Overland Flow as a Source of Mineral and Organic Compounds for the Lake

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ABSTRACT

Physico-chemical properties of overland flow occurring in forested catchment of Piaseczno Male Lake were investigated. The lake has an area of about 8 ha, maximal depth about 6.5 m. The catchment (area of 21.2 ha) is 100% forested, mainly by scotch pine (*Pinus silvestris*) and beech (*Fagus silvatica*), and has steep slopes with inclination up to 40°. Samples were collected in two stations: - one with pine domination and the other with beech domination. Characteristic features of the runoff waters were high concentrations of total (up to 60 mg TOC dm⁻¹) and dissolved organic carbon (DOC) – up to 50 mg DOC dm⁻¹, intensive brown color, acid reaction (pH < 6.5) and low conductivity (about 50 μS cm⁻¹). Moreover, high concentrations of nitrogen and phosphorus were found in surface runoff waters. The differences in the quality of surface runoff water, between the investigated stations were noted. The runoff water from coniferous part of the catchment contained more organic compounds, whereas the runoff water from beech-covered slopes delivered more biogenic elements. For majority of parameters, the differences were statistically significant. Concentrations of nutrients and organic compounds depended mostly on intensity of rainfalls and surface runoff, as suggested by high coefficient of correlation between the volume of runoff and concentrations of: NH₄, orthophosphates, DOC. After extremely heavy rains and runoff, the water in Piaseczno Male Lake became more humic (increased concentration of DOC, lower pH), whereas after dry periods water color decreased and water reaction was near neutral.

Keywords: Surface runoff, wooded catchment, nutrients, organic carbon

INTRODUCTION

Surface runoff is one of the diffused sources of export of elements and chemical substances to water bodies (Kajak 1979). With overland flow significant loads of nitrogen (Brusch & Nilsson 1993, Croke et al. 2000), phosphorus (Uusi Kamppa & Ylaranta 1992, Astrom et al. 2005) and organic matter (Cronan 1990, Strobel et al. 2001) can be transported from catchment to freshwaters. Quality and quantity of surface runoff waters depend on many factors. One of the most important is the morphology of catchment and degree of anthropopression. Significant loads of nutrients are exported mainly from agricultural used catchments (Hilbricht-Ilkowska 1994, Sharpley et al. 1999, Lilianiemi 2003), whereas the runoff from wooded catchments contains great loads of organic matter (Hirobe et al. 2004, Klimaszyk 2006).

An important factor controlling the quantity of export of chemical substances is inclination of catchment’s slopes – the more steep slopes are, the greater export of substances takes place (Bajkiewicz-Grabowska 1994). Mountain catchments with their steep slopes may export higher load of nutrients that lowland catchments (Niemrzyk et al. 1993).

Fundamental role in forming physico-chemical properties of surface runoff plays the type of phytocoenosis covering catchment (Hongve 1999, Zielinski et al. 2000). In forest ecosystems, input and output of essential nutrients are relatively small, compared with the total amount cycled within the system (Hirobe et al. 2004); however, elements exported from wooded catchments may affect functioning of freshwaters.

The aim of the study was to estimate the overland transfer of chemical substances from the wooded catchment, and to recognize impact of phytocoenosis on physicochemical properties of the surface runoff.

STUDY AREA AND METHODS

The investigated lake – catchment complex is located in Drawa National Park (NW Poland).

The Piaseczno Male Lake has an area of about 8.0 ha, maximal depth of 8.5 m, and mean depth of 3.1 m. The catchment area is of 21.6 ha, mean slope inclination reaches 44.1°, and catchment slopes near the lake has inclination up to 40°. The entire catchments area is forested, 80% of it is covered by scotch pine (*Pinus silvestris*) and 20% by beech (*Fagus silvatica*).

Two sampling stations on Lake Piaseczno Male catchment area were selected. Station A was located on catchment slope covered mainly by scotch pine,
and station B was located on the slope with domination of beech. On each station two surface runoff waters samplers were installed.

Water samples were collected after each rain event and during snow melting. Simultaneously, samples of surface water from the lake were taken. The investigations were carried out in 2006. The analyses of the physico-chemical properties of water samples were made according to Standard Methods for the Examination of Waters and Wastewaters (1992).

