INTRODUCTION

In the process of transformation of organic formations, wettability is an important property, highly differentiated particularly in layers with variable humidity (Morley et al., 2005), rich in organic matter (Wallis and Horne, 1992). The moorsh process results in organic formations becoming more hydrophobic. This is of significance to environmental issues (Berglund and Person, 1996). Fires on soil organic matters, occurring increasingly frequently throughout the world, modify the water-absorbing properties of soils by increasing their temperature (Doerr et al., 2004). This effect is among others related to the dehydration of soil colloids (Bauters et al., 2000).

Surface and ground fires affect the structure (Hallet and Young, 1999), fibre content (Bogacz et al., 2011), degree of decomposition of organic matter (De Bando et al., 1970; De Bando et al., 1976; Raison et al., 1986), and erosion of soils (Shakesby and Doerr, 2006).

The objective of this research was to determine the degree of organic matter transformation in strongly dried post-fire soils of the Lower Silesia region with the application of various research methods.

STUDY OBJECTS

The study objects were soils of forest areas: Cho- cianów – object Gromadka (GR), Wołów-Mikorzy- ce-Górowo (MG), and meadow soils from Lubsko (LU) and Sobin-Jędrzychów (SJ). Organic soil fires in the aforementioned forest areas occurred between 1986 and 1992. Meadow soil fires occurred in 2006 and 2008. Before the fires, the soils were composed of strongly dried moorsh layers at a medium or strong moorsh degree. The soils were classified as moorsh soils and peat-moorsh soils, hemic or sapric (Komisja V Genezy, Klasyfikacji i Kartografii Gleb PTG, 2011). Organic matter peat accumulated on sand or sand and gravel formations in fluvial valleys. Such sand formations sometimes contain silty insertions. Low peat horizons were represented by the following genera: Carex sp. and Alnus sp. (Bogacz et al., 2010). Under the moorsh layer, medium deep peats were deposited (MtIb1 and MtIIIc1). After the soil fires, shallow moorsh-peat soils with visible horizons or ash admixture were frequently encountered.

On strongly burnt surfaces, soils categorised as organic-mineral soils (Me11 or Mmr11) were also recorded. According to the currently binding Classification of Polish Soils (Komisja V Genezy, Klasyfikacji i Kartografii Gleb PTG, 2011), these soils may be classified as gley, peat, or peat-gley soils (Bogacz et al., 2011). Post-fire forest communities were represented by alder swamp forests (Alnus sp.), marshy coniferous forests, and birch swamp forests. Meadow communities were only represented by Carex sp. and post-fire substitute communities most frequ-
ently classified as *Molinio Arrhenatheretea*, with high dominance of grass, nettles, and alder seedlings (Bogacz et al., 2006; Bogacz et al., 2010; Bogacz et al., 2011).

The following is an example morphological description of post-fire soil profile Mikorzyce-Górowo:

<table>
<thead>
<tr>
<th>Ol’</th>
<th>0–2 cm</th>
<th>mull type organic horizon, wet, with <em>Alnus</em> sp. and <em>Betula</em> sp. leaves fragments, moist, abrupt distinctness and smooth topography boundaries of horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt</td>
<td>2–10 cm</td>
<td>moorsh horizon, fine grain structure, 7.5YR 3/3 gray, moist, abrupt distinctness and smooth topography boundaries of horizons</td>
</tr>
<tr>
<td>Oa1</td>
<td>10–28 cm</td>
<td>low peat horizon, smoldered, fragments of smoldered wood and peat, colour of peat 10YR 2/1 black, colour of smoldered fragments N 2/0 black, strongly decomposed peat R3, amorphous-blocky structure, wet, abrupt distinctness and smooth topography boundaries of horizons</td>
</tr>
<tr>
<td>Oa2</td>
<td>28–48 cm</td>
<td>transitional peat horizon, strongly decomposed peat R3, 10YR 2/1 black, amorphous-blocky structure, some smoldered wood in smoldered peat, wet, some redoxymorphic features – fine iron mottles, abrupt distinctness and wavy topography boundaries of horizons</td>
</tr>
<tr>
<td>Oi</td>
<td>48–67 cm</td>
<td>transitional peat horizon, low decomposed peat R1, 10YR 5/6 yellowish brown, wet, fibre structure, presence of H,S, abrupt distinctness and smooth topography boundaries of horizons</td>
</tr>
<tr>
<td>Oc</td>
<td>67–92 cm</td>
<td>transitional peat horizon, low decomposed peat R1, 10YR 4/3 dark gray, wet, amorphous-blocky structure, presence of H,S, thin sandy layers, abrupt distinctness and smooth topography boundaries of horizons</td>
</tr>
<tr>
<td>C</td>
<td>≥92 cm</td>
<td>mineral horizon, sandy – fine gravel material, 5GY 5/1 greenish gray, very wet, gley properties</td>
</tr>
</tbody>
</table>

