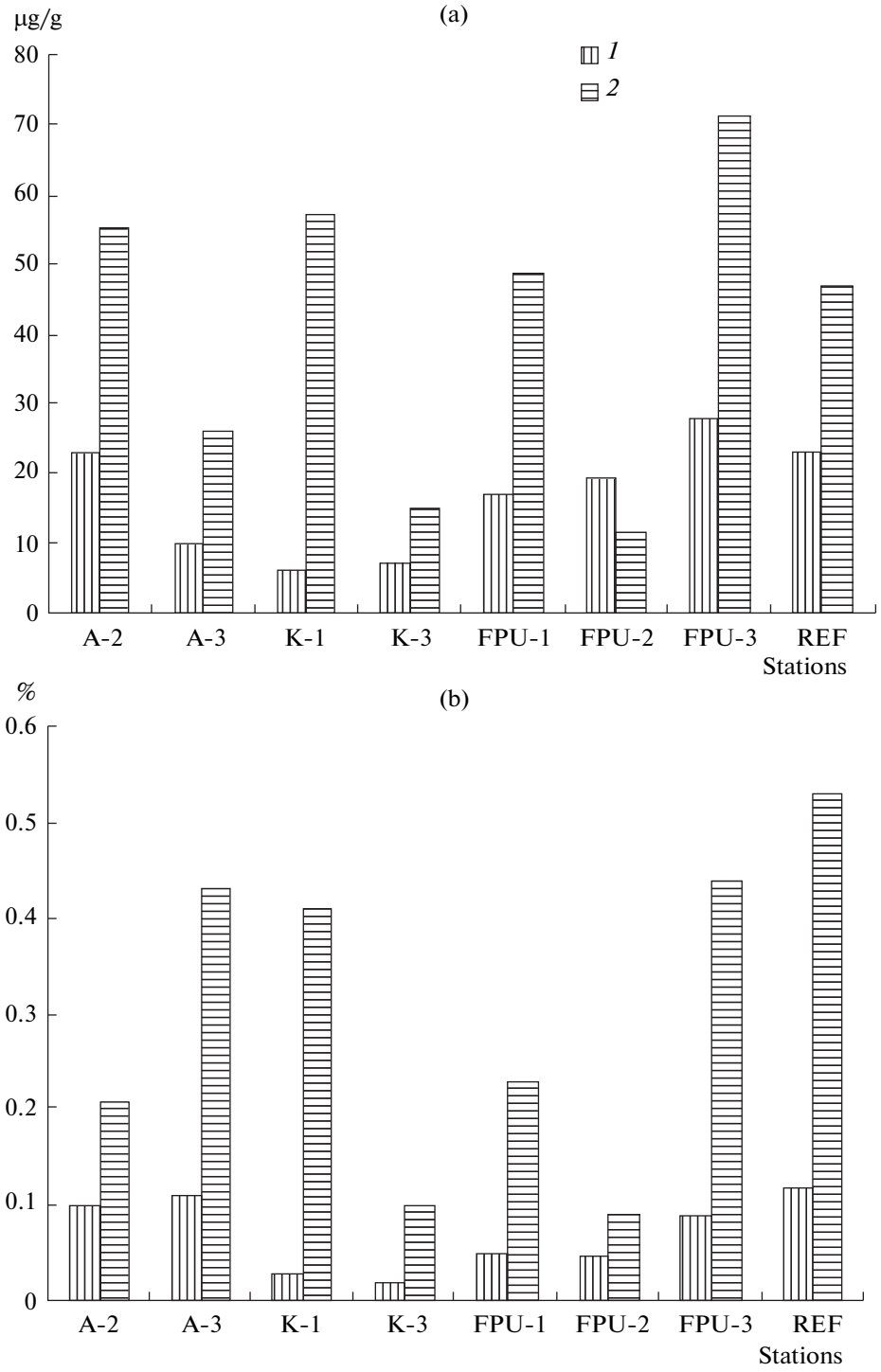

Fig. 5. (a) HC concentration and (b) HC shares in the composition of C_{org} in (*1*) the top and (*2*) bottom layers at Test ground 2.

tration in ShGCF area is attributed to the inflow of fluids from underlying strata [4]. It should be noted that in the case of World Ocean, the main marine source of oil HC (0.6 million t/year, 48% of total input) is the seepage of HC in oil-and-gas water areas [24]. This process involves not more than 10–15% of the total area of the World Ocean: in the marginal and inland seas, where oil-and-gas basins are situated [11]. Oil seepage in the Russian Arctic shelf was described for the first time in the XVI century on a bank in the Ukhta R. in the north of Timan–Pechora District, where tar nodules were found in sand [17]. Later, similar processes were

