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Current State of Deep Oil Seepage Near Cape Gorevoi Utes (Central Baikal)

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Abstract—We present data, collected in 2016, on the concentration of *n*-alkanes and polycyclic aromatic hydrocarbons in water and bottom sediments as well as the abundance and composition of the cultured microbial community in the area of the oil seepage near Cape Gorevoi Utes. Since its discovery in 2005, the development dynamics of the oil seepage has demonstrated a decrease in the total concentration of normal hydrocarbons and polycyclic aromatic hydrocarbons in oil slicks and bottom sediments, partial degradation of oil entering the water surface, and an increase and subsequent reduction in the number of microorganisms in water and bottom sediments with the maintained structure of the cultured microbial community. From 2006 to 2016, there was a low total concentration and a narrow range of detected concentrations of *n*-alkanes and polycyclic aromatic hydrocarbons in the water column, which indicates the preservation of water purity in the lake near the oil seepage.

Keywords: natural oil seepages; *n*-alkanes; polycyclic aromatic hydrocarbons; biodegradation; microbial communities; Gorevoi Utes; Lake Baikal

INTRODUCTION

The scientific issue of oil and gas content of Lake Baikal and the Baikal Rift Zone dates back to the 18th century when I.G. Gmelin (1833) described oil seepages along the east coast of Lake Baikal (Kontorovich et al., 2007). In 1902−1903, V.D. Ryazanov recorded numerous gas seepages and signs of oil in the form of films on the water, ozokerite and asphalts along the southeast coast from the Boyarskaya station to the Chivyrkuy Bay (Ryazanov, 1928). In 1931−1962, there was the intensive geological exploration of oil on the territory of Buryatia along the southeast coast of Lake Baikal. In the course of these works, natural oil seepages were studied: at the bottom of Central Baikal from a depth of 10−12 m, 300–500 m from the coast, in the area from Oblom cape to the brooks Klyuchi and Stolovaya. The second group of oil seepages was located opposite the estuaries of the rivers Bolshaya Zelenovskaya and Malaya Zelenovskaya (Kontorovich et al., 2007).

In 2005, based on the satellite data, new oil seepage was discovered in the area of Cape Gorevoi Utes (Central Baikal) (Khlystov et al., 2007). On the water surface with an area of approximately 1 km^2, there were numerous oil slicks with a diameter of up to 1 m. In 2005, the oil collected at the moment of its discharge onto the water surface near Cape Gorevoi Utes was characterized by an extremely high content of *n*-alkanes and was identified as non-biodegraded paraffin oil. The oil contained the whole range of petroleum hydrocarbons: *n*-alkanes, alkyl cyclohexanes, isoprenoids (pristane and phytane), polycyclic aromatic hydrocarbons (PAHs), hopanes, and a complex of unique biomarker molecules (Gorshkov et al., 2006; Kashirtsev et al., 2006; Khlystov et al., 2007; Kontorovich et al., 2007).

In 2008, at bottom sites near the oil discharge area, the divings of the MIR deep-sea manned submersibles led to discoveries of structures made of paraffin oil asphalts seeping oil. In the flat bottom sections with oil accumulations and near the structures, hydrocarbon gases discharged, 99% of which was methane and approximately 1% − its homologues. The characteristics of methane homologues were a high proportion of propane compared to ethane and a high butane content, which is quite unusual for modern Baikal sediments (Khlystov et al., 2009; Kalmychkov et al., 2019).

The amount of oil inflowing to Baikal waters (up to 4 tons/year) is incomparable with the emission volumes of commercial oil into the surface waters of the World Ocean during man-made disasters, such as the destruction of the Deepwater Horizon oil rig in the Gulf of Mexico as well as the accidents of the tankers Prestige and Solar 1 of the coast of Spain and the Philippines, respectively (Khlystov et al., 2007; Kontorovich et al., 2007; Hazen et al., 2010; Vila et al., 2010; Yender and Stanzel, 2011). Pollution with petroleum hydrocarbons takes place only at limited sites in Lake Baikal, which indicates natural mechanisms of the ecosystem that preserve the water purity in the lake under conditions of constant oil emissions, low temperatures and a long period of the complete substitution of its waters by tributar-

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ies (approximately 400 years) (Weiss et al., 1991; Gorshkov et al., 2010a; Pavlova et al., 2012).

