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FULL PAPER

Investigation of physical and chemical heterogeneity of lake sediment sapropols in the Okreg-Yugra territory of khanty-mansi autonomous region (Russia)

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The results of statistical processing of the physicochemical parameters of sapropel of lake deposits of the territory of the Khanty-Mansi Autonomous Okrug-Yugra are presented, which indicate that the heterogeneity of the composition and properties of sapropel is primarily determined by the available geographical position of the studied lakes: Their confinement to the right or left banks of the Ob River valley depend on the composition of the parent substrate the lake basins are formed on. The geomorphological factor imposes a minimal effect on the variability of the physicochemical characteristics of sapropel, being reflected only in the 4th most important of the identified factors. In contrast, none of the factors affects the deterioration of the balneological properties of sapropel.

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KEYWORDS

Western Siberia; Khanty-Mansi autonomous Okrug–Yugra; lakes; sapropel; factor analysis.

Introduction

The territory of the Khanty-Mansi Autonomous Okrug - Yugra is the largest bog zone, represented by heavily watered and overgrown oligotrophic bog systems, mainly with ridge-lake and ridge-lake-hollow complexes [1-3]; swamps cover 33.9% of the territory of the Khanty-Mansi Autonomous Okrug. There are also 300 thousand lakes in the okrug. 5.7% of the territory is underwater: The Khanty-Mansiysky district by 8%, the Surgut sky district by 8.3%, the Beloyarsky district by 9.8%, and the Sovetsky district by 0.7%.

Sapropels [4,5] are organic mineral bottom sediments of predominantly freshwater reservoirs. The main composition of the organic matter of Sapropels is formed of the remains of plant and animal organisms dying off in the reservoir, partly replenished by bringing in organic matter from outside. The amount and composition of the mineral components of Sapropels depend on the feeding conditions, the chemical composition of the waters feeding the reservoirs, and erosion processes [6-9]. Complex physical, chemical, and biological processes enrich Sapropels and organic matter with calcium, phosphorus, iron, trace elements, and physiologically active substances. Usually, Sapropels are odorless; only some varieties smell like hydrogen sulfide. The waters of sapropel deposits have a neutral or even alkaline reaction, less often slightly acidic [10,11].

Sapropel deposits have been identified in 160 of the 400 lakes studied in the district. We have found sapropel-containing lakes are localized mainly within the first and second, less often - the third river terraces above the floodplain [12,13]. The lakes within the floodplain part of the rivers do not contain sapropel.

Sapropel deposits are found in lakes in elongated lenticular bodies lying in the upper bottom deposits. The uppermost layers of sapropel, called pelogen, are heavily watered, liquefied, and unformed. In these layers, sapropel is formed from the primary mass of dead plankton. With depth, the jelly-like mass of sapropel gradually becomes denser. In the lower parts, the sapropel deposits have a jelly-like appearance. The color is dark olive, brown, gray, gray-yellow. It indicates the presence of some organic and inorganic components. The thickness of the sapropel deposits varies from fractions of 1-10 m and more [14-16].

Methods

The work was completed following past research [1,7]. In the preparatory period, aerial and satellite images were studied and interpreted to identify the boundaries of the terraces above the floodplain and determine surface areas with the possible development of sapropel-bearing lakes. Field studies were conducted near settlements 4-5 km along the existing access roads based on the accessibility of the studied objects for their development. The studies of the lakes excluded entities located in areas of visible manufactured pollution.

Field studies included probing of bottom sediments, registering the obtained sediment core, and sampling of sapropel for laboratory research [17-20]. A hole was drilled in the ice at the sounding point, and a hand probe with a sampler was then inserted into it. A core taken from the bottom sediments was studied and documented on-site (Figure 1). If there was sapropel in the core, a sample weighing at least 5.5 kg was taken from it. The taken sample was hermetically sealed and wrapped in heat-insulating material to prevent freezing.

FIGURE 1 Sampling of sapropel from the core material

Laboratory and analytical studies were carried out in the Federal State Budgetary Institution "National Medical Research Center for Rehabilitation and Balneology" of the Ministry of Health of the Russian Federation. A sampling of sapropel for laboratory and analytical studies considered the following factors: The quality of the sapropel (consistency, sandiness, debris), the spatial location of the sapropel deposit, which affects the sampling conditions (preferably a small area of lakes, the depth of the deposit 1-3 m from the water surface, and the thickness of the deposit up to 4 m).

