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ENVIRONMENTAL PROTECTION

Oil Pollution of the Anabranches of the Ob River on the Territory of Khanty-Mansi Autonomous Okrug –Yugra

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Abstract—An analysis is made of the oil pollution of the Ob river waters using a long-term (1993–2013) hydrochemical monitoring of oil fields in Khanty-Mansi Autonomous Okrug. Contents of oil hydrocarbons (OHC) were determined in 4277 samples from the main Ob channel, and in 7076 samples from its anabranches by using infrared spectrometry. An increase in MAC (0.05 mg/dm^3) was observed in 28% of the samples from the main channel, and in 32% from the anabranches. The total percentage of samples with an extremely high (> 50 MAC) and high (30–50 MAC) pollution level made up 0.3% of the samples for the anabranches, and 0.1% for the main channel. Maximum pollution was revealed in the eastern part of Okrug, from its eastern boundary to the mouth of the Trom'egan river which is associated with a considerable number of accidents on the pipelines within the Nizhnevartovskii district. The upper and lower quantiles in the most polluted anabranches, Pasl and Bagras, are 0.03–01.7 and 0.032–0.16 mg/dm^3, respectively, whereas in the main Ob channel they vary from 0.022 to 0.065 mg/dm^3 (0.4–1.2 MAC). The methods of geoinformatics and mathematical statistics were used to assess a dependence of OHC on the number of pollution sources (well clusters, and the area of oil spills) in zones at different distances from the river channels. By calculating the Spearman correlation coefficients, it was shown that OHC contents are dependent mainly on the number of wells, and on the area of oil spills located at less than 2 km from the channels.

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INTRODUCTION

The stretch of the Ob in its lower reaches is extremely important in studying the formation conditions for the hydrochemical runoff on the territory of Western Siberia [1]. This is associated with the specificity of the natural conditions as well as with characteristics of technogenic impact. In the Middle-Ob region, primarily on the territory of Khanty-Mansi Autonomous Okrug (KMAO–Yugra), more than half of Russian oil is produced. Every year more than three thousand accidental oil spills and mineralized strata waters occur in okrug, and the number of accidents exceeds five thousand in some years [2]. It is not coincidental that the dynamics of chemical composition of the waters in the Ob and its tributaries is often studied and followed closely; summary publications reported on increased contents of OHC, chlorides, phenols, iron, manganese and other substances [3–8].

However, almost all hydrochemical investigations neglect the floodplain braiding of the Ob. From Novosibirsk to the inflow of the Irtysh the river valley increases in width to 10 km, and its channel breaks down in numerous anabranches [9]. The ecological conditions differ greatly in small anabranches, cutoff meanders, sors, and in the main channel. It was recorded that the water in shallow inundable anabranches of the Ob is considerably warmer and the flow velocity is lower, which is responsible for the qualitative difference of the communities of hydrobionts [10]. Obviously, the hydrochemical parameters of the anabranches can differ greatly from the characteristics of the main channel of the river and can vary with hydrological regime, landscape structure of the adjacent drainage areas, and with influence of anthropogenic pollution sources. By investigating the composition of separate anabranches, it is possible to assess the factors of technogenesis in the adjacent drainage areas. However, publications devoted to the study of the Ob waters usually treat the river as a single linear object, and the existence of anabranches and branches with a special hydrochemical and hydrological regime is neglected or their characteristics are extended to the Ob as a whole.

The objective of this paper is to determine on the territory of KMAO—Yugra the sources and the level of oil pollution of the Ob as a combined hydrological body consisting of the main channel and anabranches.

OBJECT AND METHODS

Material for this research included monitoring data for the oil fields of KMAO–Yugra. The regional legislative base foresees the development and fulfillment of projects of environmental observations within the license areas (oil fields). Taking into consideration the characteristic properties of regional nature management, OHC content in the surface waters serves as one of the control indicators.