The discovery of a new area of oil seepage in 2005 has become a starting point in the study of his genesis, chemical composition of the oil, as well as composition and structure of the microbial community. For a period of more than 10 years since the discovery, the composition of the microbial communities in the water column, bottom sediments and asphalt structures have been studied, the number of microorganisms oxidizing normal hydrocarbons, oil and readily available organic matter has been determined, as well as the content of oil products in the Baikal water and its tributaries (Pavlova et al., 2008a,b; Gorshkov et al., 2010b; Kadnikov et al., 2013; Likhoshvay et al., 2013; Lomakina et al., 2014; Zemskaya et al., 2015).

This study aimed to assess the current state of deep oil seepage near Cape Gorevoi Utes, in particular, to determine the abundance and diversity of the cultured microbial community, the concentration of *n*-alkanes and PAHs in the water and bottom sediments of the studied area.

MATERIALS AND METHODS

The investigations were carried out in 2016 at the site of the natural gas seepage near Cape Gorevoi Utes (10 km from the shore, depth 900 m, Central Baikal; coordinates 53°18′33″N, 108°23′46″E). Oil, water, and bottom sediments were sampled from the board of the RV "G.Yu. Vereshchagin" at three stations: 1) R–4 and R–5 – the site with oil slicks on the surface; 2) R–6 – the site without oil slicks on the surface (Fig. 1). Water was sampled using the bathometer system SBE 32 Carousel Water Sampler from depths of 0, 5, 200, 400, 600, 800 and 860 m. Oil, in the form of oil slicks on the water surface, was sampled using a sterile glass into glass bottles with a volume of 1 dm^3. To study the composition of n-alkanes and polycyclic aromatic hydrocarbons (PAH) in water column water was sampled into glass bottles with a volume of 1 dm^3. Fifty cm^3 of methylene chloride were added to each water sample; the mixture was shaken, corked with aluminium foil padding and kept at + 5 °C until analysis. Bottom sediments were collected at one station (VER–16–01, GC.4) using a gravity corer with a plastic liner (Fig. 1).

Samples for microbiological analysis were taken in sterile vials. The number of cultured hydrocarbon-oxidizing microorganisms was counted on Bushnell Haas agar medium (Bushnell and Haas, 1941) by inoculation with 1 ml of the test sample added by 70 µl of crude oil or *n*-alkanes $C_{10}H_{22}$, $C_{12}H_{26}$ and $C_{16}H_{34}$ on the surface of the agar medium. Crude oil (Angarsk petrochemical company, Russia) and *n*-alkanes reagents were sterilized by filtering through a filter with a pore diameter of 0.45 µm and stored in sterile vials. Platings were incubated at 1 °C for 7 days. Organotrophic bacteria were determined on 10-fold dissolved fish peptone agar. Platings were incubated at 10 °C for 7 days (Pavlova et al., 2008a). Pure cultures of hydrocarbon-oxidizing microorganisms were obtained according to (Lomakina et al., 2014). The identification of the isolated pure cultures of hydrocarbon-oxidizing microorganisms was determined based on their morphological and physiological biochemical features by the Bergey's Manual (Garrity et al., 2005a,b; Vos et al., 2009; Whitman et al., 2012). Based on the similarity of morphological properties and Gram stain, pure cultures were divided into groups. To clarify the taxonomic position of the isolated strains, the most frequently occurring strains were selected from each group. The phylogenetic status of these strains was determined by the structure of the nucleotide sequences of the 16S rRNA. DNA extraction from pure cultures and phylogenetic analysis of the obtained sequences were performed according to the method described in (Rochelle, 1992). 16S rRNA genes were amplified using universal bacterial primers (500l/1350r) as described previously in (Lomakina et al., 2009). The obtained sequences of Baikal bacteria were registered in GenBank under the numbers MG786582–MG786588 and MG786759.