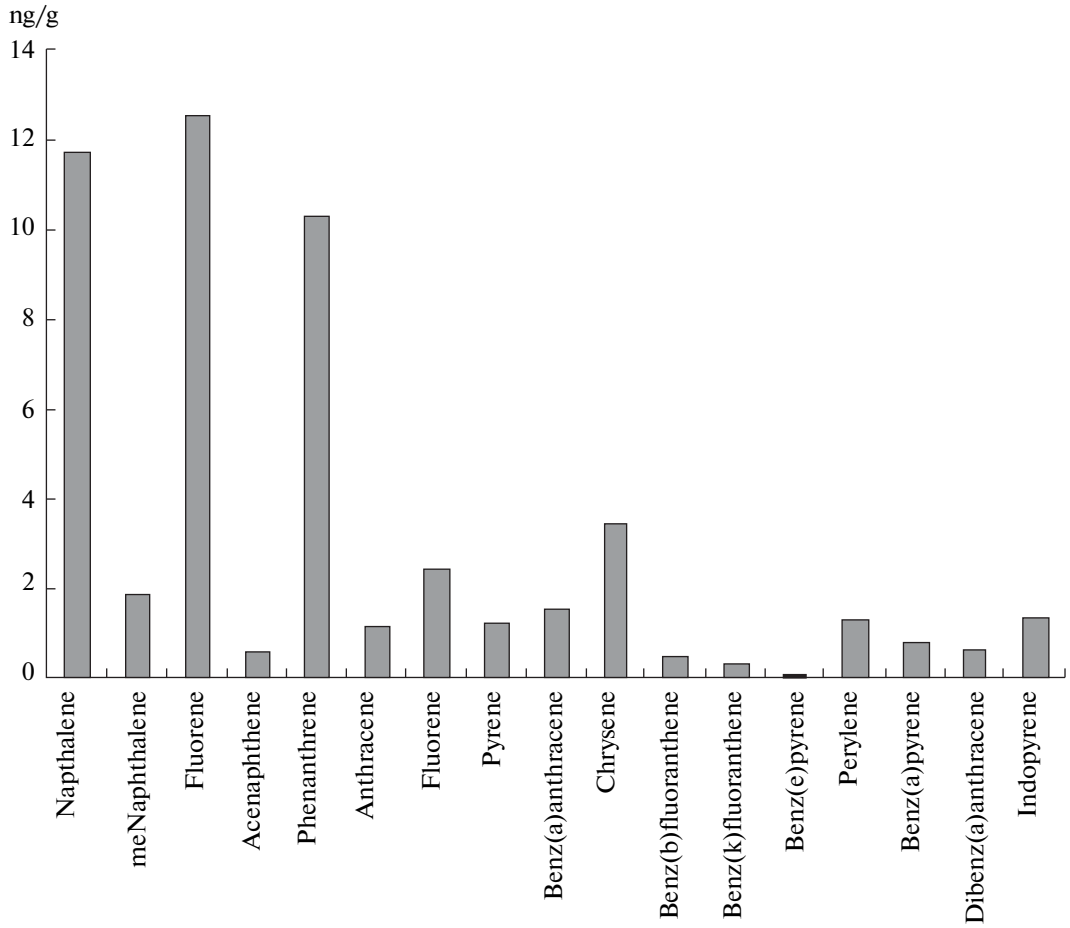

Fig. 6. Averaged composition of PAH in BS at Test ground 2.

recorded in the Chukchi, Bering, Barents, and Kara seas [1, 17, 22, 24]. Considering the high oil-and-gas content of the Russian Arctic shelf, we have to suppose that this natural source accounts for not less than 50% of the total oil input into Arctic seas.

The highest PAH concentrations in Barents Sea BS were recorded in the coastal zone of Spitsbergen Isl.: 2698–6026 ng/g [22]. Dominating in PAH composition here were alkylated homologues of naphthalene and phenanthrene, and the source of polyarenes here was supposed to be the erosion of carbonaceous deposits in the western part of the island [4, 22]. A genetic relationship with the carbon-bearing deposits of Spitsbergen Isl. is also typical of deep-water BS in the water area of Medvezhii Isl. [17], since relatively high PAH concentrations (900–2200 ng/g) were also recorded here with 3-ring homologues dominating in their composition.

In the southwestern Barents Sea, PAH concentrations varied within 27–467 ng/g. Dominating in their composition in coastal regions were pyrogenic compounds: benzfluoranthene, indo(1,2,3–cd)pyrene, and benz(ghi)perylene, suggesting as a sources high-temperature processes of polyarene formation. Compared with 1991–1998, the samples taken in 2001–2005 showed larger amounts of two- and three-ring PAH with oil genesis. The latter may be due to pollution input from the Atlantic and an increase in oil transportation in Barents Sea water [17, 22].

