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Influence of climatic and hydrological factors on structure and composition of peat from northern wetland territories with low anthropogenic impact

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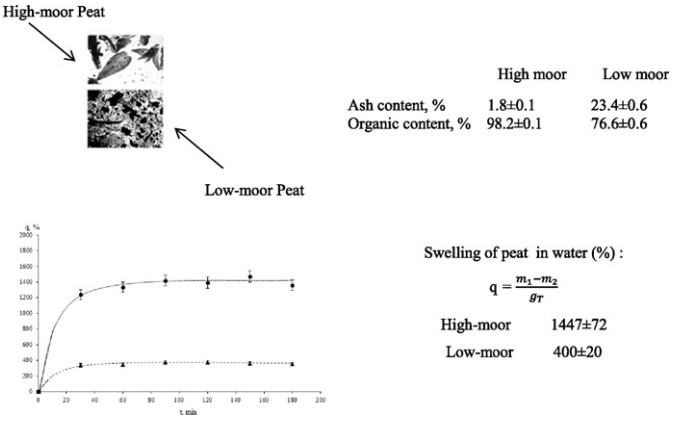
HIGHLIGHTS

- Experimental determination of component and element composition of peat
- Influence of hydrological and climatic factors on peat properties
- The structural organization at different levels (macro-, micro-and nano-levels)
- Degree of peat swelling can be used as structural-sensitive parameter

GRAPHICAL ABSTRACT



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ABSTRACT

Northern wetlands ecosystems play an important role in the hydrological balance of neighboring areas, where they act as chemical barriers against anthropogenic and technogenic contaminations. Studied region is well known for quantity of peat deposits and the volume of peat resources. Peat can be considered as a highly informative marker for assessing change in environmental conditions. The study presents the results of the first investigation of peat samples, collected from representative ecosystems of northern wetland territories with low anthropogenic impact.

Component and element composition of various peat types were studied in a relation to hydrologic, climate and sampling conditions. It was found out that organic and ash contents are more dependent on the type of the bog, than geographic location. Climatic factors are more important for the formation of bitumen. The degradation degree in peat increases proportionally to content of humates. High content of biogenic and lithogenic elements was observed in transition- and low-moor peat. The content of trace elements in peat samples do not depend on the type of the peat.

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Dynamic light scattering
AFM
Swelling degree

The structural properties of peat were studied by the light microscopy, AFM and dynamic light scattering. It was determined that the conformation of studied peat samples is characterized by elements of asymmetry. The observed particles in the solutions exist in dynamic equilibrium with separated globular macromolecules. The size of these nanoparticles is comparable with the size of the particles of other biopolymers of similar nature. Swelling of peat in liquid water was studied. The relationship between structural specificities, origin of peat and its maximum degree of swelling was found. The degree of swelling can be used as structural-sensitive parameter in further research.

1. Introduction

Wetlands are vital ecosystems, they plays very important role in the hydrological balance of the neighboring areas, acting as geochemical barriers against anthropogenic and technogenic contaminations, and provide the habitat for unique living organisms. Such territories have a significant impact on the traditional economic activities in the region, but on the other hand complicate its industrial development (Turner et al., 2000).

Peat lands are wetlands with a thick water-logged organic soil layer (peat) made up of dead and decaying plant material, they represent half of the Earth's wetlands and cover 3% of the global total land area and contain twice as much carbon stock as the entire forest biomass of the world (400–600 Gt carbon, Frolking et al., 2011). Most of such areas (c. 350 million ha) are present in northern hemisphere, covering large areas in North America, Russia and Europe. Northern peat lands developed mostly after the last deglaciation in the circum-Arctic region and represent one of the largest carbon pools in the biosphere (Yu, 2012, Strack, 2008). Their dynamics have played an important role in the global carbon cycle during the Holocene (Gorham, 1991; Yu, 2012), and it has become essential to include peat lands in the modeling and analysis of the global carbon cycle to constrain the changes in other carbon reservoirs (Kleinen et al., 2010; Menviel and Joos, 2012) and in the discussion of relative roles of anthropogenic and natural processes (Ruddiman et al., 2011; Comas et al., 2014). About 60% of the world's peat lands are found in Russia, particularly in Siberia. These peat lands cover an area of more than 300 million ha (Bleuten et al., 2006). Perhaps, the largest single high-moor bog in the world, covering some 5.16 million ha is found in West Siberia, where the elements of the carbon balance are best studied (Inisheva, 2002; Kalyuzhny and Lavrov, 2005; Naumov, 2001, 2002). Russian European North is also characterized by the high density of peat lands, but peat bog ecosystems of this area are not well investigated.

