Organic matter of floodplain lakes in the middle courses of the Ob River during the winter low-water season and the spring flood

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Abstract. The features of the organic matter composition of the lake waters of the Ob River floodplain in the winter low-water and the spring flood periods were investigated. It is shown that the organic matter of the studied lakes is significantly different from the organic matter of the Ob water. In the winter low-water season, floodplain lakes accumulate a large amount of organic aromatic allochotic substances, and in the flood there are changes in the composition of organic matter.

1. Introduction

The originality of the Ob River is the presence of a vast floodplain that can reach tens of kilometers and is one of the largest floodplain areas in the world [1]. On the one hand, the Ob floodplain is a source of organic substances entering the world ocean, and on the other hand, it is a gigantic geochemical barrier regulating the flow of substances and elements from the catchment [2]. At the end of the last century, considerable attention was paid to the study of the floodplain territory [3-9], but they were mainly of a utilitarian nature. In recent years, the study of dissolved organic carbon (DOC) and chemically related elements in the Ob, streams, lakes, and soils has been carried out in the area of the Kaibasovo station [2, 9-15]. However, the study of the organic matter composition in the lakes of the Ob floodplain in which a significant amount is accumulated has not yet been carried out. Meanwhile, considerable attention is being paid to the study of the DOM characteristics in the lakes in the world [16-19] since this knowledge can make a significant contribution to understanding the stability mechanisms of surface water ecosystems, which are determined by soluble substances of different origin [20].
2. Objects and methods of research
In the winter low-water (during March, 2019) and the spring flood (during May, 2019), the organic matter of four typical floodplain lakes was studied. The studies were carried out in the area of the Kaibasovo research station located in the middle courses of the Ob River (Figure 1).

![Sampling location](image1)

**Figure 1.** The study site and sampling location (a, b); sampling in the winter low-water in March, 2019 (c); sampling in the flood period in May, 2019 (d)

Samples were taken at different depths in the central part of the lakes as well as for comparison in the Ob River at a depth of 0.5 m. The floodplain lakes are shallow and the maximum depth is 4 m. in the Inkino Lake. Using a bathometer, the surface (0.5 m), middle (1.0-2 m), and bottom (2.1-4 m) water layers were studied (Table 1). The temperature, pH, electrical conductivity, and O\textsubscript{2} content in the waters were determined in situ by the Multi 3400 analyzer. The collected water samples were filtered through 0.45 μm Millipore filters and stored frozen prior to analyses.

The study of dissolved organic carbon (DOC), dissolved inorganic carbon (DIC) and the structure of the organic matter of the samples was carried out at the Institute of Forest named after V.N. Sukachev SB RAS in Krasnoyarsk using TOC minicube analyzer Elementar and a spectrophotometer Varian 100 UV-Vi.

Using the absorption spectra of water samples in the ultraviolet and visible regions, the parameters (SUVA\textsubscript{254}, E\textsubscript{254}:E\textsubscript{436}, E\textsubscript{2}:E\textsubscript{3}, E\textsubscript{4}:E\textsubscript{6}) characterizing the DOM were calculated. Specific ultraviolet absorbance (SUVA) was measured at 254 nm by Varian 100 UV-Vis spectrophotometer and further normalized to DOC concentration (m/l/mg C). We used SUVA\textsubscript{254} to estimate the content of dissolved aromatic substances in waters [21-24], given that SUVA\textsubscript{254} > 4 indicates the predominance of
hydrophobic material, and SUVA$_{254}$ < 3 indicates the predominance of hydrophilic material [25, 26]. We also calculated the ratio of E$_{254}$: E$_{436}$ [27-29] to assess the prevalence of autochthonous or allochthonous DOM, the ratio of E$_{250}$: E$_{365}$ [30, 31], that is, the content of unoxidized aromatic structures to oxidized to understand the relative size of DOM molecules and the ratio E$_{400}$: E$_{600}$ [32, 33] to assess the degree of the DOM humification. We used statistical packages of the program "Statistica 6.0" to process the obtained results.

3. Discussion of results

Table 1 shows the values of some physico-chemical indicators in the waters of the Ob River and floodplain lakes in the winter low-water and the spring floods of 2019. In the winter low-water season, floodplain lakes are characterized by a high concentration of dissolved CO$_2$, an almost complete absence of oxygen, a higher pH level, and high electrical conductivity, which is apparently associated with the underground waters rich in calcium and iron [2].