In accordance with the requirements for efforts of ecological monitoring on the oil fields of KMAO–Yugra [11, 12], samples were collected four times in a year with due regard for the hydrological regime, in different seasons: the winter low-water period, high water, and the summer-autumn low-water period. The OHC concentration was determined by infrared spectrometry (PND F 14.1:2.5-95; PND F 14.1:2:4.168-2000) in laboratory centers with state certification. For determining reliability of data made available, the laboratories were supervised by the Khanty-Mansi Branch of the Federal State Institution "Center of Laboratory Analysis and Technical Measurements for the Ural federal District".

The objective in this study was achieved by using results of monitoring the waters of the main channel of the Ob and 27 anabranches in areas experiencing the most intense technogenic impact, from the eastern boundary of okrug to the Endyrskaya anabranch having its origin downstream of the inflow of the Irtysh (Fig. 1).

The surveyed anabranches are at different stages of the channel process and differ in hydrographic parameters, characteristics of hydrological regime, and in intensity of technogenic impact. The longest and most water-abundant anabranches (Endyrskaya, Neuleva, Bol'shaya Salymskaya, Bol'shaya Yuganskaya, Tundrina, Yuganskaya Ob, Langepas, Kiryas, Mulka, and Chekhlonei) are typical river branches several hundreds of meters in width. According to the runoff volume, they are comparable with the main channel. The small anabranches ("eriks") several tens of meters in width are characterized by a low flow velocity, and by a small runoff volume. They include Singapai, Syroi Agan, Ochimkina, Signei, Chumpas, Ganzheeva, Pokur, Kayukova, Materikovyi Pasl, Bagras, Posal 1, Bol'shoi Posal, Posal 2, and Nikulkina. The degree of influence from the local sources of pollution on the composition of their waters is considerably stronger than for the large branches.

The geological exploration and oil extraction well, the oil pipelines and other technological facilities that are located in the Ob floodplain and on the adjacent terraces pose a serious ecological threat. Protective earth walls are currently being built always around the well sites in order to prevent the runoff. In some cases, however, the old geological exploration wells are not provided with such a protection so that they would be inundated during a high water. Within the drainage areas

