| ACTA HYDROBIOL. | 23 | 2 | 107—123 | KRAKÓW 1981 |
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# Ecology of the forest stream Lane Błoto in the Niepołomice Forest

## 1. Chemism of water and bottom sediments and its changes under the influence of industrial pollution

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Abstract — The chemical composition of water and bottom sediments from five stations located on the stream Lane Błoto was investigated in the year 1977—1978 at monthly intervals. A marked accumulation of all elements supplied into the stream with rainfalls was found in the stream environment. Physico-chemical processes favour to precipitation of basic macroelements and heavy metals into the bottom sediment.

Key words: chemistry of forest stream, pollution, heavy metals, balance of elements.

Manuscript submitted October 20, 1980

## 1. Introduction

The stream Lane Błoto is a right tributary of the stream Drwinka. It flows across the southern part of the Niepołomice Forest, a large forest complex of a surface area of 8 thousand ha. In consequence of its close situation to urban-industrial agglomerations of Cracow the territory of the basin is exposed to constant immission of dusts and gases from industrial and power plants. The amount of dust falls in this part of the Forest is on the average 7.0 t/km$^2$/month (Manecki unpub.). The content of elements in the falling dusts readily soluble in water is relatively high, varying from 30 to 55 per cent.



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The present paper aims at determining the changes occurring in the ionic composition of water and sediments of the stream caused by the supplied pollutions. The range of variations in elements of the chemical composition of the water and sediments was characterized and the balance of chosen elements permitting determination of the amount of their outflux and accummulation in the stream was calculated.

A chemical analysis of water and bottom sediments of the stream has been meant as part of an analysis of the environment for future biological investigations (J ó p 1981).

## 2. Investigation area

The stream Lane Błoto takes its origin from a spring of a helocrene type at the edge of a forest in the vicinity of the village Szarów, 185 m above the sea level. It flows across the middle part of the clearing Błoto where it takes in two tributaries A and B (fig. 1); subsequently it flows across the territory of the southern complex of the Niepołomice Forest. In that sector the stream takes in two other tributaries C and D. After crossing the forest part the stream flows out into meadows situated in a depression of the stream Drwinka (B z o w s k i 1973) and falls into it near the locality Wola Batorska. The total lenght of the stream is 3500 m of which 800 m is running in a wooded sector. The territory of the stream Lane Błoto crosses is characterized by small denivelations, this making the total gradient of the stream only 1.0‰.

The present condition of the stream is the result of river control works carried out in the sixties consisting in a considerable straightening of the river bed and erecting embankments and a few sluice gates of concrete. These works prevent damming up of water and submerging the adjacent territories. Since the river bed gets overgrown with vascular plants hampering the water efflux the plants overgrowing it are cut every year in August within the preservation works of land reclamation equipments. In its upper part the subsoil of the stream consists mainly of organic matter of peat origin. In the middle part of the stream it gives way to sands and loams which in the depression of the stream Drwinka are replaced in their turn by loams and formations of marshy accummulation. On the whole length of the stream five investigation stations (fig. 1) were appointed. In choosing the particular investigation stations the following factors have been taken into account: a) division of the stream into three basic sectors: upper, middle, and lower, b) the width of the bed, c) character of bottom sediments, and d) composition of vascular plants (Table I).

Throughout the course of the stream its bed and banks are overgrown, to a great extent, with vascular plants. The plant association of