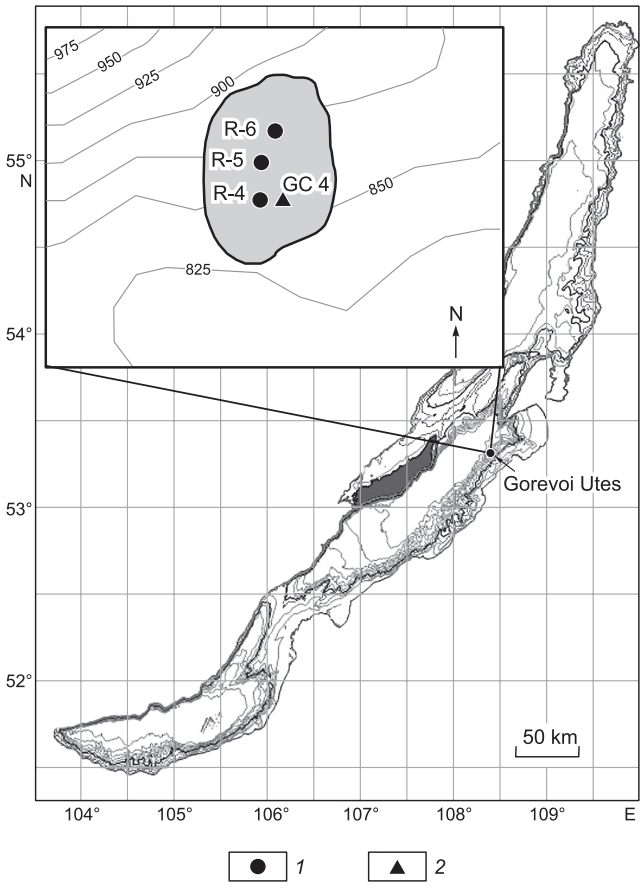

Fig. 1. Schematic map of sampling in the area of the natural oil seep near Cape Gorevoi Utes : *1*, water samples; *2*, bottom sediments.

Normal alkanes and PAHs in water samples were determined by liquid-liquid extraction into methylene chloride. Before the extraction, water samples (volume ~ 1 dm^3) were added by 100 mm^3 of PAH solution (mixture of naphtha-

lene-d_8, acenaphthene-d_{10}, phenanthrene-d_{10}, chrysene-d_{12}, and perylene-d_{12}) in acetonitrile at a concentration of 5 ng/mm^3, and 200 mm^3 of squalane solution in methylene chloride at a concentration of 0.332 μg/mm^3. Normal alkanes and PAHs were twice extracted with 30 cm^3 of methylene chloride; the extracts were combined and concentrated to a volume of ~ 1 cm^3. Na_2SO_4 (calcined, high grade) was added to the concentrates; the mixture was shaken and centrifuged; the supernatant was separated and transferred to the vials of the GC-MS autosampler.

Analysis of *n*-alkanes and PAHs was carried out for samples corresponding to the depths of 0, 50, 100, 250, and 275 cm. Samples were dried at room temperature to constant weight, ground in a mortar to a particle size of less than 0.74 μm; then, samples were taken by quartering and twice analysed using a 2–3 g of each sample. Weighed samples were added by internal standard solutions, 25 mm^3 of PAH solution and 50 mm^3 of squalane solution. PAHs and *n*-alkanes were extracted with methylene chloride in an ultrasonic bath (15 cm^3 × 2). The combined extracts were centrifuged; the supernatant was separated, concentrated to a volume of ~ 1 cm^3 and transferred to the vials of the GC-MS autosampler.

Prepared samples were analysed using Agilent Technologies 7890B GC System 7000C GC-MS Triple Quad with a capillary column OPTIMA®–17 ms (30 m × 0.25 mm × 0.25 μm) in the column temperature programming mode from 50 to 310 °C at a rate of 20 °C / min; then, at a constant temperature of 310 °C for 35 minutes. The injector temperature was 280 °C; the source temperature was 230 °C; ionization energy was 70 eV. Sample volume introduced into the chromatography column in the regime without flow separation was 2 mm^3. The peaks of *n*-alkanes, PAHs and internal standards were registered in the regime of selected ions with m/z: 51 and 74 (*n*-alkanes), 128, 136, 142, 152, 154, 164, 166, 178, 188, 202, 228, 240, 252, 264, 276, and 278 (PAHs); and identified by relative retention times; extraction of *n*-alkanes and PAHs was more than 75–80%, and the determination error did not exceed 15%.