Soil definition (Komisja V Gieniecy, Klasyfikacja i Kartografii Gleb, PTG 2011): moorsh soil, low intensity of moorsh process, developed from strongly decomposed peat R3 on medium R2 and low R1 decomposed peat, with thin sandy layers on sand (Mtlb1). WRB 2006 – Hemic Histosols (Eutric Dericic Fluvic)

**STUDY METHODS**

The study on the degree of transformation of post-fire organic soils covered a total of 24 soil profiles, described in detail in terms of morphology. The described profiles were represented by 98 soil samples. The soil samples were divided into groups covering: organic-mineral formations, containing between 5 and 20% of organic matter (7 samples), ashes remaining after peat burning (7 samples), moorsh (25 samples), peats (44 samples), and humus layers (10 samples). Values of the following transformation degree indicators were determined: organic soil formation water capacity indicator ($W_1$) by Gawlik (1996) and potential wettability. The indicator values were determined by means of the following tests: water drop penetration time (WDPT) (Vant’Woudt, 1959) and ethanol drop penetration time in soil formations (MED) (Letey et al., 2000). The measurements were conducted at a temperature of 20°C. Mean test results based on 10 tests are presented in Table 1, Table 2 and Figs. 1–5. The study also covered organic carbon content (OC) following removal of carbonates, determined by means of the gas analysis method in a CS-MAT 5500 device, as well as degree of decomposition of organic matter, measured by means of the half syringe method (Lynn et al., 1974) based the content of so-called rubbed fibre or decomposition resistant fibre – unrubbed (B), and on the absorbency measurement method in soil extractions in 1mol NaOH dcm$^{-3}$ following Sapek and Sapek (1997). Results regarding the degree of decomposition are pre-

**RESULTS AND DISCUSSION**

Genetic horizons of post-fire transformed soils are primarily distinguished by a strong diversification of organic carbon content (OC) resulting from different intensity of fires and time of their occurrence (Forbes et al., 2006). The study showed higher mean OC contents in moorshes than in peats. This phenomenon might be caused by low temperature fires, frequently occurring in deep moorsh. At low oxygen availability, a process similar to pyrolysis results in an increase in carbon content in analysed samples. Low temperature fires often increase carbon content by as much as 30–50% before a fire incident (Ponomarienko and Anderson, 2001; Forbes et al., 2006). Such a possibility is described by Efremova and Efremov (2006), who studied fires of large areas of Siberian peats. Peat or moorsh burning also results in a decrease in the volume of decomposition-resistant fibre (B). Results presented in Table 1 classify organic matters as sapric ones, and only in some cases as hemic ones.

One of the physical indicators used to evaluate transformation of secondary organic formations is $W_1$ – absorbing capacity by Gawlik (1996). It is applicable to the diagnosis of moorsh horizons in different

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decession phases, distinguished earlier during field works. The
threshold value for the W1 indicator is 0.35 for low ash forma-
tions, and 0.41 for high ash formations. It distinguishes peats
showing no secondary transformation symptoms from moorsh
(Gawlik, 1996). For the majority of genetic horizons of organic
soils and organic-mineral soils, the study results were equivalent
to field observations. GR soils were distinguished by an initial
(I) or low (II) degree of secondary transformation only in cer-
tain surface or subsurface horizons. A higher degree of
transformation occurred in horizons with ashes. Soils of the second forest object (MG) were much
stronger transformed than GR soils, and were distin-
guished by an initial (I), weak (II), or medium (III)
degree of secondary transformation. Peat transforma-
tion sometimes covered the entire soil profiles. A si-
gnificant degree of transformation in the analysed
organic formations of meadow areas LU SJ was ob-
served in all of the organic horizons of the second
meadow object (SJ). Surface horizons were frequen-
tly determined as subject to strong secondary trans-
formation.

<p>| TABLE 1. Coefficients of the degree of transformation of soil formations |
|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Type of formation</th>
<th>OC mg kg⁻¹</th>
<th>B %</th>
<th>Type of organic material</th>
<th>W₁</th>
<th>WDPT [s]</th>
<th>MED class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litter</td>
<td>139–466</td>
<td>4–33</td>
<td>hemic sapric</td>
<td>–</td>
<td>4–19260</td>
<td>2–7</td>
</tr>
<tr>
<td>Peat</td>
<td>127–511</td>
<td>2–40</td>
<td>hemic sapric</td>
<td>0.10–0.87</td>
<td>3–32400</td>
<td>1–7</td>
</tr>
<tr>
<td>Moorsh</td>
<td>253–497</td>
<td>1–39</td>
<td>hemic sapric</td>
<td>0.10–0.96</td>
<td>165–31320</td>
<td>2–7</td>
</tr>
<tr>
<td>Ash</td>
<td>25.5–112</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1–3771</td>
<td>1–5</td>
</tr>
<tr>
<td>Organic-mineral</td>
<td>55.5–109</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>3–32400</td>
<td>1–6</td>
</tr>
</tbody>
</table>