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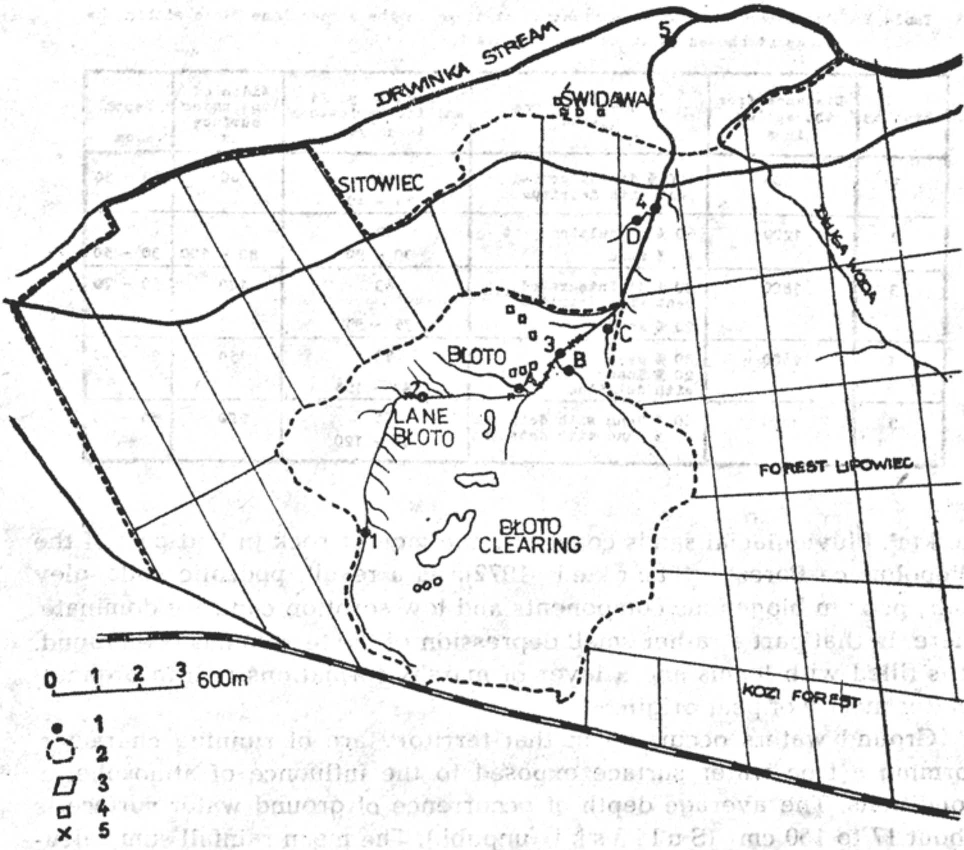


**Fig. 1. Map of the investigation territory. 1 — stations; 2 — clearing; 3 — water shed lines of Niepołomice Forest; 4 — buildings; 5 — concrete thresholds on the river**

the stream Lane Błoto is not rich in species; the sectors chosen for investigations varied, however, as far as dominant species were concerned. At station 1 the most numerous were: *Nasturtium officinale, Glyceria aquatica,* and *Caltha palustris;* at station 2: *Glyceria aquatica, Iris pseudoacorus;* at station 3: *Potamogeton natans, Batrachium aquatile;* at station 4: *Nasturtium officinale, Glyceria aquatica, Batrachium aquatile,* and at station 5: *Batrachium aquatile* markedly dominated on the whole width of the stream bed. The development of plants in the stream started in the second half of April, and the main weight increase of plants took place in May.

The area of the stream basin is about 8.0 km² of which the major part, i.e. 5.0 km² are intra forest meadows of the clearing Błoto within which arable land takes up 0.3 km². The rest consists of meadows 2.0 km² in the depression of the stream Drwinka and of a wooded area of about

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Table I. Characteristics of investigation stations in the stream Lane Błoto within the range of chosen environmental factors

| Station | Distance from the spring in m | Character of the bottom | Mean water yield and its variations in $dm^3/s$ | Width of the water surface cm | Depth cm |
|---|---|---|---|---|---|
| 1 | 600 | 100 % disintegrated peat with detritus | 20<br>15 - 40 | 60 | 20 - 30 |
| 2 | 1200 | 60 % granulated peat<br>40 % sand | 52<br>30 - 90 | 80 - 100 | 30 - 50 |
| 3 | 1800 | 80 % disintegrated peat with detritus<br>20 % sand | 63<br>35 - 95 | 120 | 50 - 70 |
| 4 | 2600 | 80 % sand<br>20 % loamy sediments with detritus | 73<br>43 - 105 | 150 | 20 - 40 |
| 5 | 3800 | 60 % loam with detritus<br>40 % sand with detritus | 85<br>45 - 120 | 200 | 50 - 70 |

1.0 $km^2$. Fluvioglacial sands constitute the mother rock in that part of the Niepołomice Forest (Starkel 1972); as a result, podzolic soils, gley soils, poor in biogenous components and low sorption capacity dominate there. In that part a rather small depression of the terrain has been found. It is filled with loams and a layer of marshy formations rich in organic matter mostly of peat origin.

Ground waters occurring in that territory are of running character, forming a free water surface exposed to the influence of atmospheric conditions. The average depth of occurrence of ground water surface is about 17 to 150 cm (Suliński unpubl.). The mean rainfall sum calculated over a couple of years is 650 mm, and the annual mean air temperature is 8.2°C (Klein 1978).

The degree of preservation of natural plant associations in the Niepołomice Forest varies greatly. In the southern part around the clearing Błoto, crossed by the stream, a considerable decrease in alder carr associations: *Circaeo-Alnetum* and *Ficario-Ulnetum* typical of that territory was found. Both the subassociation of the oak hornbeam forest *Tilio-Carpinetum stachetosum* and alder carr associations are in the southern part of the forest floristically much poorer than the respective associations in the northern part (Grodzińska 1977).

