ABSTRACT: The authors determined the concentration of dissolved organic carbon (DOC) and electrical conductivity, as well as the colour and pH in the ground waters of 26 peat-bogs in Pomerania (NW Poland). Three kinds of peat-bogs have been taken into account – forestless sphagnum-cover bogs, bog coniferous forests and birch swamps. The condition of bogs was classified as good, moderate or poor as regards their natural qualities. In good natural-status peat-bogs the lowest amounts of DOC (about 30 mg C dm–3) and conductivity (<100 µS cm–1) were found in the water of the peat of sphagnum-cover bogs, higher levels were recorded in forest peat-bog water (DOC – 50 mg C dm–3, conductivity – 100 µS cm–1). Drainage of all the kinds of peat-bog under study leads to an increase in the concentration of DOC (>70 mg C dm–3) and conductivity (up to 90 µS cm–1 in degraded sphagnum-cover bogs and 140–150 µS cm–1 in degraded forest bogs); there also occurs an increase in acidity (from pH 4.0–3.7 to 3.7–3.4) and coloration (from 300 to 1000 mg Pt dm–3 in forestless peat-bogs and from 600–800 to 1400–1600 mg Pt dm–3 in forest bogs).

KEY WORDS: peat-bogs, peat-bog reclamation, humic substances, peat-bog waters

1. INTRODUCTION

Peat-bog degradation, mainly as the result of drainage, is a commonly known process that concerns both the peat deposit and the vegetation which develops on it. It has, however, much wider impacts, because of the carrying of water out of swamp areas. In lakeland areas with a large number of peat-bogs the water of many lakes is brown in colour (Lillie and Mason 1983, Wright 1983, Gorham et al. 1986, Overton et al. 1986, Rogalla 1986, Górniak 1996, Banaś and Gos 1998). Numerous researchers indicate that peat-bog water are responsible for the higher concentration of organic matter and the resulting colour (Engstrom 1987, Gorham et al. 1986, Wojciechowski 1997).

The matter released during peat-bog reclamation, primarily in the form of humic substances, is transported along ditches to lakes or rivers, which brings about far reaching changes in the water and sediments. Light intensity under water then lowers, which affects the primary production of plankton and macrophytes (Effler et al. 1985, Wojciechowski 1997, Bociag 1998, Gos et al. 1998).

Recognition of the properties of the waters deposited in the top layer of peat in various kinds of peat-bogs, and of the changes in these properties resulting from peat-bog drainage is therefore of great practical importance, connected with the preservation of swamp and aquatic ecosystems. This is the aim of the present research which studies these relationships under the local conditions of north-western Poland.
2. STUDY AREA

Investigations were carried out in three kinds of peat-bogs – forestless sphagnum-cover bogs, coniferous forests bog and birch swamps.

Dominant in forestless sphagnum-cover bogs are peat mosses, and their vegetation depends on the water content and fertility of the substrate. Extremely oligotrophic, acidic peat-bogs that become partly dry in summer are characterized by the presence of hummock peat mosses, *Calluna vulgaris*, *Eriophorum vaginatum* and dispersed dwarfish *Pinus sylvestris* individuals.

Waterlogged sites on the peripheries of dystrophic lakes, forest edges and in hollows between hummocks in raised bogs are occupied by extremely hydrophilous species of the genera *Sphagnum*, *Carex* and by *Eriophorum angustifolium*.

Bog coniferous forests are characterized by a well-developed moss layer made up of peat mosses with an addition of coniferous-forest species. The species composition of herbs and dwarf shrubs is similar to that of hummocks on raised bogs; it is characteristic for an abundant presence in bog coniferous forests of *Ledum palustre* and *Vaccinium uliginosum*. The canopy closure of the pine stand, with an insignificant addition of birch, is poor and the individual trees are low.

Coniferous forest bogs are forest raised bogs, and their formation is often connected with the reclamation of forestless raised bogs.

Birch swamp forests are made up of *Betula pubescens* with an addition of *B. verrucosa*. It is a community with a rich herb layer including ferns and club mosses, occupying mesotrophic habitats. Because they are shaded considerably, the habitats lack dwarf shrubs of the family Ericaceae. Dominant among the mosses are brown mosses, mainly *Polytrichum commune*. Peat mosses occur there in smaller numbers, represented by shade-tolerating species. Birch swamp forests are forest transition bogs, formed by shallow terrain depressions, on bog coniferous forest edges and in partly dry bog coniferous forest habitats.

3. MATERIAL AND METHODS

The studies were carried out in the spring and summer of 1998 in Pomerania (NW Poland). The existing natural-quality state of the peat-bogs was assessed on the basis of the degree of peat dryness, number of draining ditches and physiognomy of the plant communities. A 3-grade natural-quality state scale has been adopted: 1/ good, i.e. without signs of degradation in vegetation and peat deposit, 2/ moderate, i.e. with single draining ditches and first signs of partial dryness of peat, and swamp vegetation degeneration, 3/ poor, i.e. with a strong vegetation degeneration, numerous draining ditches and peat-pits. Investigations were carried out in 6 sphagnum-cover bogs, 12 bog pine forests and 8 birch swamp forests, jointly in 57 variants differing in natural-quality state. From each community three water samples were taken from the peat at the depth of 0.5 m.

