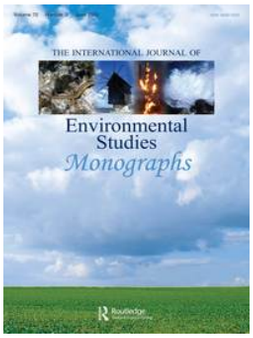

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Oil contamination of the Ob basin

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Oil contamination of bodies of water in the Russian Federation is one of the most widespread impacts on ecosystems. The Khanty-Mansiysk autonomous district-Yugra, the main oil extraction area in Russia, is one of the most oil-contaminated regions. The article summarises data from hydrochemical research on the level of petroleum hydrocarbons in water and bottom sediments of water bodies located in the basin of the river Ob.

Keywords: Oil contamination; Ob river basin; Vasyugan

Introduction

The Russian Federation is one of the world leaders for its reserves of raw hydrocarbons. Oil deposits are located in 16 oil and gas provinces. The main ones are the West-Siberian, Volga-Ural, Timan-Pechora, Caspian, North-Caucasian, Lena-Tungus and East-Siberian provinces. Annually more than 1000 accidents occur on extraction and transportation facilities just within the Khanty-Mansiysk autonomous district-Yugra (KHMAD-Yugra), but it is believed that actual figures are ten times larger. The level of petroleum hydrocarbons in river water depends on the accident rate at oil deposits [1]. According to Greenpeace, every year about 10 million tonnes of oil spill out from broken pipelines in Russia [2].

The Ob river basin is 2990 thousand km^2 and is the largest in Russia. The Ob is the third Russian river by its flow (after the Yenisei and the Lena). The main contamination of the Ob-Irtysh basin water bodies is caused by oil and petroleum products, which mostly come into river water of the Middle Ob where large oil deposits of West Siberia are situated.

KHMAD-Yugra is the centre of oil production in the Russian Federation, with more than half of all oil produced there. More than thirty oil-production enterprises use subsurface resources in this autonomous district. In 2007, 5480 oil spills were registered on the district oil fields, of which 2739 accidents were on oil pipelines, and 2741 accidents were on water supply lines. In the same year, there were 10,381.4 tonnes of pollutants; of these, 1252.7 tonnes were oil and oily mixture. In 98% of cases, the main cause of these accidents was pipeline corrosion. The highest accident rate was found on oil deposits of OOO[1] 'RN-Yuganskneftegaz' (2712 accidents), OAO[2] 'Tomskneft' (1273 accidents), and OAO 'Samotlorneftegaz' (809 accidents), which accounts for 87.4% of all registered accidents on KHMAD-Yugra oil deposits [3]. On the territory of OOO 'RN-Yuganskneftegaz' production operation every second oil spill and two thirds of contaminated area are in

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swamp lands [4]. The water surface comprised 3.7% of the polluted area, while the number of polluted water bodies occupied 17.3%.

Dynamic development of new oil production districts in West Siberia comes amid a large number of negative effects. For example, in 1971, there were losses of 2000 tonnes of oil because of pipeline ruptures and oil spills on oil fields of Nizhnevartovsk district. In May 1972, 400 tonnes of oil were lost and the site was contaminated because of delivery pipe damage on 526 km of active oil pipeline 'Aleksandrovskoe – Tomsk – Anzhero-Sudzhensk'. In August 1976, there was an oil spill of more than 200 tonnes on the Fedorovskoe oil field ('Surguttruboprovodstroi' business group). In the 1970s, regulatory authorities did not pay much attention to ecological issues. Development of oil deposits brought about a number of negative effects on the environment [5].

Results and discussion

Accumulation of oil contamination in the Ob basin is also in the Gulf of Ob and the Barents-Kara shelf. The analysis of parameters in bottom sediments in the Gulf of Ob [6] shows that they correspond to background characteristics of the west-Arctic shelf. The level of aromatic hydrocarbons (on average 7.5 mg/kg) does not exceed background values for bottom sediments, while its group composition gives evidence for its genetic connection with initial humic material. The distribution of n-alkanes proves the dominant role of terrigenous humic material in the evolution of organic substance in bottom sediments, while sustainability of quality and quantity indicators over time shows the stability of the ecosystem of the Gulf of Ob. There were found pyrogenous components in the sediments, which could be because of atmospheric transfer of technogenic stack ash and/or because of flux of transformed organic substance from bank sediments into precipitation.