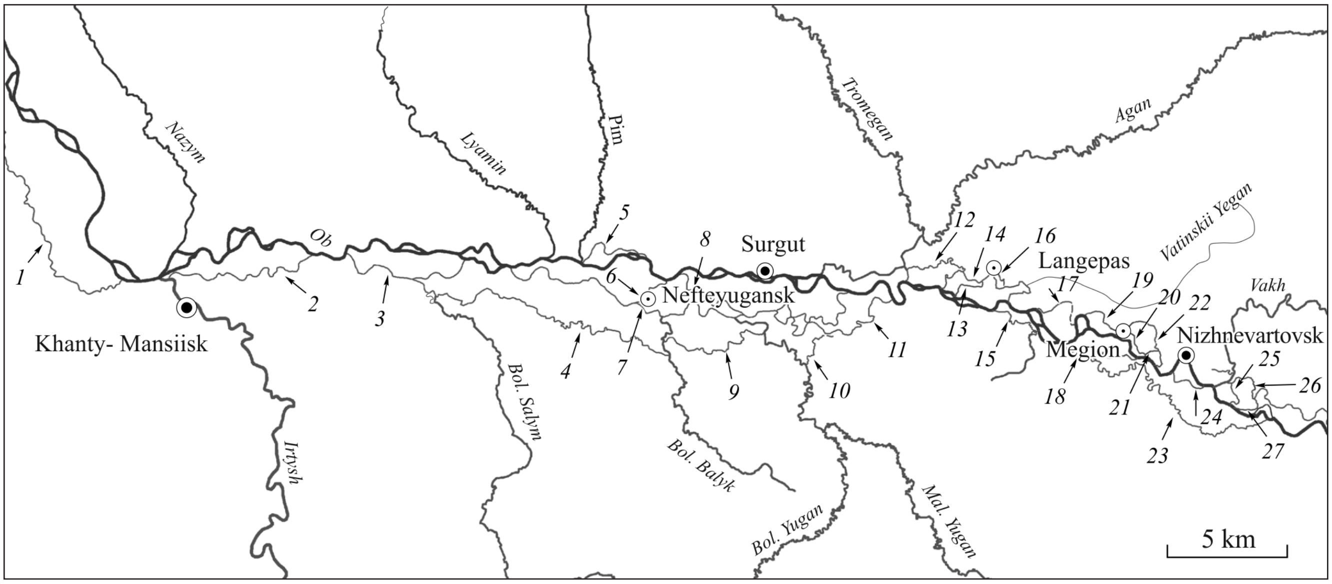

Fig.1. The surveyed anabranches of the Ob.
Anabranches: *1* – Endyrskaya, *2* – Neuleva, *3* – Bol'shaya Salymskaya, *4* – Bol'shaya Yuganskaya, *5* – Tundrina, *6* – Singapai, *7* – Yuganskaya Ob, *8* – Syroi Agan, *9* – Ochimkina, *10* – Signei, *11* – Pokomas, *12* – Chumpas, *13* – Ganzheeva, *14* – Langepas, *15* – Pokur, *16* – Kayukova, *17* – Materikovyi Pasl, *18* – Kiryas, *19* – Posal 1, *20* – Mulka, *21* – Bagras, *22* – Mega, *23* – Bol'shoi Posal, *24* – Chekhlonei, *25* – Bezymyannaya, *26* – Posal 2, *27* – Nikulkina.

of the longest anabranches (Bol’shaya Yuganskaya, Yuganskaya Ob, and Langepas) there are several hundreds of well clusters and outlets of municipal treatment works. Morphometric characteristics of the anabranches and the indices of technogenic influence are provided in Table 1.

For assessing oil pollution, the results of analysis of 11 353 samples (7076 samples from the anabranches, and 4277 from the main channel of the Ob) were processed. The observing period was uneven: in some of the anabranches, the observations have been made for 20 years, and on the others for the last 7–8 years. The largest number of measurements has been made in the last decade. During 1993–2003, due to a lack of the relevant legislative and normative base, a monitoring was carried out at irregular intervals, and the number of observations during this time interval was shorter by about a factor of 3 than during 2004–2013.

The analysis of the ecological situation used the value of MAC for water bodies of fisheries significance (MAC_{wf}). The proportion of samples with an exceedance of MAC_{wf} was counted for each of the surveyed anabranch, and the statistical parameters of OHC content were determined: the upper and lower quartiles (Q1–Q3), the median (Me), and the arithmetic mean (M). The values below the lower measurement limit were taken into account as half of the value of this limit [13]. A next stage involved estimating the correlations between the OHC concentration and the indices of technogenic impact, i. e. The number of oil well clusters and the area of oil spills, which were determined on the basis of yearly reports from the users of mineral resources submitted to Prirodnadzor (Federal Service for Supervision of Natural Resources) of KMAO—Yugra. It is known that oil hydrocarbons come in most cases from diffuse sources of pollution,

Table 1. Morphometric indices of the surveyed Anabranches, and number of well clusters at different distances from the channel