Concentration of dissolved organic carbon (DOC) in the samples was determined by a spectroscopic method based on the strong correlation between absorbance and organic carbon content (Moore 1985, 1987, Górniak 1995). For filtered samples absorbance was measured at 330 nm on a UV-VIS (SHIMADZU UV-1202) spectrophotometer.

Peat-deposit water was used for the measurement of: electrolytical conductivity by an LF-95/SET conductivity meter with a 4-electrode TetraCon 96 system, and water pH by a SET-1 pH-meter with a combined electrode of the EPH-11 type. Water colour was determined in the laboratory, according to Hermanowicz et al. (1999).

4. RESULTS

The water contained in the top peat layer of forestless sphagnum-cover peat-bogs is very acid (pH 3.64–4.56). Its pH is highly negatively correlated with the concentration of DOC (r = −0.8) and conductivity (r = −0.94), while the concentration of DOC is positively correlated with conductivity (r = 0.8). The physical and chemical characteristics of the sphagnum-cover bog water have a wide range of variation, related to the wide microhabitat variation of these peat-bogs.

For the water of good natural-quality sphagnum-cover bogs a low DOC (30.6 mg C dm⁻³) and conductivity (61 µS cm⁻¹) are found. In the water of moderate and poor natural-quality peat-bogs much higher DOC concentrations occur (47.1 and 65.1
mg C dm$^{-3}$). Increased concentrations of organic carbon cause a lowering of the water pH from 4.0 to 3.7 (Table 1, Fig. 1).

In bog coniferous forests the waters contained in the top layer of peat are characterized by levels of conductivity which are twice as high as in the sphagnum-cover bogs (120.6 versus 67.3 µS cm$^{-1}$). Water pH is insignificantly lower, but the range of pH variation is much narrower. The dark brown coloration of the water (colour $>1000$ mg Pt dm$^{-3}$) is the result of a high DOC content (61.3 mg C dm$^{-3}$). As in the case of sphagnum-cover bogs, there occurs a highly negative correlation between pH and conductivity ($r = -0.95$), and between pH and DOC ($r = -0.93$), as well as a positive correlation between conductivity and DOC ($r = 0.87$).

In the process of bog coniferous forest drainage, the direction of changes in the physical and chemical traits of the water is concordant with that seen in forestless sphagnum-cover bogs. The water pH drops from 3.6 to 3.5, conductivity rises from 102 to 141 µS cm$^{-1}$, and so does DOC concentration from 53.8 to 74.9 mg C dm$^{-3}$ (Table 1, Fig. 2), but the range of variation of these characteristics is narrower than in the case of sphagnum-cover bogs.

Table 1. Characteristics of the ground water of various kinds of peat-bogs in relationship to their natural-quality state.

<table>
<thead>
<tr>
<th>Natural quality state</th>
<th>Number of sample</th>
<th>pH ± SD</th>
<th>Conduct. ± SD (µS cm$^{-1}$)</th>
<th>Colour ± SD (mg Pt dm$^{-3}$)</th>
<th>DOC ± SD (mg C dm$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>forestless sphagnum-cover bogs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>good</td>
<td>9</td>
<td>3.97 ± 0.32</td>
<td>61.0 ± 29.5</td>
<td>333 ± 135</td>
<td>30.6 ± 12.3</td>
</tr>
<tr>
<td>moderate</td>
<td>3</td>
<td>3.78 ± 0.03</td>
<td>70.0 ± 4.0</td>
<td>660 ± 60</td>
<td>47.1 ± 3.2</td>
</tr>
<tr>
<td>poor</td>
<td>3</td>
<td>3.71 ± 0.04</td>
<td>83.7 ± 5.9</td>
<td>2533 ± 289</td>
<td>65.1 ± 2.8</td>
</tr>
<tr>
<td>bog pine forests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>good</td>
<td>10</td>
<td>3.64 ± 0.08</td>
<td>102.9 ± 18.7</td>
<td>709 ± 241</td>
<td>53.8 ± 6.9</td>
</tr>
<tr>
<td>moderate</td>
<td>10</td>
<td>3.56 ± 0.13</td>
<td>130.2 ± 35.6</td>
<td>1041 ± 405</td>
<td>63.4 ± 11.9</td>
</tr>
<tr>
<td>poor</td>
<td>4</td>
<td>3.49 ± 0.08</td>
<td>140.9 ± 36.1</td>
<td>1675 ± 96</td>
<td>74.9 ± 3.9</td>
</tr>
<tr>
<td>birch swamp forests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>good</td>
<td>9</td>
<td>3.70 ± 0.17</td>
<td>107.0 ± 24.2</td>
<td>814 ± 162</td>
<td>58.1 ± 5.7</td>
</tr>
<tr>
<td>moderate</td>
<td>3</td>
<td>3.50 ± 0.05</td>
<td>142.0 ± 10.4</td>
<td>833 ± 76</td>
<td>61.0 ± 6.7</td>
</tr>
<tr>
<td>poor</td>
<td>6</td>
<td>3.44 ± 0.08</td>
<td>154.9 ± 35.6</td>
<td>1427 ± 360</td>
<td>73.0 ± 5.5</td>
</tr>
</tbody>
</table>
The physical and chemical characteristics of the water in birch swamp forests only slightly differ from those found in bog coniferous forests. Water pH is the same (pH 3.6), slightly higher are conductivity (129 versus 121 µS cm\(^{-1}\)) and DOC concentrations (63.5 versus 61.3 mg C dm\(^{-3}\); Table 1). Water pH is negatively correlated with electrolytical conductivity (\(r = -0.93\)); a similar though weaker relationship exists between pH and DOC (\(r = -0.75\)), while conductivity and DOC are correlated positively (\(r = 0.75\)).