Hydrologic behaviour of the Kara Sea, especially in its southwestern part, is determined by river stream-flow, mostly from the Ob and the Yenisei. About 58% of annual river input falls within spring snowmelt (May–July) and 80% falls within the period from June to September [7]. The level of hydrocarbons in sea surface water is on average 0.016 mg/l, which is much less than fishery maximum allowable concentration (MAC) for petroleum products, and shows evidence for their inconsiderable input or rapid degradation. The composition of polycyclic aromatic hydrocarbons (PAH) indicates the natural genesis of hydrocarbons. Rather small concentrations of aromatic hydrocarbons are characteristic of the surface layer of bottom sediments, which are 3.3–76.6 mcg/g for aromatic hydrocarbons and 9–87 ng/g for PAH. This is because of the low level of organic substances in bottom sediments (less than 2.4%). This may be caused by the short growing period of diatoms and low annual average amounts of biomass [7]. Both the lithological type of sediment and the conditions of sedimentation affect the level of hydrocarbons. A similar rate of PAH was detected in the sediments of the Niger Delta, which varied from 20.7 to 72.1 ng/g dry weight [8]. The largest variability of hydrocarbon concentrations in water and bottom sediments was noticed in the 'the Gulf of Ob – the Kara Sea' profile cut. There are both degradation and formation of hydrocarbons in modern bottom sediments of the Kara Sea. That could indicate the high rate of their transformation in the deposits of north-polar seas. Comparative investigations of PAHs' concentrations in bottom sediments of the Kara Sea shelf, Gulf of Ob and Yenisei Bay showed that highest total PAH concentrations (sum of two- to six-ring aromatic hydrocarbons) were found in sediments from the Yenisei Bay (ranging from 443 to 657 (mean 537) ng/g dry weight) [9].

The analysis of colour response curves of aromatic hydrocarbons in bottom sediments of the Gulf of Ob shows that they mostly consist of biogeneous polyaromatic compounds, which is common for shelf deposits. The organic substance of these deposits is genetically related to ground vegetation [10]. When considering summarised colour response curves of organic substances from river, interior and seaward zones of 'marginal filter', the researchers found restructuring of molecular composition of aromatic hydrocarbons. The level of tetra- and penta-aromatic compounds decreases rapidly towards the river-sea, while the level of light mono-, bi- and tri-aromatic hydrocarbons remains practically the same. This is because there is selective deposition of the tetra- and penta-aromatic compounds in the zone of strong coagulation of weighed and colloidal fractions of organic substances. Sedimentation of low-molecular freely soluble aromatic hydrocarbons is in the seaward zone with high value of water salinity, and this is indicated by the correlation of C org. level and high-molecular aromatic hydrocarbons for the sediments in mixing zones ($r = 0.37$) and river ($r = 0.62$), and also its decrease for the seaward zone ($r = 0.52$) [10]. In August 2001, the level of petroleum products in the water of the large and small Ob was in the range of 0.03–0.09 mg/dm^3. In winter near Salekhard the level of petroleum products was 0.06–0.07 mg/dm^3, which insignificantly exceeded fishery MAC (0.05 mg/dm^3) [11]. Different concentrations of the petroleum products were identified in the sediments. Their level depended on the quality composition of soil. Bottom sediments are sand, dirty sand and silted clay. Based on the classification by Uvarova [12], bottom sediments of the large Ob refer to 'slightly contaminated' soil, sediments in the river Ob to 'moderately contaminated soil', and those in the small Ob to 'slightly contaminated' type. All sediments analysed from the Niger Delta were classified as slightly contaminated [8], according to Belanchen et al. [13] and Johnson and Larsen [14]. The bottom sediments most contaminated with petroleum products are upstream from the village Kazym-Mys (up to 37.3 mg/kg); and upstream from the village Ilya-Gort (up to 36.0 mg/kg); downstream from Salekhard (26.7 mg/kg); downstream from the village Aksarka (33.0 mg/kg); and downstream from Salemal (up to 53.3 mg/kg) [10]. In 1995–1998, the average level of petroleum products in bottom sediments in the Ob was 28 mg/kg near Nizhnevartovsk and 33 mg/kg near Surgut [15].