## 3. Investigation method

An analysis of physico-chemical factors was carried out over the period from April 27th 1977 till November 21st 1978. During this period water and bottom sediment samples were collected from five stations on the stream Lane Błoto at monthly intervals, while from four stations

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in the sectors close to the mouth of the tributaries water and sediment samples were collected four times on 10th April, 5th May, 11th July, and 9th November 1978. Water was sampled with a van Dorn bathometer (L i n d 1974) at a depth of 5 to 10 cm below the water surface and kept in plastic containers. Bottom sediments were collected with a modified Morduchaj-Boltovski bottom corer (Ż a d i n 1966); a core 4 cm long and 3 cm in diameter was cut off. Temperature and ionic reaction of the water was measured at the stations between $9^{00}$a.m. and $3^{00}$p.m. by means of a sampling thermometer and a battery pH-meter of the N-511 type, standarized before every measurement with buffers of pH equal 4.0 and 6.8. Daily investigations of oxidation were carried out on 4th May 1978 at station 3, temperature of the water and rounding being recorded simultaneously. The rate of the water current was measured with a propeller meter according to the standards recommended by the Institute of Meteorology and Water Economy. Conductivity was measured by means of a conductivity meter of the type OK-102/1, colorimetric determinations were carried out by use of a spectrocolorimeter EK-5 Specol, nephelometric determinations on a spectrophotometer Spectromom-204, determinations of emission on a flame spectrophotometer Flapho-4, and absorption was determined on a spectrophotometer of atomic absorption IJ-251.

Chemical analyses were carried out in a time lapse not longer than 96 hours following the delivery of the samples at the laboratory. Macroelements were determined according to the methods given by H e r m a - n o w i c z (1976) and in Standard Methods (1971). Microelements in the water were determined by the method of spectral emission analysis with the use of the technique given by P a s t e r n a k (1973); in sediments it was carried out according to the method given by M a t h i s and C u m m i n g s (1973).

In the statistic elaboration of the material the following calculations were applied according to O k t a b a (1974): a) for samples of one variable the following characteristics of the sample were calculated: arithmetical mean ($\bar{X}$), standard deviation ($\pm$ SD); b) for samples of two variables the correlation coefficient between the investigated features and the regression coefficients.

Once the amount of inflow and outflow of the element at the station was known the daily balance of some elements of the ionic composition of the water between particular sectors of the stream could be calculated. For this purpose daily balances between the stations were listed from monthly samplings and the annual balance of chosen elements was calculated. Further, the knowledge of the amount of inflow of elements into the stream (approximation from Zi e l i ń s k i's data in prep.) and their balances, permitted to calculate the percentage participation of the outflow of the elements in relation to their content in the atmospheric

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precipitations. Once the actual amount of the element, i.e. its pool in the analysed part of the ecosystem and the charge of the element leaving the stream were known the outflow of the element was calculated in relation to its pool.

## 4. Results

The distribution of water temperature in the stream during the investigations was typical for small flows (fig. 2). This is indicated by daily investigations carried out in spring and summer. Greatest variations in water temperature during the day were found in spring time. They reached 10°C (fig. 3) and corresponded with the changes in air temperature. The mean values of water temperature taken from the investigation period show values approximate to the annual mean temperature of air for this territory. The course of temperatures conditioned freezing of the stream which in the investigated period did not exceed 45 days. Maximum thickness of the ice cover on the whole length of the stream was 6 to 10 cm.

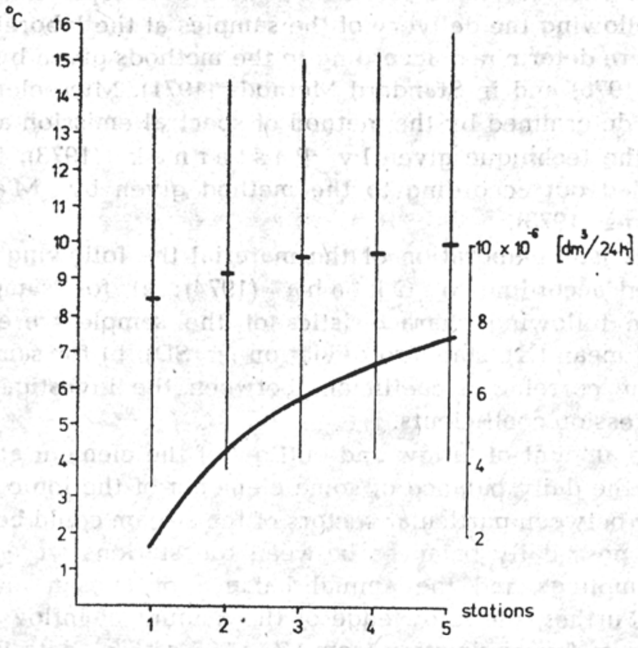


**Fig. 2. Mean values and range of temperature variations of water measured at the station at 9.00 a.m. to 3.00 p.m. (top) from the investigation period and values of the mean annual yield (bottom)**