Anabranches	Length, km	Prevailing width, m	Number of well clusters in zones with different distance from anabranch (mean values for 2006–2012)			Number of well clusters in terms of 1 km of anabranch length for different zones		
			< 1 km	1–2 km	2–5 km	< 1 km	1–2 km	2–5 km
Endyrskaya	254	100–150	4	7	9.5	0.02	0.03	0.04
Neuleva	77	250–350	0	0	2	0	0	0.03
Bol’shaya Salymskaya	63	350–500	4	6.5	23	0.06	0.10	0.37
Bol’shaya Yuganskaya	151	150–200	34.5	29.5	68.5	0.23	0.20	0.45
Tundrina	38	250–350	1	3	29.5	0.03	0.08	0.78
Singapai	19	30–40	1	3	28	0.05	0.16	1.47
Yuganskaya Ob	200	300–500	35	43	80.5	0.18	0.22	0.40
Syroi Agan	42	25–30	32	30	67.5	0.76	0.71	1.61
Ochimkina	60	30–40	14	19	36.5	0.23	0.32	0.61
Signei	23	25–30	6	3	9	0.26	0.13	0.39
Pokomas	91	50–150	5.5	8	27.5	0.06	0.09	0.30
Chumpas	42	30–40	6	1.5	27.5	0.14	0.04	0.65
Ganzheeva	17	20–30	16	12.5	37	0.94	0.74	2.18
Langepas	70	80–150	27	25.5	61	0.39	0.36	0.87
Pokur	35	20–40	0	0	0.5	0	0	0.01
Kayukova	10	10–25	4	6	11.5	0.40	0.60	1.15
Materikovyi Pask	28	15–25	15	19	21.5	0.54	0.68	0.77
Kiryas	44	150–250	0.5	1.5	6.5	0.01	0.03	0.15
Posal 1	21	10–20	11	15	44.5	0.52	0.71	2.12
Mulka	19	300–400	2.5	3.5	18	0.14	0.19	1.00
Nagras	16	40–60	2	6	3.5	0.13	0.38	0.22
Mega	31	100–150	14.5	15.5	47	0.47	0.50	1.52
Bol’shoi Posal	130	25–50	12	5	30	0.09	0.04	0.23
Chekhlonei	19	300–500	0	0	0	0	0	0
Bezymyannaya	14	20–30	2.5	2	10	0.18	0.14	0.71
Posal 2	37	80–150	42.5	21	54	0.53	0.26	0.68
Nikulkina	14	10–30	10	5.5	3.5	0.71	0.39	0.25

primarily local spills within the drainage area [14, 15]. The number of oil components also increases due to migration and diffusion in the usual, accident-free operation of oil production facilities: from the wellhead, mud pits, and fuel storage [16]. The volume of unrecorded inputs depends indirectly on the number of technological facilities, potential sources of pollution.

It is obvious that the influence of technogenic facilities on the pollution level is caused by their location: the nearer to the water edge are the oil wells or oil spillage, the higher is the likelihood that OHC arrive in the river waters. Therefore, the number of pollution sources was counted in the zones at a different distance from the anabranch channels: up to 1 km, 1–2 and 2–5 km. For each of the surveyed water body, the Mapinfo 7.8 software package was used to construct the buffer zones with a corresponding radius, their boundaries were updated having regard to the structure of the hydro network, and the quantitative indicators were determined, which characterize the sources of OHC input. Further, the indices of specific load were calculated: the relationship of the number of wells and the area of spills in each of the zones with respect to the length of the anabranches. Since the number of well clusters for the period used in the analysis varied (it increased due to a continual increase in the well stock), the mean values were calculated for the period 2006–2012. Next, a correlation analysis was made to determine a dependence of OHC content on the indices of technogenic load. When the traditionally used Pearson correlation coefficients are employed, this is valid only when the distributions are close to normal, and the relationships are linear [17]. However, an assessment of the laws of differentiation for the indices of technogenic load with regards to absolute as well as specific values shows the absence of a normal distribution. Therefore, Spearman's rank correlation coefficients were used, which are suited for any types of distributions.

RESULTS AND DISCUSSION

Statistical indices of OHC content in the waters of the main channel of the Ob and its anabranches are summarized in Table 2. Analysis of long-term hydrochemical regime information showed that the range of variation in OHC concentration is very large. In the main channel of the Ob, sometimes it reached 100 MAC_{wf} or more, the mean value was 0.062 mg/dm^3 (1.2 MAC_{wf}) and, to a lesser extent, differs from data obtained in the process of monitoring at the stations operated by Rosgidromet [18]. According to them, the OHC content in the Ob waters during 2000–2010 was mostly within the range of 0.2–6.6 MAC_{wf} downstream of Nizhnevartovsk and Nefteyugansk and up to 5 MAC_{wf} downstream of Surgut. The differences can be attributed to the fact that the Rosgidromet stations are located nearby large industrial cities which are responsible for continual input of OHC to the Ob waters. It should also be noted that in earlier summaries of results of the monitoring operations in the oil field of KMAO—Yugra, the mean content of OHC in the Ob for the period 1995–2005 was determined at the level of 1.8 MAC_{wf} [6]. This suggests that the level of oil pollution has decreased.