RESULTS

Water column. The analysis of surface and deep-water samples from the area of the deep oil seepage near Cape Gorevoi Utes indicated that petroleum hydrocarbons were mostly concentrated in oil slicks on a water surface. Oil slicks collected from the stations R–4 and R–5 contained *n*-alkanes, PAHs and isoprenoids (phytane and pristane); chromatograms of oil samples recorded naphthenic and aromatic humps. Interval of total hydrocarbon content (Σ_{alk}) from 16 to 36% (Table 1) estimated the revealed homolo-

Table 1. The content of normal hydrocarbons and PAHs on the water surface, in the water column and bottom sediments

Hydrocarbons	Year of sampling	
	2006	2016
	Oil collected at the time of release to the water surface *	Oil slicks on the water surface
Series of *n*-alkanes	C_8–C_{29}	C_{12}–C_{29}
Σ_{alk}, %	90	16–36
Unresolved complex mixture of branched and cyclic hydrocarbons	absent	present
Series of PAHs	21 compounds	21 compounds
Σ_{PAHs}, %	0.15	0.05–0.07
$\Sigma_{naphthalenes}$, ppm	330	13–120
Benzo[a]pyrene, ppm	3.7	5.1–5.6
Water column (5-800 m), on the site with oil slicks		
Σ_{alk}, μg/L	0.77–14	0.80–4.5
Σ_{PAHs}, ng/L	6.2–82	4.8–21
Benzo[a]pyrene, ng/L	0.70–2.2	< 0.1
Water column (5-800 m), on the site without oil slicks		
Σ_{alk}, μg/L	0.21–1.0	0.35–0.94
Σ_{PAHs}, ng/L	6.2–71	3.9–15
Benzo[a]pyrene, ng/L	0.3–1.9	< 0.1
Bottom sediments (dry weight of the core)		
Series of *n*-alkanes	C_{22}–C_{37}	C_{13}–C_{29}
Σ_{alk}, ppm	50–70	1.7–50
Series of PAHs	24 compounds	24 compounds
Σ_{PAHs}, ppm	0.9–69	1.6–16
$\Sigma_{naphthalenes}$, ppm	0.14–2.6	0.10–0.84
$\Sigma_{phenanthrenes}$, ppm	0.15–50	0.90–12
Benzo[a]pyrene, ppm	0.01–0.68	0.01–0.27

Note: * [Gorshkov et al., 2010a]

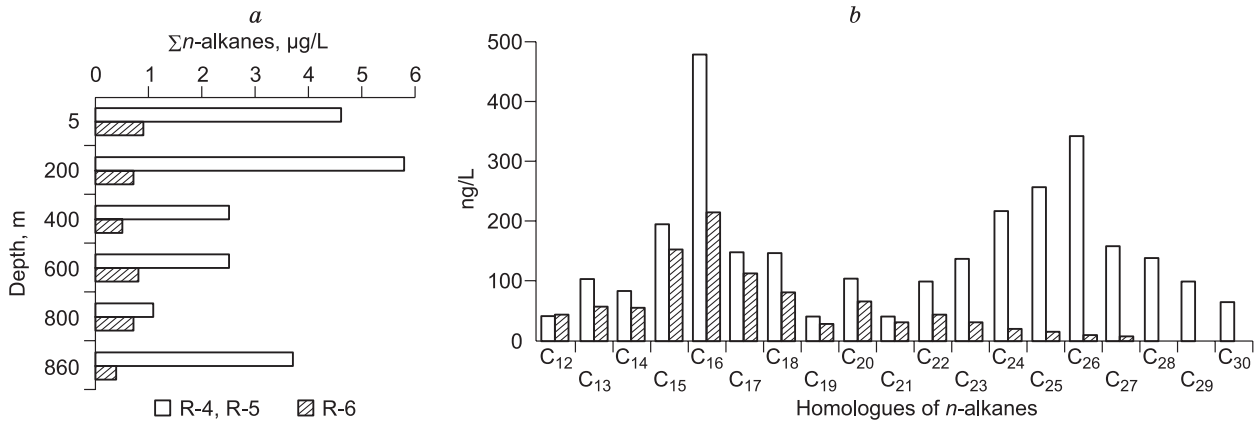

Fig. 2. The distribution of *n*-alkanes in the water column (*a*); the ratio of homologues of normal hydrocarbons in water samples from a depth of 5 m (*b*).