According to geochemical sampling in the flood plain and tributaries (the rivers Karagaika, Nelym and Grishkina protoka) in the Irtysh basin, the level of petroleum products changes insignificantly in bottom sediments and is 159–171 mg/kg [16]. According to sampling records of 64 water bodies in the basin of the river Tromyegan (the Middle Ob basin), the average level of petroleum hydrocarbons in the water was 0.050 mg/dm^3 in 2009 and 0.039 mg/dm^3 in 2010 [17]. In 2003–2006 screening of watercourses which flow through areas of oil fields (in Surgut, Nefteyugansk and Nizhnevartovsk districts) determined the levels of various components in surface water, including petroleum products [18,19]. The lowest level of petroleum products was 0.04 (0.01–0.16) mg/dm^3 during snow-melt flood. The level of petroleum products exceeded fishery max in 15.8% of samples. During autumn and winter drought period, an increase in the level of petroleum products can be seen. During these periods, the level of petroleum products exceeded fishery MAC in 50.0–85.7% of samples. The 2005–2006 engineering and environmental surveys by OAO 'Giprotyumenneftegaz' in the Irtysh basin (130 water samples and 28 bottom sediments samples) estimated the condition of water bodies in Uvatsky district of Tyumen region [20]. The average level of petroleum products in surface water was 0.38 mg/dm^3, which is 7.6 times higher than fishery MAC (excess of MAC in 72% of samples). The level of petroleum products in bottom sediments on average was 14.6 mg/kg

(5–48.6 mg/kg), which did not exceed the prescribed legal standard for the maximum allowable level of petroleum products (20 mg/kg) for water bodies in KHMAD-Yugra. A significant amount of petroleum products gets into rivers with precipitation. In the Middle Ob basin, the deposition of petroleum products on the surface of the watershed area is by estimate 11.5 thousand tonnes (in warm season), and annually is 16.5 thousand tonnes [21].

The Vasyugan basin (65,000 km^2 area) lies within the northern part of the Ob-Irtysh interfluve and is one of the most oil-contaminated basins within the Middle Ob. Development of oil fields in the Vasyugan basin began in 1970s. The Vasyugan river (1082 km long) is the tributary on the left side of the Middle Ob. It flows from the Vasyugan Swamp at the height of 125 m. The Vasyugan receives ground (21%), snowmelt (68%) and aerial (11%) water. The river has more than 5000 tributaries. The valleys of rivers are inundable, the width of the Vasyugan flood plain is up to 2.5–4.0 km [22].

In 2000, petroleum products were found only in the upper part of the river, upstream from the mouth of the river Egolyakh (0.11 mg/dm^3, i.e. twice higher than MAC). Obviously, this is because of the flux of petroleum products with the water of the Vasyugan tributaries, which flow through the areas of new oil fields (the basins of the Chertal and the Yagylyakh). In the middle area of the river (downstream from the village Novyi Tevriz) and near the village Staroyugino (the lower area) there was no sign of petroleum products in surface water [23]. In 1991–1997, the level of petroleum products in the village Srednyi Vasyugan) on average was 0.404 mg/l (eight times higher than MAC) [24], and in 1999 in the mouth of the Vasyugan the level of petroleum products was 0.180 mg/l [25].

In the Ob there was on average 1067 kl/ml of oil-degrading bacteria (in 12 samples from the mouth of the Tom to the mouth of the Vasyugan, 1999); downstream from the Vasyugan (six samples on the area of about 500 km downstream from the Vasyugan mouth) the amount of oil-degrading bacteria was more than eight times bigger, and was on average 8833 kl/ml [26]. It is obvious that the increase in the amount of hydrocarbon–oxidating microorganisms results from the high level of oil hydrocarbons in the water of the Vasyugan.