Table 1. Physico-chemical characteristics and concentration of dissolved gases in the Ob River and the floodplain lakes in the winter low-water and the spring flood of 2019

| Simple, month | Sampling depth, m. | t °C | pH | Conductivity, μS/cm | O$_2$, mg/l | CO$_2$, ppm |
|---------------|--------------------|-----|----|---------------------|-------------|-------------|
| Ob River      | March              | 0.5 | 0.1| 7.70                | 422         | 6.15        | 3470        |
|               | May                | 0.5 | 2.6| 8.20                | 319         | 5.01        | 1203        |
| Domash-nee    | March              | 1   | 0.5| 0.4                 | 183         | 0.8         | 11540       |
|               |                    | 2   | 1.5| 1.2                 | 184         | 0.0         | 12500       |
|               |                    | 3   | 3.0| 3.1                 | 223         | 0.0         | 11754       |
|               | May                | 1   | 0.5| 12.1                | 118         | 8.52        | 5012        |
|               |                    | 2   | 1.5| 10.0                | 122         | 4.25        | 6335        |
|               |                    | 3   | 3.0| 7.2                 | 141         | 0.49        | 14820       |
| Maleva        | March              | 1   | 0.5| 0.2                 | 353         | 0.3         | 8830        |
|               |                    | 2   | 1.5| 2.3                 | 376         | 0.0         | 10320       |
|               |                    | 3   | 3.0| 3.5                 | 420         | 0.0         | 14600       |
|               | May                | 1   | 0.5| 10.8                | 257         | 5.4         | 10000       |
|               |                    | 2   | 1.5| 8.4                 | 240         | 0.83        | 12200       |
|               |                    | 3   | 3.0| 7.3                 | 330         | 0.42        | 15000       |
| Inkino        | March              | 1   | 0.5| 0.1                 | 215         | 0.6         | 8854        |
|               |                    | 2   | 2.0| 1.8                 | 224         | 0.0         | 8992        |
|               |                    | 3   | 4.0| 2.5                 | 262         | 0.0         | 12199       |
|               | May                | 1   | 0.5| 10.2                | 148         | 10.45       | 4790        |
|               |                    | 2   | 2.0| 8.4                 | 143         | 7.74        | 4300        |
|               |                    | 3   | 4.0| 7.5                 | 153         | 5.52        | 7600        |
| Karasnoe      | March              | 1   | 0.5| 0.3                 | 652         | 0.0         | >400000     |
|               |                    | 2   | 1.0| 0.5                 | 670         | 0.0         | >400000     |
|               |                    | 3   | 2.1| 2.1                 | 842         | 0.0         | >400000     |
|               | May                | 1   | 0.5| 10.0                | 218         | 9.05        | 4700        |
|               |                    | 2   | 1.0| 11.2                | 217         | 6.91        | 4970        |
|               |                    | 3   | 2.1| 9.8                 | 215         | 4.21        | 8200        |

1 - the surface (0.5 m); 2 – the middle (1.0-2 m); the bottom (2.1-4 m) water layers

In the course of the work, it was found that the concentration of dissolved organic carbon in floodplain lakes is significantly higher than in the Ob River (Figure 2).
The highest DOC concentrations were observed in the lakes in March (up to 21.18 ppm). In the water column of the floodplain lakes DOC is distributed unevenly. During the flood period, DOC is located mainly in the middle and bottom layers. In the winter, DOC is higher in the Domashnee and the Maleva lakes in the surface layer, and in the Karasnoe and the Inkino lakes in the middle and bottom water. In May, a negative correlation ($r=-0.68$) between the content of DOC and pH was detected, as was shown earlier [2]. However, in the winter low-water season, there is no correlation, which is most likely due to the high amount of inorganic substances entering groundwater.

The values of SUVA$_{254}$ in the studied water bodies vary from 1.04 to 10.8, reaching a maximum in the lake waters and a minimum in the Ob River waters. A maximum is linked with high degree of aromaticity (Figure 3).