gous series of *n*-alkanes from C_{12} to C_{29}. The PAHs series in oil slicks included 21 compounds with total arene content (Σ_{PAHs}) within the range from 0.05 to 0.07% and benz[a] pyrene – from 5.1 to 6.1 ppm. Notably, the dominance of methylated phenanthrene homologues in oil composition, the anthracene/(anthracene + phenanthrene) ratio of 0.04, indicates the petrogenic source of oil on the water surface. High molecular weight PAHs such as indeno[1,2,3-cd]pyrene, benzo[ghi]perylene and dibenz[a,h]anthracene lacked in the composition of slicks.

In water samples from the photic layer (5–200 m, stations R–4 and R–5), the average Σ_{alk} concentration did not exceed 5.8 μl (Fig. 2*a*). Homologous series of the revealed *n*-alkanes had a bimodal distribution with two maximums at C_{16} and C_{26} (Fig. 2*b*). At depths of 400–800 m, the Σ_{alk} concentration decreased to 1.1 – 2.5 μg/l, and in the near-bottom layer, it increased to 3.7 μg/l. The PAHs concentration in water samples collected from 5–800 m depths lacked benz[a] pyrene (< 0.1 ng/l). The Σ_{PAHs} content ranged from 4.8 to 21 ng/l and the anthracene/(anthracene + phenanthrene) ratio – from 0.01 to 0.09.

In the surface water layer (0 m) from the areas of the lake without oil slicks (station R–6), the Σ_{alk} concentration ranged from 0.35 to 0.94 μg/l and the Σ_{PAHs} concentration – from 3.9 to 15 μg/l; benz[a]pyrene lacked in the studied samples. At all depths of the water column (station R–6), the Σ_{alk} concentration did not exceed 0.9 μg/l, and it was 2.5 times lower than in the corresponding samples from the stations R–4 and R–5 (Fig. 2*a*). The PAHs concentrations corresponded to the interval from 3.9 to 15 ng/l. It should be noted that the qualitative composition of normal hydrocarbons and PAHs in the water is similar to their composition in oil slicks, which suggests oil and methane seep as a single source of hydrocarbons.

The number of cultured hydrocarbon-oxidizing microorganisms and organotrophs in the water column depended on the sampling station. In the surface water layer with oil slicks (stations R–4 and R–5), the number of microorganisms was minimal. The number of hydrocarbon-oxidizing microorganisms was 2–16 ± 2 CFU/ml and organotrophs – 2–16 ± 2 CFU/ml. At a depth of 5 m, the number of hydrocarbon-oxidizing microorganisms (170 ± 14 – 370 ± 30 CFU/ml) and organotrophs (160 ± 13 – 800 ± 65 CFU/ml) increased. In the underlying layers of the water column, the number of these groups of microorganisms varied from 60 ± 5 to 300 ± 30 CFU/ml for hydrocarbon-oxidizing microorganisms and from 100±8 to 290±23 CFU/ml for organotrophs (Fig. 3*a*, *b*).

The greatest number of the investigated microorganisms was at the station R–6. The maximum number of organotrophs (1380 ± 140 CFU/ml) as well as bacteria oxidizing *n*-alkanes (up to 1000 ± 103 CFU/ml) and oil (up to 500 ± 61 CFU/ml) was in the subsurface water layer (5 m). In the water column, organotrophs prevailed (up to 800 ± 9 CFU/ml); the number of hydrocarbon-oxidizing microorganisms varied from 40 ± 3 to 200 ± 32 CFU/ml) (Fig. 3*c*). In the near-bottom water layers, the number of oil-oxidizing microorganisms was comparable with the number of organotrophs (Fig. 3*c*).

Bottom sediments of the core VER–16–01, GC.4 in the upper interval (from the surface to 140 cm) contained gas-saturated aleuropelitic muds impregnated with oil; in the lower one (from 140 to 310 cm) – clay that had vertical or core-axis inclined discharge channels with a diameter of 5 mm, shear and degassing fractions of 1–2 mm and horizontal interlayers of silty sand also impregnated with oil. In the fractions and interlayers of the core, the amount of oil was within the range from 0.18 to 2.9% with the Σ_{alk} concentration between 1.7 to 48 ppm (dry weight of the core).