The analysis of data on the level of petroleum products in bottom sediments of the Vasyugan in 2000 has shown that figures vary for different areas of the basin [23]. Watercourses on the areas of oil fields on average have higher levels of petroleum products in bottom sediments. In the basins of tributaries in the middle area of the Vasyugan there are the earliest oil fields (water-shed areas of the Katylga, Makhnya and Cheremshanka), development and exploitation of which has been carried out for more than 30 years. These watercourses are the main vectors of the oil hydrocarbons, which contaminate the downstream areas of rivers. The concentration of petroleum products in bottom sediments of the rivers in these areas was on average 300 mg/kg of soil. In the basins of the Yagylyakh and the Cheretala, where exploitation of oil fields is relatively recent, the level of petroleum products in bottom sediments is four times lower (i.e. 77 mg/kg). Upstream from the mouth of the Katylga, the level of petroleum products in bottom sediments was only 19 mg/kg. In downstream areas of the river (i.e. 250–400 km downstream from the inflow of contaminated tributaries), the level of petroleum products in bottom sediments shows a slightly decreasing trend. Near the mouth of the Nyurolka it is 66 mg/kg (moderately contaminated) and near the village Staroyugino it is 59 mg/kg (moderately contaminated). According to Turov et al. [27], in 2000 the concentration of petroleum products in the mouth of the Vasyugan was 55 mg/kg of soil, which corresponds to our data. The level of petroleum products in bottom sediments in the Ob in 1995–1998 on average was

28 mg/kg near Nizhnevartovsk, 33 mg/kg near Surgut [15], these figures are twice or three times lower than those in the Vasyugan in the year 2000.

According to the summarised data over 1997–2005, the average level of petroleum products in bottom sediments of the Vasyugan was 69.7 mg/kg; in the Chizhapka (first order stream) it was 42.1 mg/kg; and in the Makhnya it was 231.8 mg/kg. On average, first and second order stream of the Vasyugan showed the level of 117.4 mg/kg [28]. High concentration of petroleum products were registered in the Vasyugan and the Parabel basin in the lower reach of the Omelich (the Parabel basin) and equated to 0.49 mg/l and in middle reach of the Samlat (the tributary of the Salat, the Vasyugan basin). The maximum level of petroleum products in bottom sediments was 68.9 mg/kg in the headwater of the Oglat (the tributary of the Salat, the Vasyugan basin) [29].

The survey of the Vasyugan and its tributaries [30] indicated that the Vasyugan basin remains an ecological area of oil contamination. There were indications of concentrated petroleum products, exceeding fishery MAC (from 2.8 to 15.4 mg/l), from the inflow of the Katylga (465 km from the river mouth) to the lower reaches of the Vasyugan. The most contaminated tributaries of the Vasyugan are the Chizhapka (7.7 mg/l), the Katylga (7.2 mg/l), the Nyurolka (4.6 mg/l) and the Makhnya (3.0 mg/l).

Various groups of organic compounds are present in the Vasyugan peat water. These include carboxylic acids, phenols, aromatic and paraffin hydrocarbons, organic phosphates and other compounds. In many cases, the level of natural hydrocarbons in peat water which are identified as 'petroleum products' exceeds both fishery MAC (0.05 mg/l) and household MAC (0.30 mg/l) [31,32]. This is caused by the presence of paraffins from C_{25}:C_{33} with an uneven number of carbons in relatively 'clear' peat water [33].

It is obvious that the level of petroleum products in bottom soil of rivers flowing through oil fields mostly depends on the exploitation period. A similar pattern was observed during the analysis of surface water samples [34]. Analysis of 605 samples clearly traced the increase of petroleum products level in the water when the exploitation of the oil fields was of longer duration.

Conclusion

The analysis of research data of oil hydrocarbons in surface water and bottom sediments of water bodies in the Ob basin indicates a high level of these pollutants in the areas of oil extraction. Most water bodies show that the level of oil hydrocarbons exceeds normative standards for water bodies of commercial fishing importance.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Notes

1. [Limited Liability Company].
2. [Open Joint-Stock Company].

References

[1] Lozovoy, D.V., 2009, Ekologicheskoye soprovozhdeniye deyatel'nosti toplivno-energeticheskogo kompleksa na territorii Vostochnoy Sibiri [Environmental support activities of the fuel and energy complex in Eastern Siberia]. *Ekologiya i promyshlennost' Rossii*, **6**, 46–49 [in Russian].

[2] Sobgayda, N.A., Ol'shanskaya, L.N., Kutukova, K.N. and Makarova, Y.A, 2009, Ispol'zovaniye otkhodov proizvodstva v kachestve sorbentov nefteproduktov [The use of waste products as sorbents oil]. *Ekologiya i promyshlennost' Rossii*, **1**, 36–38 [in Russian].