SUVA$_{254}$ describes the nature of dissolved organic carbon in terms of hydrophobicity and hydrophilicity: hydrophobic DOC consist from active aromatic rings, phenol hydroxyl groups, and double bond conjugation. Hydrophilic DOC consist from aliphatic ketones and alcohol groups. The values of SUVA$_{254} > 4$ indicate a predominance of hydrophobic material, and of SUVA$_{254} < 3$ indicate a predominance of hydrophilic material. It can be argued that hydrophilic organic matter predominates in the waters of the Ob River, both in the low-water season and the flood. In the waters of most lakes, the aromatic hydrophobic organic matter prevails during the winter low-water season, and the hydrophilic organic matter prevails in the flood. At the end of winter, clear differentiation of SUVA$_{254}$ was noted according to the deep profile of the lake. In the bottom layers of the lakes, the values of this indicator are higher than in the surface, therefore, here the degree of aromaticity is higher. In May, when the lakes are filled with a large amount of snowmelt, such differentiation is not observed. The exception is the Lake Karasnoe, where in the bottom layer the maximum degree of aromaticity was...
noted in May. Note that often this indicator is used to understand the reactivity of the DOC when interacting with coagulants and inorganic substances (the higher the degree of aromaticity, the closer the interaction) [20-23].

Assessing the predominance of the autochthonous or allochthonous DOM, it was found that the values of the coefficient E254: E436 for natural water samples of the study area range from 4.39 to 44.14 (Figure 4). In the waters of the Ob River, the autochthonous organic matter formed in a water body as a result of the life of macro and microhydrobionts prevails both in low-water and in high water. However, the value of this indicator in the flood is almost two times lower. This suggests the inclusion of allochthonous substances in the composition of DOM, which is a mixture of organic substances of humic nature of the terrigenous origin, which are products of incomplete decomposition of plant and animal residues [19]. The minimum values of this indicator were obtained for samples of lakes in the low-water period, which indicates the predominance of the terrigenous component in the DOM at this time [18, 19], and in floods, the value of this coefficient in lakes is much higher.

![Figure 4](image)

**Figure 4.** The ratio of E254:E436 in March 2019 (a), and in May 2019 (b)

The spectral coefficient E250: E365 is directly proportional to the molecular weight and the content of condensed carbon fragments in the structure of the DOM components [30, 31]. It is believed that the larger the size of the molecules, the smaller the ratio E250: E365 due to the stronger absorption of light by high molecular weight CDOM at longer wavelengths [30]. The distribution of the coefficient E250: E365 (Figure 5) over the profiles of lakes and in the Ob River is similar to the distribution of E254: E436 (Figure 4).

![Figure 5](image)

**Figure 5.** The ratio of E250: E365 in March 2019 (a), and in May 2019 (b)

It is known that the ratios E4: E6 correlate better with the ratios of the sizes of O: C and C: N molecules and the content of carboxyl groups and total acidity than with aromaticity and, therefore, can be used as a general sign of humification [34-36]. The values of the coefficient E4:E6 in the samples of the studied lakes vary from 2.4 to 35.3; and it is much lower during the period of low water...
than in flood (Figure 6). The lowest values of $E_{400}$: $E_{600}$ are characteristic of the waters of Karasnoe and Domashnee lakes, which indicates a rather high degree of the OM humification in these samples.

**Figure 6.** The ration of $E_4$:$E_6$ in March 2019 (a), and in May 2019 (b)

For the waters of other lakes, the values of $E_{400}$: $E_{600}$ are higher, and in May the values of this indicator approach the values characteristic of solutions of fulvic acids [35, 36].

4. Conclusions

Thus, the organic matter of the studied lakes is significantly different from the organic matter of the Ob water. In the winter low-water season, floodplain lakes accumulate a large amount of organic aromatic allochthonous substances of terrigenous origin. In floods, changes in the composition of organic matter occur.

Acknowledgements

This research was supported by the RF Federal Target Program, project RFMEFI58717X0036. Work was conducted with the application of equipment of the large-scale research facilities «System of experimental bases located along the latitudinal gradient» (http://ckp-rf.ru/usu/586718/).

Reference

[1] Petrov I B 1979 Ob-Irtyshskaya poyma. Tipizatsiya i kachestvennaya otsenka zemel’ [The Ob-Irtysh floodplain. Typification and quality evaluation]. Novosibirsk: Nauka, Siberian Branch Publ.; 136p In Russian

[2] Vorobyev S N, Pokrovsky O S, Kirpotin S N, Kolesnichenko L G, Shirokova L S, Manasypov R M 2015 Flood zone biogeochemistry of the Ob River middle course *Applied Geochemistry* 63 133-145.