In the core composition, we identified 24 PAHs whose concentrations ranged from 1.6 to 16 ppm (dry weight of the core). Phenanthrenes had maximum total concentrations, between 0.9 to 12 ppm (phenanthrene, 1-methylphenanthrene, 2-methylphenanthrene; 3-methylphenanthrene; 9-methylphenanthrene), whereas the concentration of high molecular weight PAHs (benzo[a]pyrene, indeno[1,2,3-cd] pyrene, benzo[ghi]perylene, and dibenz[a,h]anthracene) did not exceed 12 ppm (Table 1).

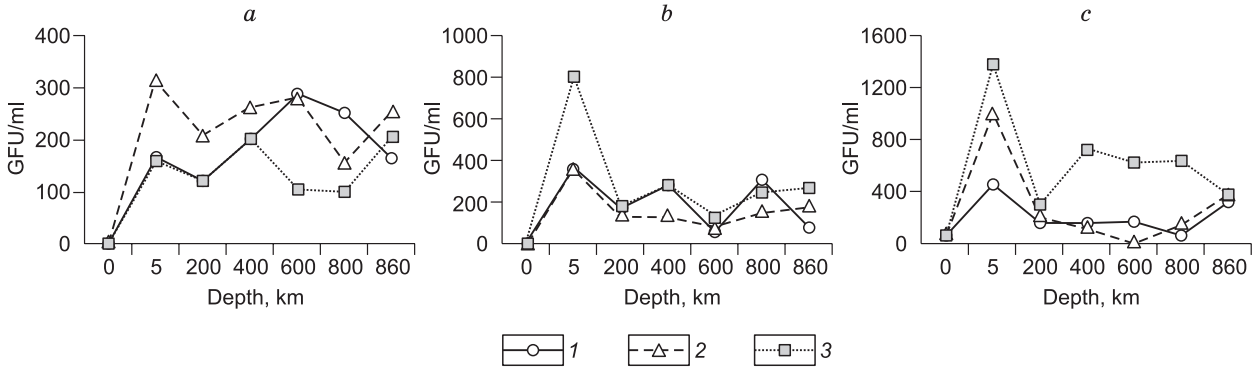

Fig. 3. Distribution of microorganisms oxidizing: *1,* oil, *2*, *n*-alkanes, and *3*, organotrophs in water column of the stations R–4 (*a*), R–5 (*b*), R–6 (*c*).

The number of culture microorganisms in the bottom sediments was maximum in the upper oxidized layer of sediments where oil-oxidizing microorganisms dominated (90±1 thou CFU/g) (Fig. 4). Bacteria of the genera *Bacillus* и *Paenibacillus* mainly represented cultured organotrophs. With the core depth, the number of all groups of microorganisms decreased. The second-largest number of microorganisms oxidizing oil (26±1 thou CFU/g) and *n*-alkanes (13±1 thou CFU/g) is the sediment layer at a depth of 250–255 cm. A significant increase in the number of microorganisms can be due to the degassing fraction through which bottom sediments are saturated not only methane and hydrogen but perhaps also oxygen, deep porewaters and oil. Interestingly, this sediment layer had the maximum Σ_{alk} concentration of up to 50 μg/g of the core (dry weight) with the minimum oil content of 1.8 to 3.4 μg/g of the core (dry weight).

In the water and bottom sediments, we detected cultured hydrocarbon-oxidizing microorganisms belonging to the genera *Pseudomonas*, *Sphingomonas, Rhodococcus, Williamsia, Microbacterium, Brevundimonas*, *Bacillus,* and *Paenibacillus*. Bacteria of the genera *Bacillus* and *Paenibacillus* dominated the bottom sediments. In the water column, the members of the phylum *Actinobacteria*, bacteria of the genera *Rhodococcus, Williamsia* and *Microbacterium*, prevailed.

