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HYDROPHOBICITY OF DISSOLVED ORGANIC CARBON IN FEN PEATLANDS

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SUMMARY

Peatlands contain various organic carbon fractions; among which dissolved and labile carbon are the most important, especially in drained peatlands, which are the source of CO_2 emissions. The research was carried out in fen (lowland) peatlands drained and used as grasslands, in NE Poland. Hydrophobicity is a very important parameter in peatlands protection, as it suggests the possibilities of water retention. Potential soil hydrophobicity can be measured using the Water Drop Penetration Time test. In this test the time of retention of drops of distilled water is measured. The aim of the study was to assess: (i) the hydrophobicity of a soil, and (ii) its content of hydrophobic/hydrophilic compounds, i.e. hot water-extractable carbon and cold water-extractable carbon fractions, using the solid phase extraction (SPE) technique. Hot water-extractable carbon and cold water-extractable carbon were divided into hydrophobic and hydrophilic fractions. The study revealed that both studied peatlands are hydrophobic. However, the peatland influenced by alluvial and deluvial processes had lower hydrophobicity. The extracts of HWC and CWC contained more hydrophilic fraction than hydrophobic one (the ratio of hydrophilic to hydrophobic fraction amounted to 4.032 in HWC extracts and 2.173 in CWC extracts) additionally, the extracts of HWC had diversified retention times (1.802-1.831 min.) in chromatographic analysis, whereas in case of CWC the retention times were similar (1.801-1.815 min.).

Keywords: *organic soil, water repellency, polarity*

INTRODUCTION

Globally, soil organic carbon plays an important role in carbon (C) cycling. It can be divided into labile and refractory carbon forms (Lützow *et al.*, 2007). Labile organic carbon compounds may oxidize easily and are degradable. The labile organic carbon fraction of organic soils can be extracted using for example hot and cold water and SPE technique. These two fractions respond to changes in C supply in organic soils very quickly (Zhang *et al.*, 2006) and may indicate changes occurring in land use. The hot water-extractable fraction corresponds with microbial biomass and is a good indicator of peatland transformations.

After drainage peatlands decrease their ability to retain water and become hydrophobic. In hydrophobic soils, absorption of water decreases and the filtration of water occur mainly through “preferential paths”, made by cracks and holes (Łachacz and Kalisz, 2006). High hydrophobicity often occurs in drained peats (Szatyłowicz *et al.*, 2006). Hydrophobicity is also dependent on the activity of microorganisms and soil physical and chemical properties. The amount and type of soil organic matter (quantity of labile and refractory carbon fractions) may influence soil hydrophobic / hydrophilic properties (Bisdom *et al.*, 1993; Maryganova, Szajdak, 2006). The quality of organic matter fractions (content of polar / non-polar groups of compounds; labile or refractory forms; content of fulvic acids, humic acids and humins) and their influence on soil hydrophobicity is of great importance. We decided to examine labile fraction of organic matter (dissolved organic carbon) and find out whether it influenced the hydrophobicity of drained peat soils used as grassland and influenced by alluvial and deluvial processes.

The aim of the study was to assess

- the potential hydrophobicity of studied soil
- amounts of dissolved organic carbon
- relations between hydrophobic and hydrophilic compounds which are present in cold and hot water extracts of drained peat soils.

METHODS

The study area was located in north-eastern Poland, which was shaped during the period of the Vistulian Glaciation. The studied peat soils were drained in 20th century. Peat samples were taken from surface horizons (0-30cm) from two drained peatlands used as grasslands (A) and two peatlands modified by alluvial and deluvial processes (B). Organic matter (OM) content was calculated on the basis of loss-on-ignition after dry ashing of soil samples for 6 hours at a temperature of 550ºC. The hydrophobicity of the samples was determined at 20ºC using the Water Drop Penetration Time (WDPT) test (Doerr, 1998). This test was carried out on air-dried soil samples therefore the results reflect potential hydrophobicity and are regarded as a proxy for soil hydrophobicity. Based on the time taken for the water drop to infiltrate the soil sample, the studied peat soils were classified according to the following classes:

Class 1 – hydrophilic (WDPT < 5s);
Class 2 – slightly hydrophobic (5 < WDPT ≤ 60s);
Class 3 – strongly hydrophobic (60 < WDPT ≤ 600s);
Class 4 – very strongly hydrophobic (600 < WDPT ≤ 3600s);
Class 5 – extremely hydrophobic (WDPT > 3600s).