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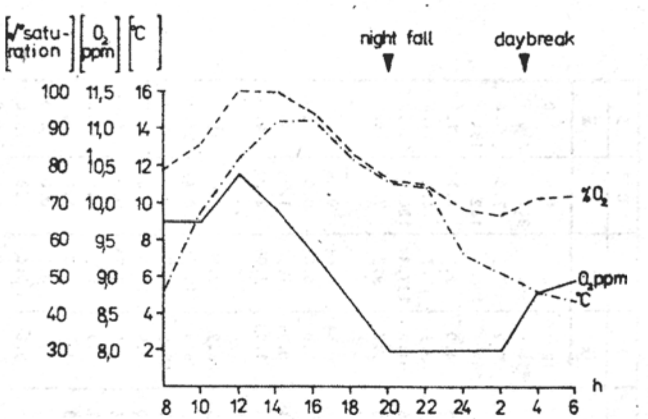


Fig. 3. Diurnal investigations of water oxidation carried out at station 3 in May 1978

The water of the stream Lane Błoto is the carbonate-calcic type. This is shown by a high percentage share of carbonates (60.9 to 85.3 per cent) and calcium (52.8 to 75.7 per cent) at a relatively low percentage participation of chlorides, sulphates, sodium, and potassium. Variations in the total water hardness were influenced mainly by changes in calcium content. Greatest variations in the content of calcium were recorded in spring at stations 2 and 3 into which this component was brought in with surface water run off from the meadows on the banks fertilized with calcium compounds. In summer time a considerable decrease in its content was found in the water, mainly due to a decrease in the inflow of calcium from the area of the basin, as well as to increased photosynthesis. At intensive photosynthesis which occurred a number of times during that period a total exhaustion of free carbon dioxide and a constant oxygen oversaturation of the water took place. This oversaturation reached sometimes 140 per cent. In this connection, calcium carbonate precipitated as a result of which the water assumed an alcaline reaction reaching pH 8.5. This process caused a considerable increase in the concentration of calcium in the bottom sediment; its level varied at that time from 8046 ppm (station 2) to 2373 ppm (station 5). Only in the forest sector of the stream (station 4) the concentration of calcium in the sediment was considerably lower and equaled 130 ppm. Other macroelements did not show any considerable variations (Table II). Only in summer a certain decrease in the concentration of sodium in the water was recorded.

Transformations of mineral nitrogen compounds corresponded strictly to the concentration of dissolved oxygen. The concentration of nitrates, which constituted the dominant form of mineral nitrogen increased in summer concomitantly with an increase in water oxidation at a simultaneous decrease in the ammonium form; this seems to point out to an

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Table II. Physico-chemical properties of the water of the stream Lane Błoto at five chosen stations (1-5) for the years 1977-1980 and its four tributaries (A-D). Mean values ($\bar{x}$) with standard deviations ($\pm$ SD)