DISCUSSION

In 2016, the area of the water surface of the lake where oil slicks appeared did not change in comparison with the results of the 2006 studies (Khlystov et al., 2007) and was

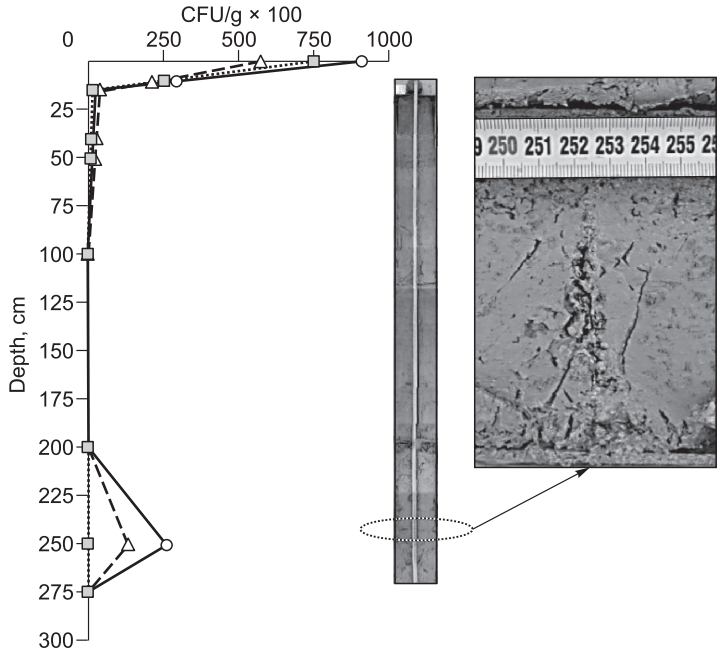

Fig. 4. Distribution of microorganisms oxidizing: *1,* oil, *2*, *n*-alkanes, and *3,* organotrophs in the core VER–16–01, GC.4

approximately 1 km^2. PAHs in the composition of oil slicks have shown that the ratio of indicator compounds anthracene/anthracene+phenanthrene equal to 0.04 indicates a petrogenic source of oil slicks (Yunker et al., 2002), i.e., oil entered the waters of the lake as a result of deep-water discharge in this area. However, the composition of oil collected from the water surface in 2016 differed from that investigated in 2006 (Gorshkov et al., 2006; Khlystov et al., 2007) in the following characteristics: a) decrease in the total number of normal hydrocarbons and PAHs, b) partial oil degradation, as evidenced by the appearance of naphthenoaromatic hump recorded in chromatograms. These changes may be associated with a decrease in oil entering the water surface and, consequently, its more effective degradation on the water surface due to evaporation or weathering. Errors of sampling, which was carried out in different periods of the study, should be also considered for the recorded changes in the composition of oil slicks.

A decrease in the amount of alkane fraction in oil, Σ_{alk}, in the investigated bottom sediment core up to 1.7–48 ppm (dry weight of the core) can be due to both reduction of oil flow in the lake waters and oil biodegradation. An increase in the number of hydrocarbon-oxidizing microorganisms by an order of magnitude in the bottom sediments in 2016 compared to the 2008–2009 data indicates possible active oxidation of oil by the microbial community from bottom sediments.

Due to oil fractioning in the upper layers of bottom sediments and formation of asphalt structures on the lake bottom (Gorshkov et al., 2010a), a fraction enriched with *n*-alkanes enters the lake waters. These *n*-alkanes are easily oxidized, as model experiments show (Pavlova et al., 2012). An assessment of oil hydrocarbon content in the water column confirms a low level of Σ_{alk} and Σ_{PAHs} in the water column near the oil seepage. Contribution of biological processes in oil degradation is more significant in the upper photic water layer (5 m), as evidenced by a higher number of hydrocarbon-oxidizing microorganisms by one-two orders of magnitude than in the samples of surface water and water column.