[3] Ioganzen B G, Tumentsev N F 1968 Poyma Obi: priroda, osvoenie, melioratsiya [The Ob floodplain: nature, reclamation, melioration] *Novosibirsk: Zapadno-sibirskoye knizhnoe izdatel’stvo* Publ 157 In Russian

[4] Dobrovol’skiy G V, Afanasieva T V, Remezova G L, Stroganova M N, Palechek L A, Balabko P N 1971 Tipy poymy Sredney Obi [Floodplain types of the Ob River middle course]. *Biologicheskiye nauki – Biological sciences* 4 117-121 In Russian

[5] Novosyolov A N 1970 Poyma Tomskogo Priob’ya [The Ob floodplain in Tomsk region]. *Tomsk: Zapadno-sibirskoye knizhnoe izdatel’stvo, Tomsk Branch Publ.* 118p In Russian

[6] Burakov DA 1978 Osnovy gidrologicheskih prognozov ob’ema i maksimuma vesennogo polovod’ja v lesnoy zone Zapadno-Sibirskoy ravniny [Fundamentals of hydrological forecast capacity and maximum of spring flood in the forest zone of the West-Siberian Plain]. *Voprosy Geografii Sibiri* 11 3-48 In Russian

[7] Slavnina T P, Pashneva G E, Kakhatkina M I, Ivanova R G, Abramova M D, Seredina V P, Izerskaia L A 1981 Pochvy poymy sredney Obi, ikh meliorativnoe sostoyanie i
agrokhimicheskaya kharakteristika [Soils of the middle Ob floodplain, their ameliorative condition and agrochemical characteristics]. Tomsk: Tomsk State University Publ 224 p. In Russian

[8] Shepelev A I, Shepeleva L F, Pashneva G E, Tsytsareva L K, Adam A M 1996 Biologicheskiye resursy poimy Sredney Obi: dinamika i prognoz [Biological resources of the middle Ob: dynamics and forecast]. Adam A M, editor. Tomsk: NIIIB pri Tomskom gosuniversitete; 212 p. In Russian

[9] Rozhkova-Timina I. O., Zemtsov V. A., Vorobyev S. N., Kolesnichenko L. G., Loyko S. V., Kirpotin S. N. 2016 The relevance of the contemporary landscape-ecological and biogeochemical studies of the Ob floodplain Vestnik Tomskogo gosudarstvennogo universiteta. Biologiya – Tomsk State University Journal of Biology 3 (35) 182–200

[10] Vorobyev S N, Drozdov V V, Sorotchinskiy A V, Kirpotin S N, Kolesnichenko L G, Shirokova L S, Manasyrov R M, Pokrovsky O S 2016 Biogeochemistry of organic carbon, major and trace elements in the flooded and riparian zone of the Ob river Riparian Zones: Characteristics, Management Practices and Ecological 231–261

[11] Vorobyev S N, Pokrovsky O S, Kolesnichenko L G, Manasyrov R M, Shirokova L S, Karlsson, J, Kirpotin S N 2019 Biogeochemistry of dissolved carbon, major, and trace elements during spring flood periods on the Ob River Hydrological Processes 33 (11) 1579-1594

[12] Cazzolla G R, Callaghan T V, Rozhkova-Timina I, Dudko A, Lim A, Vorobyev S N, Kirpotin S N, Pokrovsky O S 2018 The role of Eurasian beaver (Castor fiber) in the storage, emission and deposition of carbon in lakes and rivers of the River Ob flood plain, western Siberia Science of the Total Environment 644 1371–1379

[13] Rozhkova-Timina I O, Vorobyev R S, Kolesnichenko Y Y, Pokrovsky O S, Kirpotin S N, Vorobyev S N 2018 Features of measuring dynamic biochemical parameters in the middle Ob [Electronic resource] IOP Conference Series: Earth and Environmental Science 201 5 p.

[14] Kolesnichenko L G, Shepeleva L F, Rahtsevich E S, Ledeneva E A, Teslinova M S, Rozhkova-Timina I O, Kirpotin S N 2018 Elemental chemical composition of some meadow plants in the Middle Ob basin [Electronic resource] IOP Conference Series: Earth and Environmental Science 201 8 p

[15] Rozhkova-Timina I O, Kolesnichenko L G, Mukortov V V Shepeleva L F, Vorobyev S N, Kirpotin S N 2019 Contribution of floodplain lakes to the global carbon cycle [Electronic resource] IOP Conference Series: Earth and Environmental Science 232 5 p

[16] Smith R E H, Allen C D, Charlton M N 2004 Dissolved organic matter and ultraviolet radiation penetration in the Laurentian Great Lakes and tributary waters Journal of Great Lakes Research 30 367–380.