In the anabranches, the indices of oil pollution differ from the main channel on either side: some of the anabranches are characterized by low content of OHC whose concentration is lower than in the main channel and does not exceed MAC_{wf}; in the other anabranches, on the contrary, the pollution level is increased. The quantitative distribution of the anabranches with increased or decreased OHC content is about the same: in half of them, the OHC contents are lower than in the main channel, in the other half, they are higher by a factor of 1.1–2.3 раза, i. e. in accordance with [19], the pollution level is low and moderate. Overall, the proportion of samples with an exceedance of MAC_{wf} made up 32% for the anabranches and 28% for the main channel of the Ob.

The highest OHC content was determined in the waters of the Langepas (M = 2.8 MAC_{wf}), Bagras (M = 2.2 MAC_{wf}) and Materikovyi Pasl (M = 2.1 MAC_{wf}) anabranches. In them, an exceedance of MAC_{wf} was observed in 69% of the samples used in the analysis. In accordance with [19], in terms of the recurrence rate of pollution, 32% of the surveyed water bodies refer to the category of single pollution, 29 to unstable pollution (including the main channel of the Ob), 21 to stable pollution, and 18% to characteristic pollution. Characteristic pollution where more than half of samples have OHC concentrations above the MAC_{wf} level was observed in the Langepas, Bagras, Materikovyi Pasl, Ganzheeva, Kayukova and Posal 1 anabranches.

Instances of extremely high pollution with an exceedance of MAC_{wf} by a factor of 50or more were observed in the Ganzheeva and Langepas anabranches and in the main channel of the Ob, and by a factor of 30 or more (a high pollution level) in the Yuganskaya Ob, and in the Mega, Savkinskii Pasol, Singapai and Endyrskaya anabranches. Extreme and high pollution is due to accidents on the pipelines within the floodplain and adjacent terraces. The proportion of samples with an extremely high (> 50 MAC_{wf}) and high (30–50 MAC_{wf}) pollution level makes up 0.3% of all samples for the anabranches and 0.1% from the main channel.

Since the extreme values that are not characteristic for the variational series have a significant influence on the arithmetic mean, the structural characteristics, namely the median and quartiles, are best suited for assessing the ecological situation for a long period of time. A calculation of the median demonstrated

Table 2. Statistical indicators of OHC content in the waters of the Ob river system on the territory of KMAO–Yugra