It is worth noting that the samples collected outside the zone of visible oil slicks (station R–6) revealed the maximum number of organotrophs and hydrocarbon-oxidizing microorganisms. This is probably due to the physical state of oil which was no longer in the form of a concentrated oil slick but dispersed droplets. In (Brakstad et al., 2015), it was shown that dispersed droplets of 10 μm decompose much faster than those of 30 μm. Unlike the World Ocean, where in the event of accidental oil spills, dispersants are purposely introduced into the ecosystem to dissolve oil slicks, in Lake Baikal, emulsification of oil occurs naturally. Biological surfactants formed by Baikal microorganisms contribute to the change in the physical state of oil (Pavlova et al., 2010). The revealed ability to synthesize biological surfactants with the strain cells of Baikal microorganisms can also contribute to the paraffin sorption on the suspended solids in the Baikal water and their deposition onto the lake bottom. Low PAHs concentration in the water column may be also associated with the activity of microorganisms. Selective biodegradation of fluoranthene, phenanthrene and pyrene was previously indicated for bacteria of the genera *Pseudomonas* and *Bacillus* isolated from Lake Baikal (Pavlova et al., 2005).

Comparison of the abundance estimates of the studied groups of microorganisms in the surface and near-bottom water samples over the 2006–2016 study period has shown a slight decrease. The maximum number of hydrocarbon-oxidizing microorganisms in the investigated area was in 2007 in the surface water layers and bottom sediments. In 2008–2009, there was a decrease in the number of hydrocarbon-oxidizing microorganisms to the values revealed in 2005–2006, maintaining the basic pattern, dominance of hydrocarbon-oxidizing microorganisms in the microbial community of this area (Pavlova et al., 2012).

The structure of the cultured microbial community did not change throughout the study period from 2006 to 2016. Among the cultured hydrocarbon-oxidizing microorganisms, the members of the phyla *Proteobacteria* and *Actinobacteria* dominate. The obtained data are consistent with the results of the study of the structure of microbial communities from the water column, bottom sediments and asphalt structures using high-throughput sequencing of 16S rRNA gene. According to this study, the microbial community is mainly represented by the phyla *Actinobacteria*, *Cyanobacteria* and *Proteobacteria*, with the dominance of bacteria of the genus *Rhodococcus* which are involved in biodegradation of aromatic hydrocarbons and *n*-alkanes of oil (Likhoshvay et al., 2013; Lomakina et al., 2014; Zemskaya et al., 2015; Zakharenko et al., 2019). Genomes of Baikal microorganisms inhabiting the area of natural oil seep probably have the ability to degrade hydrocarbons (Likhoshvay et al., 2013; Lomakina et al., 2014), because of geological processes, oil and its transformation products belong to the constant ecosystem components on the east coast of the central basin of the lake, whose formation took place in the Oligocene−Miocene (Kontorovich et al., 2007).

CONCLUSION

The water surface area of the lake with oil sleeks near Cape Gorevoi Utes did not change from 2005 to 2016 and was approximately 1 km^2. An assessment of PAH indicator ratios in the composition of oil slicks indicates a petrogenic source of oil. There was a decrease in the total concentration of normal hydrocarbons and PAHs in oil slicks and bottom sediments as well as growth and subsequent reduction in the number of microorganisms in the water and bottom sediments with the maintained structure of the cultured microbial community. Low total concentration and narrow range of detected concentrations of *n*-alkanes and PAHs in the water column between 2006 and 2016 indicates the preservation of the water purity in the lake near the oil seepage.

Near the oil seepage located near Cape Gorevoi Utes, there are the same mechanisms of self-cleaning as in other

oil-seepage areas of Lake Baikal. The transition of the oil-seepage near Cape Gorevoi Utes to the new stage of its development is likely to be expressed in an increase in the oil degradation degree. This process has been taking place for over 200 years near the oil seepage located at the estuaries of the rivers Bolshaya Zelenovskaya and Malaya Zelenovskaya (Ryazanov, 1928; Ryabukhin, 1934; Taliev et al., 1985; Petrova and Mamantova, 1985; Kashirtsev et al., 1999, 2006; Isaev et al., 2003; Isaev and Presnova, 2003; Kontorovich et al., 2007). Oil collected from this area of Lake Baikal at the present stage lacks *n*-alkanes, monomethylalkanes and acyclic isoprenoids because bacterial oxidation processes significantly changed the initial oil composition (Kashirtsev et al., 2006).

Despite the studies of these specific areas of the lake using new and modern techniques, the question on the role of anaerobic microorganisms in oxygen-free processes of oil degradation remains open. The study of anaerobic processes will be the subject of further research, which will enable to compare the importance of aerobic and anaerobic processes and assess their contribution to self-cleaning of the lake from oil "pollution".

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