The studies involved the following types of tests: Complete physical and chemical analysis (consistency, color, odor, volumetric weight, shear resistance, contamination with mineral particles larger than 0.25 mm (including larger than 0.5 mm), the nature of the contamination, pH, Eh, humidity, heat capacity, iron sulfide content), content of radionuclides (Ra226, Th232, Ce137, K40, Sr40, total alpha, beta and gamma activity), the content of heavy metals (Zn, Mn, Cu, Hg, Ni, Co, Pb, Cd, Cr), and sanitary and microbiological analysis (total microbial number of TMP, coliform bacteria, sulfate-reducing clostridia, pathogenic microorganisms) in compliance with past research [6,8].

The sapropel composition was determined by the water and organic matter content, the ash content of dry matter, and the ash composition. The composition of the sapropel extraction was analyzed with the determination of anions and cations, the total mineralization, and the formula of the chemical composition of the extract.

For statistical studies, 23 physicochemical parameters were used (the first column of Table 1); we do not present the results of analytical studies due to the cumbersome summary Table.

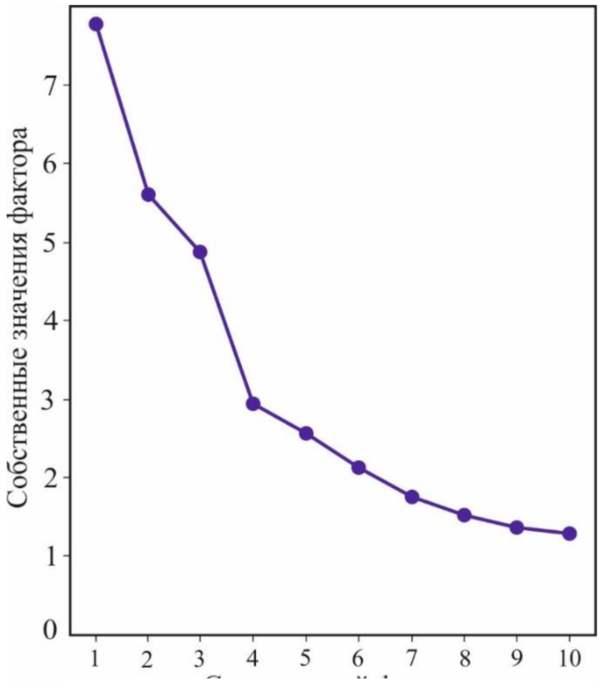
Results and discussion

Statistical studies were performed using the Statistical 13 Trial software package by factor analysis [12] (principal component analysis) to preserve 4 factors. The number of saved factors was determined following the "scree" criterion [9] (Figure 2) - a curve showing the eigenvalues of each factor (amount of dispersion produced by each of 10 factors). Decrease of eigenvalues from left to the right slows down as much as possible after displaying information on the 4th factor.

We obtained a matrix of factor loads based on factor analysis to maximize the variance by varimax rotation (Table 1). The specified table highlights the loads for the initial data, which are more than 0.5; that is, they are the most important in this factor.

TABLE 1 Characteristics of the selected factors

Properties	Factors			
	1	2	3	4
Shear strength	0.275	-0.142	**-0.865**	-0.014
Eh	-0.052	**-0.671**	0.159	-0.273
Humidity	**-0.843**	0.095	0,410	-0.053
Heat capacity	**-0.852**	0.119	0.380	-0.058
percentage of other impurities	0,231	-0.089	**-0.808**	-0.105
Ash content	**0.915**	-0.061	-0.004	0.137
Insoluble residue	0.248	-0.428	**0.742**	0.076
CaO	-0.381	-0.193	**-0.675**	-0.273
SO_3	-0.079	0.228	**-0.707**	-0.204
Zn	-0.164	0.223	0.021	**0.726**
Mn	-0.011	**0.665**	0.062	0.295
Ni	0.164	0.031	0.192	**0.908**
Co	-0.001	0.095	0.127	**0.909**
Cr	-0.114	0.027	0.092	**0.886**
Ca	**0.763**	0.159	0.015	0.046
Mg	**0.617**	0.156	0.292	0.081
Fe^{+3}	0.161	**0.638**	-0.014	0.091
Fe^{+2}	0.129	**0.804**	0.032	0.185
SO_4	**0.791**	0.208	0.221	0.068
HCO_3	0.308	**-0.586**	-0.217	0,077
K^{40}	**0.798**	-0.394	-0.126	-0.028
alpha-activity	**0.770**	0.109	0.025	-0.065
beta-activity	**0.896**	-0.226	-0.115	0.016
Expl.Var	7.640	4.891	4.751	3.909
Prp.Totl	0.196	0.125	0.122	0.100