[17] Hiriaert-Baer V P, Diep N, Smith R E H 2008. Dissolved organic matter in the Great Lakes: role and nature of allochthonous material. Journal of Great Lakes Research 34, 383–394

[18] Wang G S, Liao C H, Wu F J 2001 Photodegradation of humic acids in the presence of hydrogen peroxide Chemosphere 42 379–387

[19] Ilina S M, Drozdova O Yu, Lapitskiy S A, Alekhin Yu V, Demin V V, Zavgrodnyaya Yu A, Shirokova L S Viers J, Pokrovsky O S 2014 Size fractionation and optical properties of dissolved organic matter in the continuum soil solution-bog-river and terminal lake of a boreal watershed Organic Geochemistry 66 14–24

[20] Drozdova O Yu, Ilina S M, Anokhina N A, Zavgrodnyaya Yu A, Demin V V, Lapitskiy S A 2019 Transformation of organic substances in the conjugate series of surface waters of North Karelia Water resources 46 (1) 43-50

[21] Randtke S J 1999 Disinfection By-Product Precursor Removal by Coagulation and Precipitative Softening, In Formation and Control of Disinfection By-Products in Drinking Water; Singer P C, Ed.; American Water Works Association: Denver, CO Chapter 12 237-258.

[22] McKnight D M, Bencala K E, Zellweger G W, Aiken G R, Feder G L, Thorn K A 1992 Environ. Sci. Technol. 26 1388- 1396
[23] Hoch A R, Reddy M M, Aiken, G. R. 2000 *Geochim. Cosmochim. Acta* **64** 61-72

[24] Weishaar J L, Aiken G R, Bergamaschi B A, Fram M S, Fujii R, Mopper K 2003 Evaluation of Specific Ultraviolet Absorbance as an Indicator of the Chemical Composition and Reactivity of Dissolved Organic Carbon *Environ. Sci. Technol.* **37** 4702-4708

[25] Minor E, Stephens B 2008 Dissolved organic matter characteristics within the Lake Superior watershed *Org. Geochem.* **39** 1489–1501

[26] Matilainen A, Gjessing E T, Lahtinen T, Hed L, Bhatnagar A, Sillanpaa M 2011 An overview of the methods used in the characterisation of natural organic matter (NOM) in relation to drinking water treatment *Chemosphere* **83** 1431–1442

[27] Battin T J, 1998 Dissolved organic materials and its optical properties in a blackwater tributary of the upper Orinoco River, Venezuela *Organic Geochemistry* **28** 561–569

[28] Jaffé R, Boyer J N, Lu X, Maie N, Yang C, Scully N M, Mock S 2004 Source characterization of dissolved organic matter in a subtropical mangrovedominated estuary by fluorescence analysis. *Marine Chemistry* **84** 195–210

[29] Hur J, Williams, M A, Schlautman M A, 2006. Evaluating spectroscopic and chromatographic techniques to resolve dissolved organic matter via end member mixing analysis *Chemosphere* **63** 387–402

[30] Korshin G V, Li C W, Benjamin M M 1997 Monitoring the properties of natural organic matter through UV spectroscopy: A consistent theory *Water Research* **31(7)** 1787-1795

[31] Peuravouri J, Pihlaja K 1997 Molecular size distribution and spectroscopic properties of aquatic humic 10 substances *Anal. Chim. Acta* **337** 133–149

[32] Chin Y-P, Aiken G, O’Loughlin E 1994 Molecular weight, polydispersity, and spectroscopic properties of aquatic humic substances. *Environmental Science & Technology* **28** 1853–1858

[33] Stevenson F J 1994 Humus chemistry. Genesis, composition, reactions.2nd Edition. N. Y.: John Wiley & Sons 512 p.

[34] Adani F, Ricca G, Tambone F, Genevini P 2006 Isolation of the stable fraction, the core of the humic acid *Chemosphere* **65(8)** 1300–1307.

[35] Schnitzer M, Calderoni G 1985 Some chemical characteristics of paleosol humic acids *Chem. Geol.* **53**(3–4) 175–184

[36] Chen Y, Senesi N, Schnitzer M 1977 Information provided on humic substances by E4/E6 ratios. *Soil Sci. Soc. Am.* **41** 352