Arkhangelsk region with the total area of wetlands of 5.8 million ha has the second largest peat resource in the Northern economic area, but only 1.2 million ha were studied in varying degree during exploration. Among the wetlands studied in mentioned above region 73% belong to the high-moor, 8% to the transition-moor and 19% to the low-moor peat bogs (Romão et al., 2007). Several national parks and protected zones are situated in this area and serve as a research polygons for interdisciplinary teams (Nakvasina and Fedotov, 2006; Romanyuk, 2010; Ovsepyan and Masyk, 2010).

Decomposition (humification) of peat is related to its physical, chemical, and mechanical properties. It is very complex process and includes degradation and synthetic reactions, which are dependent on different conditions both geographically (from tropical regions to the Arctic environment) and climatically. During peat formation even at one particular site, significant changes could occur in vegetation, temperature, amount of precipitation, etc., and such changes can be a subject of systematic study (Klavins and Purmalis, 2013). The impact of these conditions on peat formation in Western Siberia was discussed in details by several authors (Inisheva et al., 2013; Shinkeeva et al., 2011; Pokrovsky et al., 2014).

It is known that the physico-chemical properties of peat are strongly dependent on the composition of its phases and the quantitative relationships between them. The composition determines the structure of peat resource potential. The most important characteristics of the peat are its component and elemental content. Organic substances, formed during the decomposition of crop residues under permanent or long-lasting over wetting, predominates the composition of peat soils (Lishtvan and Loginov, 2002; Broder et al., 2012; Kuznetsov, 2012). Furthermore, bitumen or extractive resinous substances (ERS) should be considered as an important component, even they are present at much lower concentrations (Zaytseva, 2008; Zaytseva and Parmon, 2009).

This paper presents the results of the first investigation of peat samples from representative ecosystems of northern wetland territories with low anthropogenic impact. The aim of this study was the characterization of composition and structural organization of peat from these territories by different technics and the evaluation of the influence of different climatic and hydrological factors on physical and chemical properties of studied samples.

2. Materials and methods

2.1. Location and description of sampling sites

Ilas Marshes (IM) with total area of 8.9 thousand ha, situated in the Primorsky district of Arkhangelsk region, its landscape represents the system of oligotrophic (high-moor) bogs. The National Park "Kenozersky" (NPK) located in the southwest of Arkhangelsk region with total area of 139.7 thousand ha, characterized by the diversity of wetland systems (high-, transition-, low-moors) (Nakvasina and Fedotov, 2006). These two areas (IM and NPK) can be considered as a representative sites to obtain adequate information about the formation, physical and chemical properties of peat soils in the boreal zone (Parfenova et al., 2014a).

Peat samples were collected from different types of marshes at IM and NPK. The map given below (Fig. 1) presents the locations of sampling sites and theirs geographic coordinates.

2.2. Peat samples and chemicals

Peat samples were collected from sampling sites described in Section 2.1. Sampling was carried out for 5 years from 2009 to 2013 by the drilling from the depth of 50–70 cm, during the low water summer periods. Preliminary studies showed statistically insignificant differences in the component composition during collection period. Therefore the collected peat samples were randomized according to the standard procedure. Samples were dried at T = 298 K to air-dry state, and sieved through the sieve with pore diameter 2.0 mm. Samples will be called according to the type of marshes, where they were collected: high-moor, transition-moor and low-moor.

The chemicals used were procured from different sources: ethyl acetate ($CH_3COOC_2H_2$) from ComponentReactiv, hydrochloric acid (HCl) from NevaReativ, sodium hydroxide (NaOH) and sulphuric acid (H_2SO_4) from LenReactiv. All chemicals were extra pure grade (>99.9% purity). The water used was reagent grade Milli-Q water.

2.3. Scheme of determination of component composition of peat sample

Peat component composition was determined according to the scheme given on Fig. 2.