Preserved factor

FIGURE 2 Rationale for the number of preserved factors according to the criterion of "scree"

Factor one

As the table of factor loads shows, the following parameters are characterized by positive values: Ash content, calcium, magnesium, sulfates, K^{40}, alpha and beta activity, negative - heat capacity, and humidity.

A possible interpretation for this factor is as follows. Based on the list of certain components, the ash content of the studied sapropel is due to calcium and magnesium sulfates, which, if it contains radioactive K40, causes an increase in alpha and beta activity. In turn, the high ash content of sapropel and the increased role of calcium and magnesium sulfates contribute to a decrease in its heat capacity and moisture content.

Factor two

It is due to the positive values of the factor load for manganese and iron and the negative for Eh and hydrocarbons. That is, with an increase in the content of iron and manganese in sapropels, the values of the redox potential and the content of hydrocarbons decrease.

Factor three

This factor may reflect a direct relationship between the value of shear resistance and the content of organic substances (percentage of other impurities), and the opposite - the insoluble residue content.

Factor four

It characterizes the enrichment (depletion) of sapropel with heavy metals.

Actual values of factors for individual observations (sapropel sampling points) are presented in Table 2.

The sampling sites make it possible to construct a sub-latitudinal profile, passing through the Sovetsky, Khanty-Mansiysky, Surgutsky, and Nizhnevartovsky districts. The profile is based on observation sites located both in the left and right banks of the Ob River. This fact manifests itself in the significance of the identified factors for individual observation points (Figure 3).

TABLE 2 Values of factors for individual observations

Sites of observation	Factors			
	1	2	3	4
5-К	0.08	1.86	0.30	-0.49
16-К	-0.29	-0.57	0.40	-0.49
2-Х	-0.73	-0.38	0.71	-0.69
11-Х	0.10	-0.62	0.83	-0.87
14-Х	-0.79	-0.67	0.55	-0.48
21-Х	-0.81	-0.22	0.38	-0.88
28-Х	-0.68	-0.90	0.84	-0.35
32-Х	-0.74	-0.28	0.37	-0.60
95-Х	2.67	-1.45	0.19	1.13
98-Х	-0.36	-0.91	1.09	-0.49
99-Х	-0.60	-0.89	0.71	-0.49
12-НЖ	0.70	0.80	0.13	1.41
25-НЖ	-0.98	-0.01	0.19	-0.92
26-НЖ	0.90	-0.39	0.51	-0.68
39-НЖ	-0.76	-0.37	-1.39	-0.99
89-НЖ	-0.39	1.42	0.40	0.16
99-НЖ	2.44	0.63	0.44	-0.36
121-НЖ	1.94	-1.44	-1.76	0.04
14-С	-0.24	2.80	0.34	0.51
89-С	0.67	1.93	0.23	-0.40
106-С	0.53	0.59	0.49	0.10
108-С	1.67	0.62	-0.94	-0.82
149-С	-0.44	0.05	0.02	1.21
189-С	-0.33	1.41	-0.45	0.94
209-С	0.37	-0.48	0.60	-0.92
80-Н	-0.67	-0.08	0.10	-0.69
2-СВ	-0.87	-0.61	0.17	3.25
23-СВ	0.56	-0.85	1.06	0.82
24-СВ	-0.75	-0.19	-0.39	0.34
25-СВ	-0.97	-0.66	-0.23	2.32
8-О	-0.65	0.04	-2.77	-0.33
19-О	-0.55	-0.18	-3.15	-0.29

The general condition of the observed features of the identified factors 1, 2, and 3 for individual observation sites is undoubtedly the general geographical position of the studied lakes: Their confinement to the right or left bank of the Ob river valley. In this case, most likely, the composition of the parent substrate on which the lake basins are formed becomes very important. On the left bank (within which the lakes of the Sovetsky and Khanty-Mansiysky districts were studied), the parent substrate is mainly quartz-feldspar sands. In contrast, on the right bank (Surgutsky and Nizhnevartovsky districts) it is clay and loamy sediments [5].