Water bodies	Q1	Q3	Me	M	% of samples > MAC	Number of samples	Observing period
Main Ob channel	0.022 0.4	0.065 1.2	0.031 0.6	0.062 1.2	28	4277	1993–2013
Anabranches							
Endyrskaya	0.02 0.4	0.044 0.9	0.029 0.6	0.054 1.1	19	323	2006–2013
Neuleva	0.01 0.2	0.060 1.2	0.031 0.6	0.079 1.6	31	26	2006–2009
Bol’shaya Salymskaya	0.010 0.2	0.021 0.4	0.012 0.2	0.023 0.5	6	87	2007–2013
Bol’shaya Yuganskaya	0.010 0.2	0.032 0.64	0.020 0.4	0.025 0.5	7	343	2004–2013
Tundrina	0.026 0.5	0.045 0.9	0.033 0.7	0.039 0.8	19	105	2007–2013
Singapai	0,01 0.2	0,048 0.9	0,021 0.4	0,069 1.4	22	138	2004–2012
Yuganskaya Ob	0,01 0.2	0,024 0.5	0,012 0.3	0,024 0.5	8	729	2004–2013
Syroi Agan	0.01 0.2	0.028 0.6	0.012 0.2	0.040 0.8	15	88	2004–2013
Ochimkina	0.01 0.2	0.020 0.4	0.012 0.2	0.022 0.4	8	84	2004–2013
Signei	0.01 0.2	0.026 0.5	0.011 0.2	0.031 0.6	12	198	2004–2013
Pokomas	0.01 0.2	0.022 0.4	0.012 0.2	0.022 0.4	6	105	2007–2013
Chumpas	0.01 0.2	0.025 0.5	0.013 0.3	0.018 0.4	4	56	2007–2013
Ganzheeva	0.025 0.5	0.140 2.8	0.064 1.3	0.090 1.8	59	303	1993–2013
Langepas	0.028 0.6	0.150 3.0	0.070 1.4	0.141 2.8	64	1021	1993–2011
Pokur	0.015 0.3	0.028 0.6	0.025 0.5	0.027 0.5	7	188	1999–2013
Kayukova	0.02 0.4	0.100 2.0	0.068 1.4	0.073 1.5	55	115	1993–2013
Materikovyi Pasl	0.030 0.6	0.170 3.4	0.100 2.0	0.106 2.1	69	150	1993–2008, 2013
Kiryas	0.024 0.5	0.028 0.6	0.025 0.5	0.028 0.6	2	119	2006–2013
Posal 1	0.023 0.46	0.157 3.1	0.046 0.9	0.095 1.9	49	236	1994–2013
Mulka	0.023 0.5	0.037 0.7	0.025 0.5	0.034 0.7	14	256	1993–2013
Bagras	0.032 0.6	0.160 3.2	0.100 2.0	0.111 2.2	67	152	1993–2006
Mega	0.021 0.4	0.107 2.1	0.028 0.6	0.068 1.4	34	958	1993–2013
Bol’shoi Posal	0.025 0.5	0.050 1.0	0.040 0.8	0.042 0.8	18	274	1998–2013
Chekhlonei	0.02 0.4	0.040 0.8	0.030 0.6	0.031 0.6	3	61	2006–2013
Bezymyannaya	0.024 0.5	0.061 1.2	0.038 0.8	0.062 1.2	31	474	1993–2012
Posal 2	0.025 0.5	0.070 1.4	0.042 0.8	0.072 1.4	38	344	1994–2013
Nikulkina	0.027 0.5	0.079 1.6	0.046 0.9	0.070 1.4	41	143	2007–2013

Note. Above dash – mg/dm^3, under dash – in fractions of MAC_{wf}.

that in the Materikovyi Pasl and Bagras anabranches, more than half of samples have concentrations at the level of 2 MAC_{wf} or higher, and the OHC content in 50% of samples from the Langenas anabranch exceed 0.07 mg/dm^3 (1. MAC_{wf}). In the waters of the Posal 1, Langepas, Materikovyi Pasl and Bagras anabranches, 25% of samples are distinguished by an OHC concentration higher than 0.15 mg/dm^3 (3 MAC_{wf}). Thus the drainage areas of these anabranches are experiencing chronic pollution.

Spatial analysis shows that the pollution is more pronounced in the area from the eastern boundary of okrug to the mouth of the Trom'egan river which is due to a significant number of accidents within the Nizhnevartovskii district. Downstream of Surgut, the pollution of the anabranches is less pronounced, and OHC content in their waters is lower than in the main channel of the Ob, except for the Neuleva anabranch (see Table 2). A similarity of the oil pollution indices for the main channel and this anabranch is accounted for by the fact that the Neuleva is a typical large river branch which differs little from the main channel in morphometric indicators and discharge.

For assessing the influence of the various sources on the pollution level of the waters of the Ob anabranches, we considered the correlation between OHC content and the indices characterizing the intensity of technogenic impact: the area of the oil-polluted lands and the number of oil wells (in absolute and specific values). Data on the area of oil spills were determined only for the Nizhnevartovskii district in which a detailed inventory of polluted lands was carried out.