| Element | | Stations 1 | | 2 | | 3 | | 4 | | 5 | | A | B | C | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{x}$ | ± SD | $\bar{x}$ | ± SD | $\bar{x}$ | ± SD | $\bar{x}$ | ± SD | $\bar{x}$ | ± SD | $\bar{x}$ | $\bar{x}$ | $\bar{x}$ | $\bar{x}$ |
| Yield | $dm^3/s$ | | | | | | | | | | | 12 | 14 | 8.5 | 1.0 |
| Conductivity | µS 20°C | 410 | 15 | 435 | 18 | 487 | 25 | 470 | 21 | 470 | 26 | 550 | 366 | 307 | 416 |
| pH | | 6.9 | 0.2 | 7.2 | 0.2 | 7.3 | 0.3 | 7.4 | 0.2 | 7.8 | 0.5 | 7.2 | 7.5 | 7.0 | 7.4 |
| Hardness | $CaCO_3$ ppm | 231 | 14 | 255 | 22 | 285 | 25 | 279 | 23 | 275 | 23 | 292 | 178 | 162 | 194 |
| Free | $CO_2$ ppm | 2.7 | 1.8 | 3.1 | 2.0 | 3.4 | 2.0 | 3.4 | 2.1 | 3.8 | 2.5 | 4.0 | 2.0 | 4.1 | 1.1 |
| Oxygen | $O_2$ ppm | 8.3 | 0.5 | 8.3 | 0.6 | 10.0 | 0.7 | 10.9 | 0.8 | 12.1 | 0.9 | 10.3 | 15.7 | 14.4 | 13.6 |
| Oxygen saturation | % | 76.5 | 17.3 | 77.7 | 18.7 | 87.4 | 19.8 | 90.5 | 21.5 | 106.5 | 22.6 | 94.2 | 137.3 | 120.9 | 121.2 |
| $BOD_5$ | mg $O_2/dm^3$ | 2.1 | 0.5 | 2.7 | 0.7 | 3.1 | 0.8 | 3.4 | 1.2 | 4.4 | 1.5 | 3.7 | 9.3 | 7.7 | 8.8 |
| Oxidability | mg $O_2/dm^3$ | 5.1 | 0.7 | 7.5 | 1.8 | 8.2 | 2.3 | 8.5 | 2.3 | 8.7 | 2.4 | | | | |
| Ammonia | $N-NH_4$ ppm | 0.32 | .05 | 0.35 | .07 | 0.38 | 0.1 | 0.4 | 0.12 | 0.42 | 0.12 | 0.54 | 0.64 | 0.56 | 0.64 |
| Nitrites | $N-NO_2$ ppm | 0.009 | - | 0.008 | - | 0.01 | - | 0.01 | - | 0.005 | - | 0.0 | 0.02 | 0.0 | 0.01 |
| Nitrates | $N-NO_3$ ppm | 2.9 | 0.4 | 0.9 | 0.3 | 0.75 | 0.12 | 0.8 | 0.15 | 0.8 | 0.15 | 0.96 | 1.38 | 1.24 | 1.27 |
| N - total | ppm | 3.5 | 0.8 | 1.8 | 0.4 | 2.2 | 0.4 | 1.2 | 0.3 | 1.8 | 0.4 | 1.53 | 2.09 | 2.09 | 2.20 |
| P - total | ppm | .06 | .03 | .04 | .01 | .05 | .01 | .05 | .02 | .06 | .03 | | | | |
| Chlorides | $Cl^-$ ppm | 14.7 | 2.0 | 15.7 | 2.1 | 16.5 | 2.7 | 16.9 | 2.1 | 18.7 | 2.3 | 28.9 | 12.8 | 4.6 | 15.4 |
| Sulphates | $S-SO_4$ ppm | 15.6 | 1.6 | 16.9 | 1.8 | 19.6 | 2.2 | 23.2 | 2.2 | 23.6 | 2.3 | 46.5 | 19.7 | 20.4 | 25.3 |
| Calcium | $Ca^{++}$ ppm | 69.7 | 7.5 | 81.5 | 10.9 | 80.9 | 11.7 | 79.4 | 10.4 | 78.1 | 10.1 | 89.5 | 54.3 | 44.3 | 57.9 |
| Magnesium | $Mg^{++}$ ppm | 8.7 | 1.6 | 10.2 | 2.1 | 11.3 | 2.7 | 12.2 | 3.0 | 12.2 | 3.0 | 16.9 | 10.0 | 9.6 | 11.7 |
| Potassium | $K^+$ ppm | 1.0 | 0.1 | 1.7 | 0.2 | 1.9 | 0.3 | 2.1 | 0.4 | 2.1 | 0.4 | 2.6 | 3.75 | 0.9 | 1.97 |
| Sodium | $Na^+$ ppm | 8.7 | 1.8 | 11.1 | 2.2 | 12.3 | 2.2 | 13.9 | 2.5 | 14.6 | 2.7 | 19.5 | 6.7 | 4.85 | 11.2 |
| Silica | $Si^-$ ppm | 3.9 | 0.2 | 4.3 | 0.4 | 4.3 | 0.5 | 4.8 | 0.7 | 5.1 | 0.8 | 4.6 | 4.8 | 5.0 | 4.1 |
| Cadmium | Cd ppb | 0.0 | - | 0.0 | - | 0.0 | - | 0.0 | - | 1 | - | 0.0 | 0.0 | 0.0 | 0.0 |
| Lead | Pb ppb | 0.0 | - | 5 | 2 | 5 | 2 | 5 | 3 | 7 | 5 | 3.0 | 3.0 | 2.0 | 5.0 |
| Copper | Cu ppb | 4 | 1 | 6 | 2 | 6 | 2 | 9 | 4 | 10 | 5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Nickel | Ni ppb | 2 | - | 7 | 2 | 8 | 4 | 8 | 5 | 8 | 5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Zinc | Zn ppb | 77 | 12 | 74 | 35 | 69 | 32 | 73 | 35 | 97 | 53 | 18 | 27 | 22 | 25 |
| Iron | Fe ppb | 337 | 102 | 745 | 205 | 506 | 85 | 516 | 105 | 587 | 120 | 216 | 185 | 105 | 211 |

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increased nitrification at that time. At successive dates of the investigation period no evident decrease in the concentration of mineral nitrogen forms was found along the whole stream. Phosphorus behaved in a similar way undergoing during the summer even complete exhaustion in the water of the whole stream.