Reclamation of birch swamp forests leads to a lowering of the water pH (from 3.7 to 3.4) and a rise in conductivity (from 107 to 155 µS cm\(^{-1}\)) and DOC concentration (from 58.1 to 73.0 mg C dm\(^{-3}\); Table 1, Fig. 3).

5. DISCUSSION

The water deposited in the top peat layer of forestless sphagnum-cover bogs contains much less DOC, and its conductivity is considerably lower than in the water of bog coniferous forests and birch swamp forests. The near-surface peat of forest peat-bogs is more decomposed than that of forestless peat-bogs. As a result of a partial drying of peat-bogs, peat decomposition increases, due to which the concentration of DOC in the water rises. The waters of poor natural-quality sphagnum-cover bogs are in this respect similar to waters typical of bog coniferous forests, but the content of inorganic substances stays at a fairly low level. The cause of this is the complex-forming tendency of DOC (and humic substances) with inorganic substances released by the muck-formation process. The complexing of metal ions (Driscoll et al. 1980, Buffle 1984, Spósito 1986, Kinniburgh et al. 1996) affects their circulation in ecosystems (Beck et al. 1974, Sholkovitz and Copland 1982, Driscoll et al. 1988). Organic carbon concentration in the water from the peat of good natural-quality sphagnum-cover bogs amounted to 30 mg C dm\(^{-3}\). The result was identical with that found by Oliver et al. (1983) in Ontario and Nova Scotia in USA. According to Górniak’s studies (1996), in the transition and raised-bogs of north-eastern Poland DOC concentration attains the level of 27.8 mg C dm\(^{-3}\).

In respect of DOC concentration in the ground water, bog coniferous forests are very similar to birch swamp forests, and with the progressing drainage of both peat-bog forest types the differences decrease gradually. In all the habitats studied, partial drying of bogs was followed by a strong coloration of the water, caused by its enrichment with dissolved organic matter. Large amounts of the humic acids present cause a decrease in the pH of the water which is very acidic already. In Okefenook swamp, Lobartini et al. (1991) found equally acid (pH 3.8) and intensively coloured waters, which were, however, less than half as concentrated in DOC (25.1 mg C dm\(^{-3}\)).

Organogenic habitats are rich sources of dissolved organic carbon and humic substances (McKnight et al. 1985, Urban et al. 1987, 1989). The magnitude of outflow from them thus determines the amount of DOC exported from them (Brinson 1976, Mulholland and Kuenzler 1979). Reclamation increases the magnitude of the outflow, and due to the changes that occur in the peat as a result of drying, the water which flows
out contains increasingly large amounts of DOC. The action of such waters on lake ecosystems may lead on to the transformation of the latter into humic water bodies.

6. CONCLUSION

Peat-bog drainage leads to increased DOC and mineral salt concentrations, as well as acidification and coloration of the ground water present in the peat. The negative impact of the peat-bog waters carried off on the surrounding aquatic ecosystems increases with the progress of peat-bog degradation.

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7. SUMMARY

The authors determined the concentration of organic (DOC) and mineral substances, as well as the colour and pH in the ground waters of 26 peat-bogs in Pomerania (NW Poland). Three kinds of peat-bogs have been taken into account — forestless sphagnum-cover bogs, bog coniferous forests and birch swamps. The research covered objects with a good, moderate or poor status as regards their natural qualities that endure. In good natural-status peat-bogs the lowest amounts of organic (about 30 mg C dm–3) and inorganic (conductivity <100 µS cm –1) substances were found in the water of the peat of sphagnum-cover bogs, higher levels were recorded in forest peat-bog water (DOC – 50 mg C dm–3, conductivity – 100 µS cm–1; Table 1).

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In the process of bog coniferous forest drainage, the direction of changes in the physical and chemical traits of the water is concordant with that seen in forestless sphagnum-cover bogs. The water pH drops from 3.6 to 3.5, conductivity rises, and so does DOC concentration (Fig. 2), but the range of variation of these characteristics is narrower than in the case of sphagnum-cover bogs.

Reclamation of birch swamp forests leads to a lowering of the water pH and a rise in conductivity and DOC concentration (Fig. 3).

The amount of inorganic and organic substances exported due to the drainage of peat-bogs increases with the progress of peat-bog degradation. Waters flowing out of such bogs have an increasingly negative impact on aquatic ecosystems, e.g. lakes into which they are conveyed.

8. REFERENCES


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