This is consistent with the earlier conclusions made based on other analytical data [11].

The geomorphological features of the location of the lakes with the samples taken from the lakes located on the II and IV river terraces are reflected only in the fourth preserved factor; all the studied lakes of the Sovetsky district are located within the IV river terrace.

We should note practically identical balneological properties of sapropel from lakes on both the right and left banks of the Ob river [4,10].

Legend: 1 - a sampling site and its number; 2 - border of the Khanty-Mansi Autonomous Okrug - Yugra; 3 - boundaries of administrative districts; 4 - line of geochemical profile

Note on the sampling site marking: K - Kondinsky district, Kh - Khanty-Mansiysky district, NZh - Nizhnevartovsky district, SV - Sovetsky district, S - Surgutsky district, N - Nefteyugansky district, O - Oktyabrsky district.

Conclusion

The introduced aftereffects of measurable handling of the physicochemical boundaries of sapropel of lake stores of the domain of the Khanty-Mansi Autonomous Okrug - Yugra demonstrate the heterogeneity of the piece and properties of not really settled ones fundamentally by the overall topographical situation of the concentrated on lakes; their repression to the right or left banks of the Ob waterway valley rely upon the arrangement of the parent substrate the lake bowls are shaped on.

The geomorphological factor forces an insignificant impact on the inconstancy of the physicochemical attributes of sapropel, being reflected uniquely in the fourth generally significant of the recognized elements, while none of the components influences the decay of the balneological properties of sapropel.

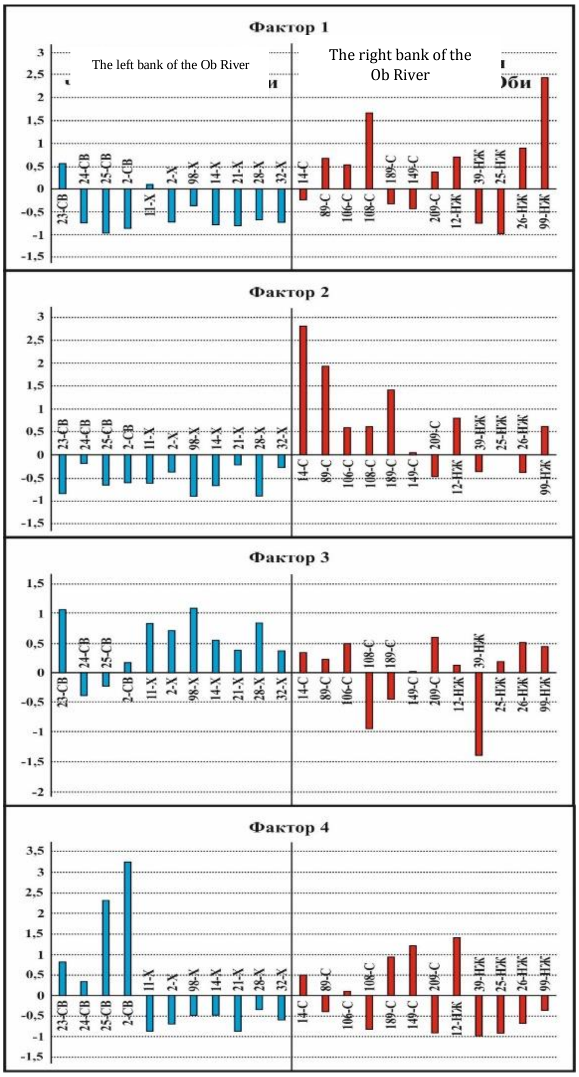


FIGURE 3 Values of the identified factors for individual observation sites on the geochemical profile map

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