Two types of dissolved organic carbon were determined: hot water-extractable carbon (HWC) and cold water-extractable carbon (CWC). The hot-water extractable C was determined in air-dried soil samples according to the method described by Sparling *et al.* (1998) with the incubation of soil samples at 70 ºC for 18 h. Cold water extractable carbon was determined in air-dried soil samples according to Landgraf *et al.* (2006). The HWC and CWC quantities were measured using a TOC (total organic carbon) analyzer (Multi NC 3100 Analityk Jena). All measurements were carried out in triplicate.
In the study, the method of extraction of organic matter dissolved in hot and cold water to solid phase using modified polymeric sorbents was applied. It is not commonly used in the soil science but is frequently used in the studies of surface waters. Hydrophilic (with higher polarity) and hydrophobic fractions were separated from HWC extracts using SPE (Solid Phase Extraction) technique and STRATA-X Phenomenex 30 mg 30 µm columns. The obtained fractions were studied chromatographically.

RESULTS

The studied peat horizons contained 53-80% of organic matter on average (Table 1). The hydrophobicity of studied peat horizons was high (3344.48-11788.69s on average) and was related to organic matter content. Extreme hydrophobicity and a WDPT exceeding 1 hour (Class 5 of WDPT) was recorded in peatlands used as grasslands (A). Various classes of hydrophobicity (Class 2-5 of WDPT) were stated in peat horizons influenced by alluvial and deluvial processes (B) (Table 1).

Studied surface horizons of peatlands contained more carbon extracted with hot water than with cold water. Peatlands used as grasslands contained more HWC than the peatlands modified by alluvial and deluvial processes but in the case of CWC, the tendency was the reverse (Table 1).

Table 1: Amounts of hot water-extractable and cold water-extractable fractions.

	WDPT	OM	HWC	CWC	WDPT	OM	HWC	CWC
	s	g kg^{-1}			s	g kg^{-1}		
	A (Grasslands)				B (Alluvial and deluvial influence)			
mean	11788.69	806.98	5.00	0.74	3344.48	535.77	3.54	0.85
min	4157.55	690.74	4.00	0.46	155.60	304.88	2.12	0.20
max	24098.00	892.45	6.07	0.94	6578.00	776.33	5.31	1.19
SD	6376.46	66.42	0.60	0.17	2674.16	158.81	1.10	0.31

The extracts of HWC and CWC contained more hydrophilic fraction than hydrophobic one (the ratio of hydrophilic to hydrophobic fraction amounted to 4.032 in HWC extracts and 2.173 in CWC extracts) additionally, the extracts of HWC had diversified retention times (1.802-1.831 min.) in chromatographic analysis, whereas in case of CWC the retention times were similar (1.801-1.815 min.).

DISCUSSION

Generally, hydrophobicity occurs in the soils containing more than 20% of organic matter. Apart from the amount of organic matter, the activity of microorganisms also influences the repellency of a soil (Doerr *et al.*, 2000). Deluvial and alluvial admixtures stabilize organic matter (Orzechowski *et al.*, 2013) and decrease hydrophobicity. The study revealed that both studied peatlands are hydrophobic. However, the peatland influenced by alluvial and deluvial processes had lower hydrophobicity. The study revealed that there is a correlation between hydrophobicity and amount of organic matter but the relation between hydrophobicity and hot water-extractable carbon, which corresponds to microbial biomass, is insignificant (Figure 1).

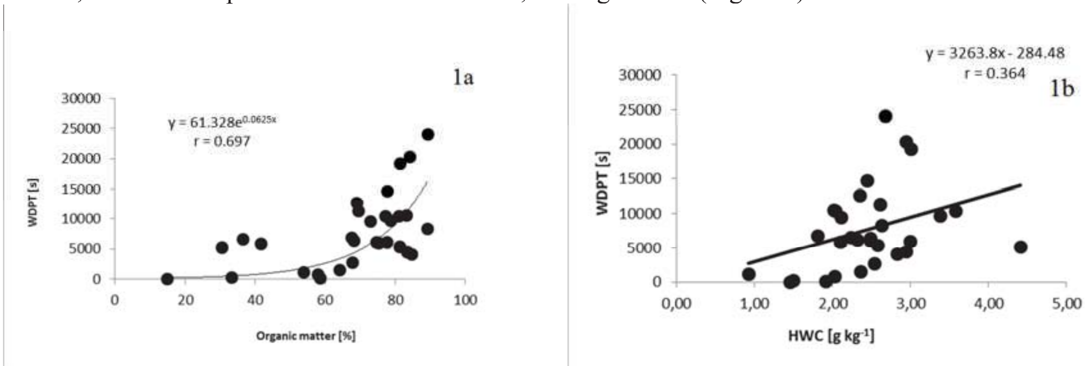

Figure 1: Relationship between the water absorption time in WDPT test (in seconds) and the content of organic matter (1a) and hot water-extractable fraction (in g kg^{-1}) (1b).