[3] Efimova, M.V., Strikh, N.I. and Kurbanov, V.S.H., 2011, Vozdeystviye neftegazovogo kompleksa na ekosistemy Khanty-Mansiyskogo okruga – Yugry [The impact of oil and gas complex ecosystem of the Khanty-Mansiysk Okrug – Yugra]. *Nauchnyye vedomosti Belgorodskogo Gosudarstvennogo universiteta*. Yestestvennyye nauki, **3**(98), 110–114 [in Russian].

[4] Soromotin, A.V., 2004, Neftyanoye zagryazneniye zemel' v zone sredney taygi Zapadnoy Sibiri [Oil pollution of land in the middle taiga zone of Western Siberia]. *Ekologiya i promyshlennost' Rossii*, **8**, 8–11 [in Russian].

[5] Chernyy, V.A., 2002, Problemy sokhraneniya okruzhayushchey sredy i razvitiye neftegazovogo kompleksa [Environmental conservation and development of oil and gas complex]. *Izvestiya Tomskogo politekhnicheskogo universiteta*, **305**(7), 164–171 [in Russian].

[6] Petrova, V.I., Batova, G.I., Kursheva, A.V., Litvinenko, I.V. and Konovalov, D.A., 2010, Organicheskoye veshchestvo donnykh osadkov Obskoy Guby: raspredeleniye, priroda, istochniki [Organic matter of bottom sediments Gulf of Ob' river: distribution, nature, sources]. *Geokhimiya*, **2**, 151–163 [in Russian].

[7] Nemirovskaya, I.A., 2010, Soderzhaniye i sostav uglevodorodov v vode, vzvesi i donnykh osadkakh Karskogo moray [The content and composition of hydrocarbons in water, suspended matter and bottom sediments of the Kara sea]. *Okeanologiya*, **50**(5), 758–770 [in Russian].

[8] Olajire, A.A., Altenburger, R., Küster, E. and Brack, W., 2005, Chemical and ecotoxicological assessment of polycyclic aromatic hydrocarbon – contaminated sediments of the Niger Delta, Southern Nigeria. *Science of the Total Environment*, **340**, 123–136.

[9] Dahle, S., Savinov, V.M., Matishov, G.G., Evenset, A. and Næs, K., 2003, Polycyclic aromatic hydrocarbons (PAHs) in bottom sediments of the Kara Sea shelf, Gulf of Ob and Yenisei Bay. *Science of the Total Environment*, **306**, 57–71.

[10] Kursheva, A.V., Litvinenko, I.V., Petrova, V.I. and Galishev, M.A., 2009, Spektrofluorimetricheskoye izucheniye aromaticheskikh uglevodorodov v donnykh otlozheniyakh i vodnoy tolshche zapadnogo sektora Arkticheskogo regiona [Spectrofluorimetric study of aromatic hydrocarbons in the sediments and the water column of the Arctic region western sector]. *Okeanologiya*, **49**(5), 707–714 [in Russian].

[11] Uvarova, V.I., 2011, Gidrokhimicheskaya kharakteristika vodotokov Nizhney Obi [Hydrochemical characteristics of watercourses lower Ob' river]. *Vestnik ekologii, lesovedeniya i landshaftovedeniya*, **11**, 132–142 [in Russian].

[12] Uvarova, V.I., 1989, Sovremennoye sostoyaniye urovnya zagryaznennosti vod i gruntov Ob'-Irtyshskogo basseyna [The current state of the level of contamination of water and soil of the Ob-Irtysh basin]. *Sbornik nauchnych trudov GosNIORH*, **305**, 23–33 [in Russian].

[13] Belanchen, K.T., Chaoui, A., Budzinski, H., Bellocq, J. and Garrigues, P., 1997, Distribution and sources of polycyclic aromatic hydrocarbons in some Mediterranean coastal sediments. *Marine Pollution Bulletin*, **34**, 298–305.

[14] Johnson, A.C. and Larsen, P.F., 1985, The distribution of polycyclic aromatic hydrocarbons in the surficial sediments of Penobscot Bay (Maine, USA) in relation to possible sources and to other sites worldwide. *Marine Environmental Research*, **15**, 1–16.

[15] Uvarova, V.I., 2000, Sovremennoye sostoyaniye kachestva vody r. Obi v predelakh Tyumenskoy oblasti [The current state of water quality of Ob' river within the Tyumen region]. *Vestnik ekologii, lesovedeniya i landshaftovedeniya*, **1**, 18–26 [in Russian].