Owing to photosynthesis the abundantly developing water plants overgrowing the whole bed of the stream in spring and autumm maintained a very high oxygen level in the whole area overgrown by them. A certain decrease in oxygen concentration was noticeable in January when the stream was frozen. At that time oxidation at the bottom at station 4 was 7.52 mg $O_2/dm^3$ which constituted 53.6 per cent saturation. Simultaneously at the same date and place the oxygen content under the ice cover was considerably higher and equaled 11.04 mg $O_2/dm^3$. It follows from daily investigations carried out in May that maxima of water saturation with oxygen occur from 12 a.m. till 2 p.m. with a maximum at $2^{00}$ p.m.; hence, oxygen saturation of the stream depends mainly on light intensity (fig. 3).

The ionic composition of the water of the affluents presented similar proportions between its elements as those of the water in the stream Lane Błoto. It is noteworthy that the values of organic matter coefficients are higher than those in the water of the stream (Table II). Since their charges are low they exert only a small influence on the increase in water trophic level of the stream Lane Błoto.

Table III. Budget of chosen elements of the ionic composition of the water of the stream Lane Błoto.

I - inflow into the basin of elements with atmospheric precipitation in kg/h/ /year in 1978 after Zieliński (in prep.);

II - outflow of elements from the basin in relation to their content in the atmospheric precipitation (in per cent);

III - mean values of the pool of chosen elements of the ionic composition of the water of the stream Lane Błoto in kg/day;

IV - outflow of elements in relation to their actual pool (in per cent)

| Element | I | II | III | IV |
|---|---|---|---|---|
| N | 64.88 | 11.0 | 48.96 | 23.5 |
| P | 3.99 | 21.3 | 19.44 | 15.3 |
| K | 31.53 | 14.5 | 37.2 | 18.1 |
| Ca | 54.56 | 39.7 | 1673.8 | 19.0 |
| Mg | 8.61 | 42.1 | 480.0 | 17.7 |
| $S_{tot}$ | 44.62 | 60.2 | 1215.3 | 27.4 |
| Fe | 4.75 | 24.6 | 12.24 | 13.9 |
| Zn | 1.36 | 42.7 | 1.8 | 29.4 |
| Ni | 0.04 | 15.2 | 0.31 | 18.5 |
| Cu | 0.17 | 5.2 | 0.26 | 7.4 |
| Pb | 0.29 | 12.6 | 0.21 | 15.6 |
| Cd | 0.02 | 12.2 | 0.03 | 14.8 |