The chromatographic analysis of HWC extracts revealed that the polarity of hydrophilic and hydrophobic fractions are similar, as are the retention times. The retention time depends on the polarity of organic fraction and the mass of the molecules. The higher the polarity of the fraction and higher the mass of the molecule, the longer the retention time. The relationship between the hydrophobic fraction of HWC expressed as the peak on the chromatogram and organic matter content or hydrophobicity was weak and insignificant (Figure 2). Similar relations were stated for hydrophilic fraction of HWC. However, the chromatographic analyses revealed the relationship between the retention time of hydrophobic or hydrophilic fractions of HWC and the hydrophobicity but the correlation was negative (Figure 3). The peatland influenced by alluvial and deluvial processes had varied retention time and lower hydrophobicity whereas peatland used as grassland had varied hydrophobicity with more similar retention times (Table 1, Figure 3). This suggests that less hydrophobic peats had longer retention times, i.e. HWC extracts of those peats had higher polarity and mass of molecules in a chemical sense. To conclude, composition of dissolved organic carbon fraction does not reveal direct relation to the potential hydrophobicity of a peatland.

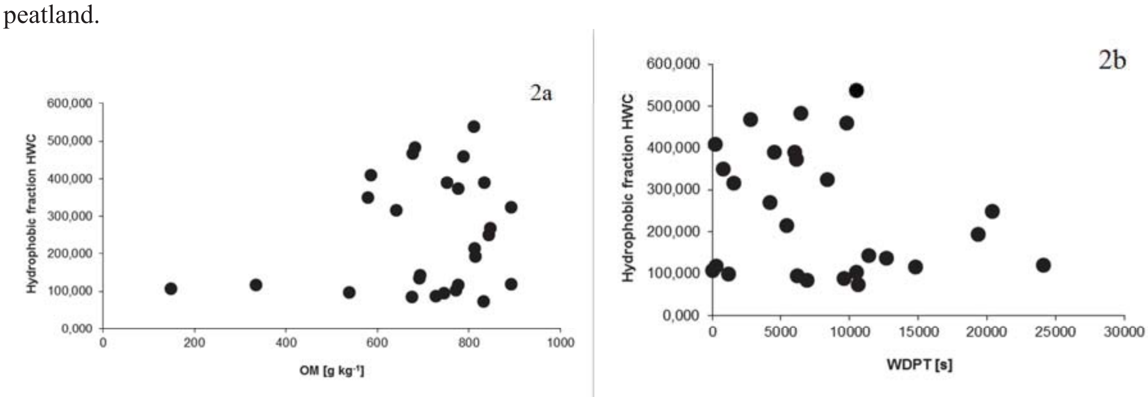

Figure 2: Relationship between hydrophobic fraction of HWC (expressed as a peak on chromatogram) and the amount of organic matter (2a) and hydrophobicity (WDPT) (2b).

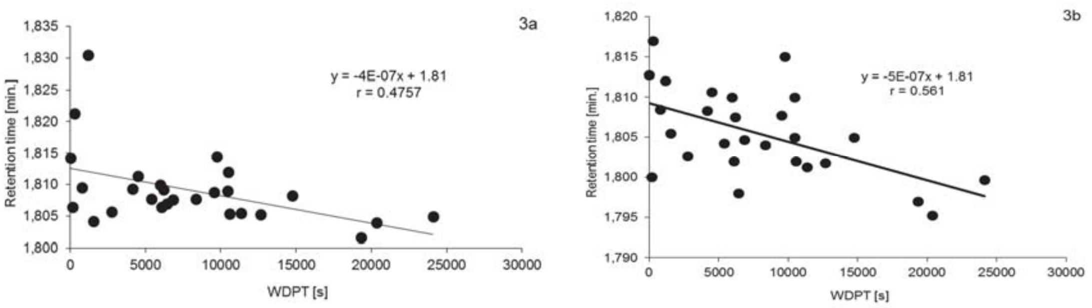

Figure 3: Relationship between the retention time of hydrophobic (3a) and hydrophilic (3b) fraction and the hydrophobicity (WDPT).

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