Analysis of the obtained data suggests that the concentrations of HC and PAH in BS in ShGCF region of the Barents Sea in summer 2010 decreased compared with earlier studies. The absence of correlation between the degree of dispersion of BS and its C_{org} and HC content can be attributed to their sources having no genetic relationship with suspension and sedimentation processes. This conclusion also confirms the distribution of molecular markers in the composition of HC and PAH. Depending on the conditions in oil-and-gas horizons and geological structures under seabed, seeps can increase or cease their activity, disappear completely and restore [13]. The general picture of the distribution of discharge sites reveals a very wide and diverse range of the conditions of their development—landscape–morphological, geodynamic, and climatic [2]. Fluid flows of HC due to their seepage via faults and fissures from oil-and-gas-bearing structures and gas-condensate accumulations were detected in

many marine regions. In particular, the rate of oil inflow into the sea from a linear seepage segment ~1.5 km in length in Santa Barbara Strait (the Gulf of Mexico, California) is estimated at 10–15 t/day [30]. The HC fluxes as large as that are due to the small occurrence depth of oil-bearing formations, as well as tectonic and lithological conditions. Because of the poor knowledge about this process, the contribution of HC to those natural discharge from regional (dispersed) fluid flows (formation sources of oil and gas) can be evaluated only approximately [24, 28]. The dynamic life of the entrails of the earth and pulsation of subsurface systems manifest themselves on the surface in the form of various "expulsions" of mobile components onto the bed and coasts of water bodies. The diverse types of natural sources of such discharge were observed at all depths in the Gulf of Mexico, in particular (as proposed in [2]), this was among the causes of the accident at the platform Deepwater Horizon. Emergency breakthroughs from subsurface not only pass through wells, but also occur when seismic–tectonic and other natural forces become more active. Under such conditions, fluid blowouts are not only quite natural, but sometimes, even inevitable, while wells just accelerate their release.

An indication to the local character of seepage processes near ShGCF can be the variability of HC concentrations over ground areas. This may be the cause of the fact that closely located wells on Test ground 1 in some cases showed nearly equal HC concentrations (stations 4 and 6), while in other cases, they were radically different (Table 1). In the surface layer at stations 5 and 5*, the concentrations were similar, while in the bottom horizon, they differ by a factor of 3.4. The latter, as well as the oil composition of high-molecular HC, may suggest their endogenous nature. Noteworthy, both near the Kravtsovskoe Field in the Baltic Sea and in the southeastern Barents Sea, the sediments showed variations of HC concentrations from year to year, higher share of HC in the composition of C_{org}, and an oil composition of alkanes in the high-molecular domain [12].

The existence of several types of systems is supposed, in which HC seepage from BS stratum can take place [28–30]. Commonly, the seeping oil has low chilling point and contains autochthonous HC [17]. The oil near seeps is a strongly reduced source of energy and is prone to microbial oxidation. The result is an increase in the biomass of oil-oxidizing bacteria [13, 25] and an enrichment of the top BS layer with heavy-isotope C_{org} [7]. This may the cause of an increase in microbial homologue n-C_{16} in addition to phytoplankton alkane n-C_{17} (Fig. 5). In this case, the share of homologue n-C_{16} in the surface layer of BS, where OM transformation processes are very intense, is higher than that in the underlying BS horizons and light alkanes dominate in the majority of samples (Table 2).

It is likely, that the low intensity of HC seepage processes has led to a decrease in their concentrations in BS near ShGCF in summer 2010. Therefore, according to data of acoustic profiling, obtained during expedition, no signs of BS saturation with gases (signs of migration of gas-saturated fluids from BS strata) were observed in the areas of occurrence of funnels (Test ground 1). Macroscopic signs of gas saturation were also not found in sections of modern BS from funnel beds. The formation of a cavern, which may have been caused by gas release, was recorded only in one case on a section of BS column.

CONCLUSIONS

BS examined near ShGCF show low HC concentrations, both converted to dry mass and in the composition of C_{org}. The hydrodynamic regime of the Barents Sea, which facilitates the formation of consolidated BS along with the low activation energies in the sedimentary stratum [1] lead to transformation and formation of autochthonous low-molecular alkanes.

The absence of correlation between the concentrations of C_{org} and HC, an increase in the share of HC in the composition of C_{org} with burial depth, as well as the distribution of markers in alkanes can be a sign of the endogenous nature of high-molecular HC. The lateral variability of their concentrations indicates to the local character of those processes. The low intensity of seepage processes has led to a decrease in HC concentrations compared with earlier studies.

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