On the basis of analyzing the spatial distribution of the pollution sources in the zones at a different distance from the channels, it can be suggested that the density of the well clusters is maximal in the coastal zone of the anabranches (< 1 km), whereas the area of the oil-polluted lands increases with increasing distances from the anabranches (Fig. 2). Predominance of well clusters near the water edge is due to technological factors, whereas the location of oil spillage at a distance of 2–5 km from the channels is conditioned by an increase in the length of the pipelines, and by an increase of the number of accidents in this zone. The most polluted are the territories that are adjacent to anabranches Posal 1 (Vatinskloe oil field) and Mega (Megionskoe and Samotlorskoe oil fields) (Table 3).

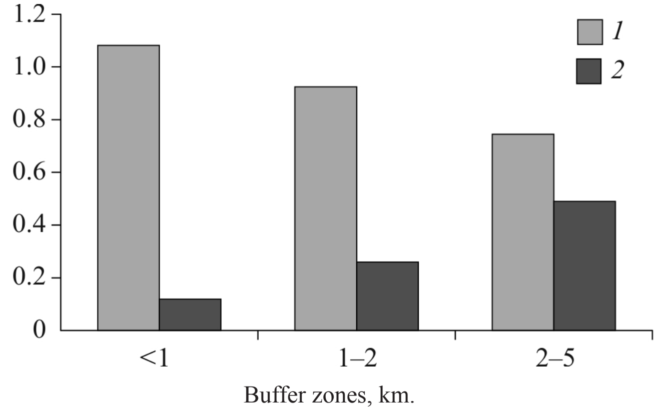

Fig. 2. Density of oil pollution sources in zones at a different distance from the channels.
1 – location density of well clusters (clusters/10 km^2); *2* – length of oil spillage within the buffer zones, km.

Table 3. Indices of oil-polluted lands in areas adjacent to anabranches

Anabranches	Area of spillage, ha			Specific load on 1 km of anabranch		
	$S_{<1}$	$S_{1–2}$	$S_{2–5}$	$S_{<1}/L$,	$S_{1–2}/L$	$S_{2–5}/L$
Langepas	7.9	1.5	105.1	0.1	0.022	1.50
Pokur	0	0	3.6	0	0	0.10
Kayukova	0	3.0	110.3	0	0.30	11.0
Materikovy Pasl	0	39.5	5.3	0	1.41	0.19
Kiryas	0	0	1.6	0	0	0.04
Posal 1	23.3	45.5	446.4	1.11	2.17	21.3
Mulka	0	0	6.9	0	0	0.38
Bagras	6.9	0	0	0.43	0	0
Mega	17.1	38.8	193.8	0.55	1.25	6.25
Bol'shoi Posal	30.5	42.1	73.6	0.23	0.32	0.57
Chekhlonei	0	0	0	0	0	0
Bezymyannaya	0	0	9.0	0	0	0.64
Posal 2	17.7	135.3	106.6	0.22	1.69	1.33
Nikulkina	1/1	0.3	9.0	0.08	0.02	0.64

Note. Here and in Table 5, S – area of oil spillage at a distance from anabranch < 1, 1–2 and 2–5 km; here and in Tables 4 and 5, L – anabranch length.

The values of the correlation coefficients are presented in Tables 4 and 5. It should first be pointed out that an analysis of the influence from the well clusters reveals a reliable dependence only in passing to the indices of specific load, i. e. between the number of well clusters with respect to the length of the anabranches (see Table 4). The largest values were observed for the zone of 1–2 km rather than < 1 km, as one might expect. This is accounted for by the increased attention paid by users of natural resources to observance of the requirements of the environmental regulations, and to awareness of a high ecological risk from the location of the wells in the immediate vicinities to the water edge. A weak correlation between the number of wells and OHC content was observed for the zone separated from the channels by more than 2 km, which is indicative of a decrease in the arriving volumes of pollutants with a distance from the channel. Small leaks from the wellheads and the release of pollutants from their mud pits at a distance of more than 2 km are not critical to the level of oil pollution of the surface waters. The only statistically significant dependence is the one between the density of wells and the proportion of samples with an exceedance of MAC_{wf}, where R = 0.46.