RESULTS AND DISCUSSION

Characteristic features of the runoff waters were high concentrations of total (up to 60 mg TOC dm⁻³) and dissolved organic carbon (DOC) – up to 50 mg DOC dm⁻³, intensive brown color and acid reaction (pH<6.5) and low conductivity (about 50 μSm cm⁻¹). Moreover, high concentrations of nitrogen and phosphorus were found in surface runoff waters. No significant differences were found between the concentrations of dissolved organic carbon in runoff from the investigated catchment with the content of DOC in the waters of high and transitional bogs, which are regarded as the main source of DOC incoming to the freshwaters and as the main factor of dystrophication (Gorham et al. 1998, Elder et al. 2000). Therefore, we suppose that surface runoff from wooded catchment is a factor of lake humification. This can be supported by the fact that after intensive precipitation and runoff, the waters of Piaseczno Male Lake became more acidic (pH decreased from 7.1 to 6.5) and had more intensive brown color (the color of epilimnetic waters increased from about 30 to over 40 mg Pt dm⁻³). Such impact of surface runoff on chemical and physical properties of lake waters has been observed on other small humic lake (Klimaszyk 2006). Concentrations of biogenic elements, N and P, transported with the runoff from the investigated catchment were relatively high (table 1) and exceeded values recorded for most forest and even agricultural-forest catchments (Hilbricht-Ilkowska 1994, Kajak 1998). It seems that a reason of this may be inclination of steep slopes, which promotes water erosion. The major factors affecting the concentration of biogenic elements and organic matter in the surface runoff waters was intensity of precipitation and runoff. The highest concentrations of nitrogen, phosphorus and DOC in runoff waters were observed after gusty rains, and significant coefficient of correlation between intensity of runoff and an concentration of: NH₄ (r=0.724, p<0.05), orthophosphates (r=0.48, p<0,05) and DOC (r=0.54, p<0,05).

Physico-chemical properties of surface runoff waters largely depended on the type of forest covering the catchment. Significant impact of plant type on quality of overland flow has been stated by Hongve (1999), Zielinski et al. (2000) Hirobe et al. (2004). The runoff from slopes covered by scotch pine was characterized by higher concentration of dissolved organic carbon, more intensive brown water color and lower water pH (table 1). This shows intensive release of humic acids from the pine detritus. Very similar results of investigations have been presented by Kortelainen (1999) and Klimaszyk et al. (2003); however, Zielinski et al. (2000) have noted four times higher concentrations of dissolved organic carbon and humic acids exported from deciduous litter comparing to coniferous. Simultaneously, comparing to beech-covered slopes, the concentrations of biogenic elements in surface runoff water from pine-covered slopes were lower (table 1). For most analyzed parameters the difference between slopes was statistically significant (table 1).

Table 1 Mean values (and Standard Deviation) of physico-chemical parameters of surface runoff waters from Piaseczno Male Lake catchment. St 1 - slope witch pine domination, St 2 – slope witch beech domination (n=8). Statistical significance of differences between stations.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ST 1</th>
<th>ST 2</th>
<th>U-Mann test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td><strong>53 ± 12</strong></td>
<td><strong>79 ± 10.6</strong></td>
<td>**</td>
</tr>
<tr>
<td>pH</td>
<td>4.5 – 5.2</td>
<td>5.1 – 6.4</td>
<td>*</td>
</tr>
<tr>
<td>PO₄</td>
<td><strong>0.11 ± 0.08</strong></td>
<td><strong>0.2 ± 0.09</strong></td>
<td>**</td>
</tr>
<tr>
<td>P total</td>
<td><strong>0.41 ± 0.21</strong></td>
<td><strong>0.51 ± 0.18</strong></td>
<td>**</td>
</tr>
<tr>
<td>NH₄</td>
<td><strong>2.58 ± 1.25</strong></td>
<td><strong>2.9 ± 1.23</strong></td>
<td>n.s.</td>
</tr>
<tr>
<td>NO₃</td>
<td><strong>1.25 ± 0.6</strong></td>
<td><strong>2.45 ± 0.65</strong></td>
<td>***</td>
</tr>
<tr>
<td>DOC</td>
<td><strong>51.6 ± 9.65</strong></td>
<td><strong>29.2 ± 4.85</strong></td>
<td>***</td>
</tr>
</tbody>
</table>

* (p<0.05)
** (P<0.005)
*** (p<0.001)
n.s. - difference not significant
CONCLUSIONS

- Surface runoff from wooded catchment may be an important factor affecting the trophic state of the investigated water body. If the slope is steep runoff may supply water bodies with large loads of nutrients and organic matter.
- Quality of the surface runoff depends on the plants covering the catchment. Runoff from coniferous forest was characterized by higher concentrations of dissolved organic carbon, while runoff from deciduous forest was richer in biogenic elements.

ACKNOWLEDGEMENTS

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