[16] Moskovichenko, D.V., Tigeyev, A.A. and Kremleva, T.A., 2011, Landshaftno-geokhimicheskiye osobennosti nizhnego Priirtysh'ya [Landscape-geochemical features of the lower Irtysh]. *Vestnik ekologii, lesovedeniya i landshaftovedeniya*, **11**, 154–161 [in Russian].

[17] Tigeyev, A.A., 2012, Kachestvo vodnoy sredy basseyna r. Trom"yegan v rayonakh dobychi uglevodorodnogo syr'ya [The quality of the aquatic environment river basin. Tromegan in areas of hydrocarbon production]. *Vestnik ekologii, lesovedeniya i landshaftovedeniya*, **12**, 137–142 [in Russian].

[18] Shornikova, Y.A., 2008, Mikrobiologicheskaya indikatsiya sostoyaniya ekosistem vodotokov na neftyanykh mestorozhdeniyakh Srednego Priob'ya [Microbiological status indication river ecosystems in the oil fields of middle Ob' river]. *Sibirskiy ekologicheskiy zhurnal*, **3**, 417–425 [in Russian].

[19] Shornikova, Y.A., 2009, Integral'naya otsenka sostoyaniya ekosistem vodotokov po gidrokhimicheskim pokazatelyam (na primere Srednego Priob'ya) [Integral assessment of the state of ecosystems watercourses by hydrochemical parameters (the middle flow of the Ob' river)]. *Geografiya i prirodnyye resursy*, **1**, 38–45 [in Russian].

[20] Pirogov, A.A., Zarayev, V.F., Kham'yanov, D.N., Borodin, Y.G. and Perekupka, A.G., 2009, Otsenka ekologicheskogo sostoyaniya vodnykh ob"yektov na territorii Uvatskogo rayona Tyumenskoy oblasti [Assessment of the ecological status of water bodies in the Uvat area of the Tyumen region]. *Neftyanoye khozyaystvo*, **4**, 108–111 [in Russian].

[21] Savichev, O.G. and Ivanov, A.O., 2010, Atmosfernyye vypadeniya v basseyne Sredney Obi i ikh vliyaniye na gidrokhimicheskiy stok rek [Atmospheric deposition in the middle Ob' river basin and their impact on the hydrochemical river flow]. *Izvestiya RAN. Seriya geograficheskaya*, **1**, 63–70 [in Russian].

[22] Evseyeva, N.S., 2001, *Geografiya Tomskoy oblasti: prirodnyye usloviya i resursy [Geography Tomsk region: natural conditions and resources]*, (Tomsk: Izd-vo Tomsk. gos. un-ta) [in Russian].

[23] Vorob'yev, D.S. and Popkov, V.K., 2005, Nefteprodukty v vode i donnykh otlozheniyakh basseyna reki Vasyugan [Petroleum products in water and sediments of the basin Vasyugan]. *Izvestiya Tomskogo Politekhnicheskogo universiteta*, **308**(4), 48–50 [in Russian].

[24] Savichev, O.G., 1999, Khimicheskiy sostav rechnykh vod basseyna verkhney i sredney Obi [The chemical composition of river water basin of the upper and middle flows of the Ob' river]. *Voprosy geografii Sibiri*, **23**, 164–170 [in Russian].

[25] Belitskaya, Y.A., Guznyayeva, M.Y., Kadychagov, P.B., Russkikh, I.V. and Turov, Y.P., 1999, Organicheskiye primesi v vodakh sredney Obi [Organic impurities in the waters of the middle flow of the Ob' river]. In: V.V. Zuyeva (Ed.) *Ekologiya poym sibirskikh rek i Arktiki* (Novosibirsk: Izd-vo SO RAN), 122–129 [in Russian].

[26] Shvartsev S.L., Savichev O.G., Khvashchevskaya A.A., Kopylova YU.G., Zarubina R.F., Trifonova N.A., Nalivayko N.G., Maruleva V.M. and Yefimova A.N., 1999, Kompleksnyye ekologo-geokhimicheskiye issledovaniya vod r. Obi [Complex ecological and geochemical studies of the Ob' river water]. In: V.V. Zuyev (Ed.) *Ekologiya poym sibirskikh rek i Arktiki In Ekologiya poym sibirskikh rek i Arktiki* (Novosibirsk: Izd-vo SO RAN), 110–115 [in Russian].