Table 4. Values of Spearman's correlation coefficient between indices of OHC content, the number and location density of well clusters

Indices	$N_{<1}$	$N_{1–2}$	$N_{2–5}$	$N_{<1}/L$,	$N_{1–2}/L$	$N_{2–5}/L$
Q1	0.05	0.02	–0.10	0.27	0.30	0.11
Q3	0.09	0.10	–0.02	0.39	0.50	0.33
Me	0.01	–0.01	–0.16	0.30	0.37	0.17
M	0.09	0.15	–0.02	0.39	0.51	0.34
% of samples > MAC	0.26	0.31	0.11	0.56	0.66	0.46

Note. $N_{<1}$ – $N_{2–5}$ – number of well clusters in zones at a distance from anabranch < 1, 1–2 and 2–5 km. Here and in Table 5, bold indicates the values at a 95% level of significance.

Examination of the correlation coefficients characterizing the correlation between the area of oil-polluted lands and OHC content (see Table 5) shows that the greatest influence on the pollution of the surface waters comes from oil spillage sites at a distance of 1–2 km from the water body. There occurs an increase in the dependence at the transition to specific indicators of load. For zones at a distance f more than 2 km, the values of the correlation coefficients are decreased. A decrease in the influence of the spillage sites at a distance of more than 2 km from the anabranches is most revealing in view of the fact that it is here that their highest density is observed: the total area of lands polluted by residual oil in zones at a distance of 2–5 km from the anabranches averages about 0-0.5%, whereas at a distance to less than 1 km the oil-polluted lands occupy slightly less than 0.1% (see Fig. 2). Hence, there is an attenuation of the influence from the pollution sources located more than 2 km from the channel, on OHC content in the surface waters.

Table 5. Values of Spearman's correlation coefficients between indices of OHC content, the area and density of oil-polluted lands

Indices	$S_{<1}$	$S_{1–2}$	$S_{2–5}$	$S_{<1}/L$	$S_{1–2}/L$	$S_{2–5}/L$
Q1	0.32	0.20	–0.14	0.30	0.17	–0.14
Q3	0.37	0.49	0.35	0.52	0.58	0.38
Me	0.27	0.41	0.16	0.31	0.43	0.22
M	0.39	0.47	0.37	0.47	0.52	0.42
% of samples > MAC	0.27	0.45	0.31	0.37	0.51	0.37

CONCLUSIONS

By summarizing the monitoring data for the oil fields of KMAO—Yugra, it was shown that the OHC content in the waters of the Ob and anabranches does not exceed MAC_{wf} in most cases. The proportion of samples with exceedances in MAC_{wf} made up 32% for the anabranches and 28% for the main channel of the river. The stably polluted petroleum products correspond top 21% of the surveyed water bodies, and 18% to the category of characteristic pollution levels. In the eastern part of okrug (upstream of Surgut), oil pollution of the Ob anabranches is more pronounced than in the main channel. The small anabranches, due to a small flow volume, have a weakened self-cleaning potential; in emergency situations within the floodplain and terraces above floodplain, pollution of their waters is more severe than in the main channel. In percentage terms, the proportion of samples that showed an extremely high and high level of pollution by OHC, is in the anabranches by a factor of 3 higher than in the main channel (0.3 and 0.1%, respectively). Taking into consideration that the small anabranches and sors are exceptionally valuable for reproduction of hydrobionts, the ecological risk caused by oil pollution in them is extremely high.

There occurs a statistically reliable dependence of OHC content on the number of well clusters and on the area of oil spillage not further than 2 km from the channels. Thus the location of the oil extraction infrastructure facilities in this zone involves a high ecological risk, which must be taken into account when planning oil field development.

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