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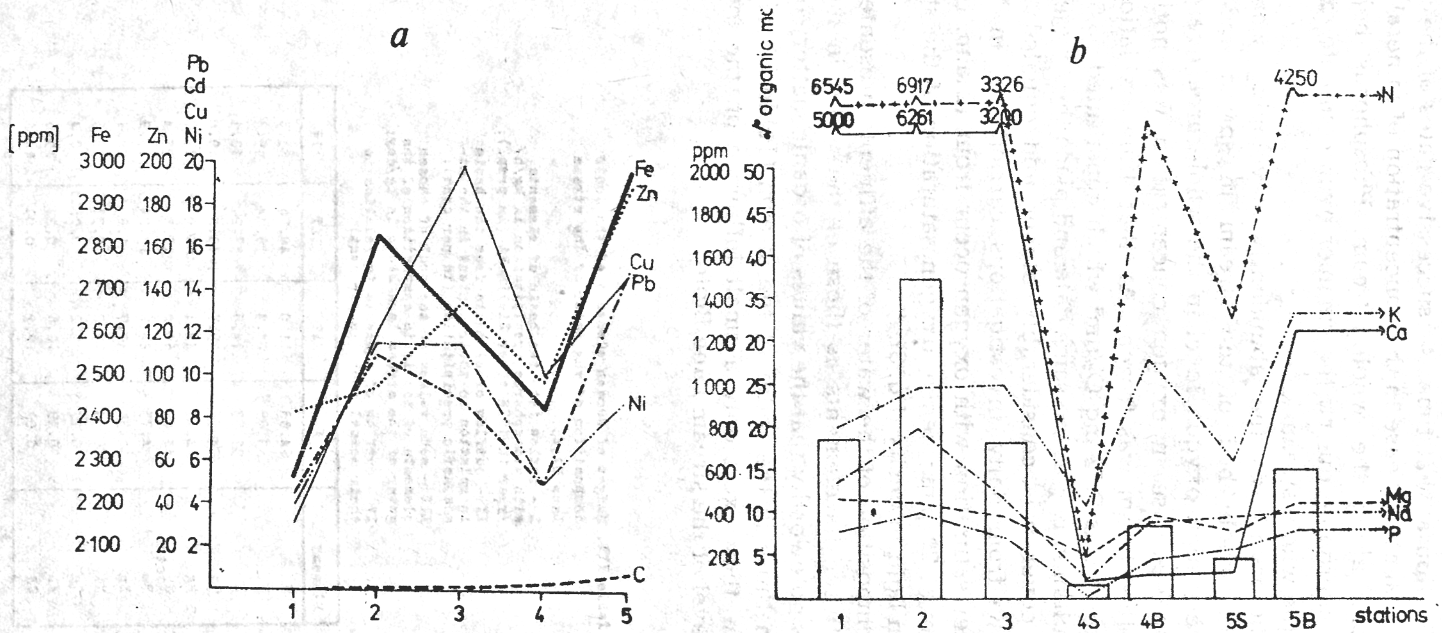


Fig. 4. Mean value for the investigation period: a — values of heavy metals; b — content of mineral components and organic matter (columns) in bottom sediments at successive stations in the stream Lane Błoto. S — middle of stream bed; B — parts close to the bank

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Out put of basic cations in a year was on the average 31.5 per cent in relation to their content in rain water. Nitrogen was accumulated in the stream in the highest degree, sulphur least of all (Table III).

Individual stations of the stream Lane Błoto greatly differ both as regards the participation of organic matter and the concentration of macroelements in the sediments (fig. 4b). In view of the great differences in the structure and quality of bottom sediments at stations 4 and 5 sand with a small amount of organic matter (S) and disintegrated sediment with detritus (B) were subjected to special analysis. The sector of the stream which crosses the clearing Błoto proved richest in mineral compounds and organic matter, whereas the lowest values of element concentration and organic matter were recorded at station 4, especially in sandy subsoil which at that station constitutes 80 per cent of the bottom (Table I). Along the course of the stream great variations occurred during the year in the bottom sediments only in the values of nitrogen and calcium. Other elements showed at each date a relatively equalized level in the sediments; this was also visible in their relation to organic carbon (Table IV). Low values of the relation of organic carbon to nitrogen show that the sediment of the stream was constituted mainly of readily decomposable organic matter consisting mostly of humified parts.

Table IV. Relation of organic carbon (C) to nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) in bottom sediments of the stream Lane Błoto calculated from mean values

| Station | C/N | C/P | C/K | C/Ca | C/Mg | C/Na |
|---|---|---|---|---|---|---|
| 1 | 8 | 217 | 39 | 8 | 64 | 85 |
| 2 | 13 | 113 | 78 | 10 | 71 | 89 |
| 3 | 15 | 95 | 46 | 52 | 67 | 106 |
| 4 | 16 | 89 | 24 | 322 | 84 | 137 |
| 5 | 17 | 189 | 43 | 268 | 150 | 151 |

The investigated elements determined three distinctly different concentration sections. The first one includes Cd, Pb, Ni, Cu, their concentrations in the water and sediment varying from 0 to 20 ppb and from 0 to 20 ppm respectively. The second one is represented by zink whose concentration in the water and sediments was from 30 to 150 ppb and from 30 to 200 ppm respectively. Iron, on the other hand, showes the higest quantitative level both in the water (250 to 950 ppb) and in the sediments (2200 to 2900 ppm) and constitutes a separate section.

A comparison of mean values of iron concentration in water with the values of the linear relation between the iron concentration and oxidation (fig. 5A) and concentration of hydrogen ions (fig. 5B) proves that the water in the stream was characterized by properties permitting maintenance of iron concentration in the lower range of possible concentrations.