Explanation: W₁ – water absorption coefficient, WDPT – water drop penetration time, MED – molar-
ty ethanol droplet, B – unrubbed fibre, OC – organic carbon.

| FIGURE 1. Number of soil samples within water absorption classes in post-fire areas based on the MED test |
|-----------------|-----------------|-----------------|-----------------|-----------------|

<p>| TABLE 2. Summary of results of MED and WDPT tests in the scope of analysis of hydrophobic properties |
|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>MED class</th>
<th>Name of class</th>
<th>C₅H₁₀OH [%]</th>
<th>WDPT [s]</th>
<th>MED class</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>extremely hydrophobic</td>
<td>36</td>
<td>&lt;5</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>very strongly hydrophobic</td>
<td>24</td>
<td>5–60</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>strongly hydrophobic</td>
<td>13</td>
<td>60–180</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>moderately hydrophobic</td>
<td>8.5</td>
<td>180–360</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>slightly hydrophobic</td>
<td>5</td>
<td>360–18000</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>hydrophobic</td>
<td>3</td>
<td>&gt;18000</td>
<td>–</td>
</tr>
<tr>
<td>1</td>
<td>very hydrophobic</td>
<td>0</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>
Impact of fire on values of organic material transformation indicators
dary transformation. The initial stage of transformation (I) was represented by 14% of samples, low degree of transformation (II) – by 12%, medium degree of transformation (III) – by 14%, high degree of transformation (IV) – by 7%, and the degraded stage (V) – by 4%. The latter group involved surface horizons of burnt moorsh. The study results show a substantially higher degree of transformation of organic meadow formations in relation to the forest soils (Fig. 1, Fig. 2 and Fig. 3).

Based on wettability tests WDPT and MED, more than 60% of the analysed soil samples were classified to the 6th and 7th class, i.e. as strongly or extremely hydrophobic, and only 10% to the 1st, 2nd, and 3rd class, i.e. as very hydrophilic, hydrophilic, or low hydrophilic. Ash horizons accumulated as a result of peat burning, as well as horizons with burnt fragments of vegetal remains and silted horizons, showed a hydrophobic capacity lower than that of peat horizons or duffs unaffected by fire (Fig. 1). The water drop penetration time (WDPT) test applied revealed results similar to those of the MED test, as presented in details in Table 2, and in the calculation of the correlation coefficient \( r=0.64, n=98, p>0.05 \), as well as the chart of this correlation in Fig. 4. An increase in OC content in soil samples affected wettability indicator values (WDPT). This phenomenon is also confirmed by a high correlation coefficient for the samples studied: \( r=0.53, n=98, p<0.05 \) (Fig. 5). A similar correlation was also observed in studies by Roy et al. (2000) and Lachacz et al. (2009). According to Lachacz et al. (2009), the observed phenomenon is particularly visible when OC > 120 g kg\(^{-1}\) of soil, when soil samples become significantly hydrophobic. This is also confirmed by the studies the results of which are presented in Fig. 4 and Fig. 5. Such behaviour of organic matter is also determined by the possibility of alternate humidification and drying (Bisdom et al., 1993). The potential water capacity of organic soils is closely related to temperature, type of burnt organic matter, and oxygen availability du-

![Figure 2. Secondary transformation of pyrogenic (forest) soils based on the water absorption coefficient \( W_1 \) (Gawlik, 1996)](image)

1 – no change
2 – initially secondary transformed
3 – weakly secondary transformed
4 – medium secondary transformed
5 – strong secondary transformed
6 – completely degraded

![Figure 3. Secondary transformation of pyrogenic (meadow) soils based on the water absorption coefficient \( W_1 \) (Gawlik, 1996)](image)

1 – no change
2 – initially secondary transformed
3 – weakly secondary transformed
4 – medium secondary transformed
5 – strong secondary transformed
6 – completely degraded

![Figure 4. Correlation between the values of the WDPT indicator, and MED test](image)

\[ y = 0.5336x + 1.4559 \]

\[ R^2 = 0.8903 \]

\[ n = 98, p < 0.05 \]

![Figure 5. Correlation between the values of the WDPT indicator and organic matter content (OC)](image)

\[ y = 27.302x + 77.282 \]

\[ R^2 = 0.338 \]

\[ n = 98, p < 0.05 \]
ring a fire incident (Doerr et al., 2004). Based on mean WDPT values calculated for the described post-fire soils, potential water repellent capacity of peats higher than that of moorsh is not confirmed.

**CONCLUSIONS**

1. Fires resulted in a decrease in potential hydrophobic capacity of organic horizons. A higher degree of secondary transformation was usually observed in surface horizons, and concerned horizons with ashes.

2. Organic matter burning or burnout significantly modified its hydrophobic capacities.

3. Values of the \( W_2 \) parameter indicated a degree of transformation of organic horizons of meadow soils higher than that of forest soils.

**REFERENCES**


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