[27] Turov, Y.P., Russkikh, I.V., Pavlov, Y.V. and Zuyev, V.V., 2002, Nefteprodukty v donnykh otlozheniyakh basseyna reki Irtysh [Petroleum products in the sediments of the Irtysh river basin]. In: V.V. Zuyev, A.V. Kurovskij, and S.L. Shvartsev (Eds.) *Ekologo-biogeokhimicheskiye issledovaniya v basseyne Obi* (Tomsk: Izd-vo RASKO), 130–134 [in Russian].

[28] Savichev, O.G. and Bazanov, V.A., 2006, Khimicheskiy sostav donnykh otlozheniy reki Vasyugan i yeye pritokov [The chemical composition of bottom sediments of the river Vasyugan and its tributaries]. *Izvestiya Tomskogo politekhnicheskogo universiteta*, **309**(3), 37–41 [in Russian].

[29] L'gotin, V.A., Savichev, O.G. and Savicheva, O.G., 2008, Ekologo-geokhimicheskoye sostoyaniye nenarushennykh bolotnykh sistem na territorii Tomskoy oblasti (Zapadnaya Sibir') [Ecogeochemical state undisturbed wetland systems in the Tomsk region (Western Siberia)]. *Izvestiya Tomskogo politekhnicheskogo universiteta*, **313**(1), 92–97 [in Russian].

[30] Balykin, D.N., Balykin, S.N. and Puzanov, A.V., 2012, Ekologicheskaya otsenka sostoyaniya reki Vasyugan i yeye pritokov po osnovnym gidrokhimicheskim pokazatelyam [Environmental assessment of Vasyugan river and its tributaries on the main hydrochemical parameters]. *Vodnyye i ekologicheskiye problemy Sibiri i Tsentral'noy Azii*: trudy Vserossiyskoy nauchnoy konferentsii s mezhdunarodnym uchastiyem, posvyashchennoy 25-letnemu yubileyu Instituta vodnykh i ekologicheskikh problem SO RAN: v 3 t. *Barnaul*, **2**, 7–10 [in Russian].

[31] Savichev, O.G., 2009, Khimicheskiy sostav bolotnykh vod na territorii Tomskoy oblasti (Zapadnaya Sibir') i ikh vzaimodeystviye s mineral'nymi i organomineral'nymi soyedineniyami [Chemical composition of the bog water in the Tomsk region (West Siberia) and their interaction with inorganic and organic compounds]. *Izvestiya Tomskogo politekhnicheskogo universiteta*, **314**(1), 72–77 [in Russian].

[32] Savichev, O.G., 2010, Fonovyye kontsentratsii veshchestv v rechnykh vodakh tayozhnoy zony Zapadnoy Sibiri [Background concentrations of substances in the river waters taiga zone of Western Siberia]. *Vestnik Tomskogo gosudarstvennogo universiteta*, **334**, 169–175 [in Russian].

[33] Shvartsev, S.L., Rasskazov, N.M., Sidorenko, T.N. and Zdvizhkov, M.A., 2002, Geokhimiya prirodnykh vod rayona Bol'shogo Vasyuganskogo bolota [Geochemistry of natural waters of the greater Vasyuganskoye swamp]. In: M.V. Kabanov (Ed.) *Bol'shoye Vasyuganskoye boloto. Sovremennoye sostoyaniye i protsessy razvitiya* (Tomsk: Institute of Atmospheric Optics SB RAS), pp. 139–149 [in Russian].

[34] Shor, Y.L. and Khurshudov, A.G., 2000, Otsenka srednikh fonovykh kontsentratsiy nefteproduktov v pochvakh i poverkhnostnykh vodakh neftyanykh mestorozhdeniy Nizhnevartovskogo rayona [Estimation of the average background concentrations of petroleum products in soils and surface waters oilfields of the Nizhnevartovsk district]. In: *Issledovaniya ekologo-geograficheskikh problem prirodopol'zovaniya dlya obespecheniya territorial'noy organizatsii i ustoychivosti razvitiya neftegazovykh regionov Rossii: Teoriya, metody i praktika*. Proceedings of the Conference, Nizhnevartovsk, Russia, pp. 147–148 [in Russian].