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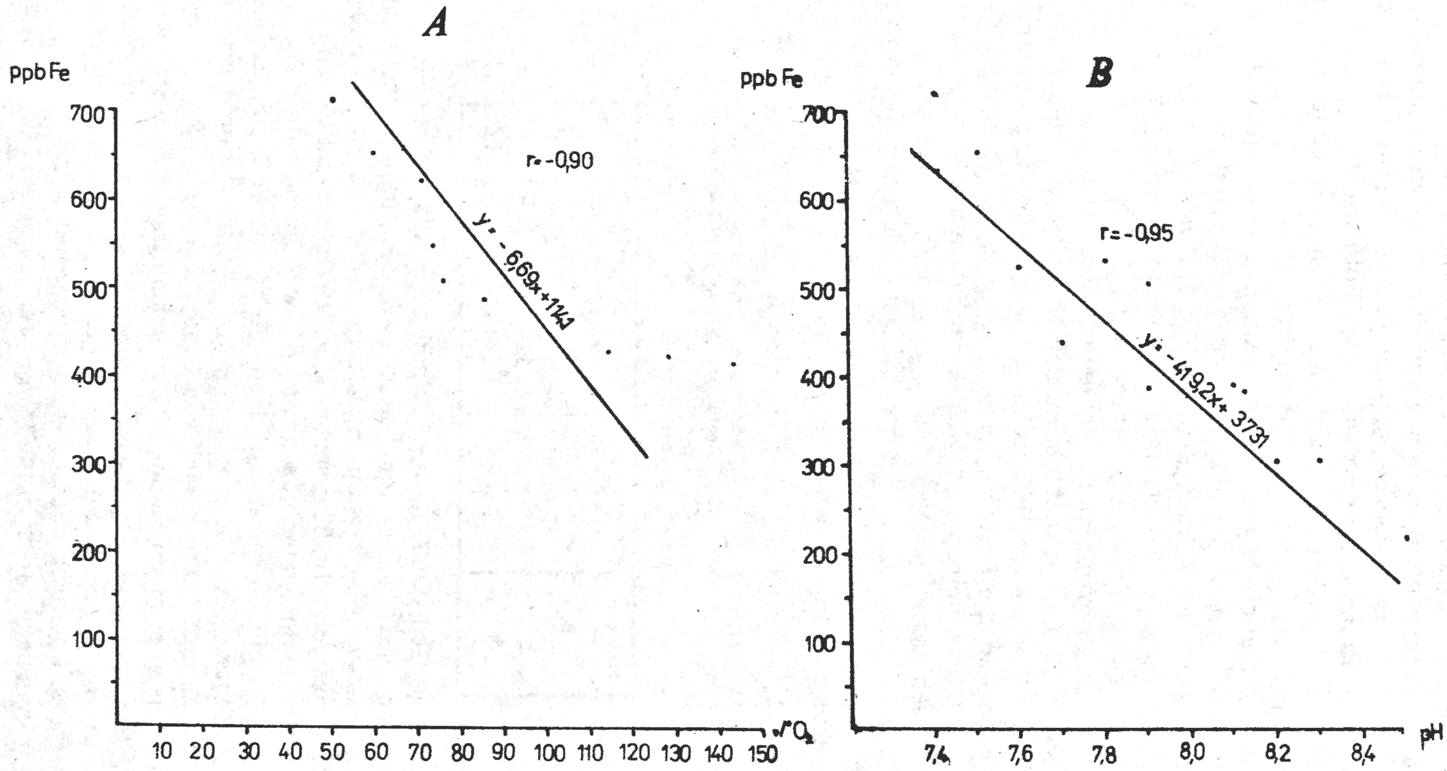


Fig. 5. Linear relation between iron concentration in the water of the stream and water oxidation (A) and its reaction (B)

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Statistically significant correlations between concentration of lead, copper, and iron (Table V) suggest that those metals precipitated into the sediment with iron hydroxides. Great sorption ability of organic matter and the process of biological water decalcination which takes place in spring is conducive to accumulation of other investigated metals in the bottom sediment.

Table V. Values of the correlation coefficient "r" of heavy metals in the water of the stream Lane Błoto for all stations and for the whole investigation period

| Metal | Pb | Ni | Zn | Fe |
|---|---|---|---|---|
| Cu | 0.03 | 0.51 | 0.57 | 0.71 |
| Fe | 0.52 | 0.30 | 0.18 | |
| Zn | 0.21 | 0.20 | | |
| Ni | 0.92 | | | |

The calculation of the microelements budget (Table III) permitted to determine the small out put of most of the investigated elements, which owing to their physico-chemical properties were arrested in the bottom sediment of the stream and consequently included into the chain of general biogeochemical transformations.

## 5. Discussion

Generally the water of the stream Lane Błoto can be classified, in spite of its high content of mineral compounds, as clean water. Most of the examined elements of the ionic composition of the stream water do not show any greater seasonal variations; only in summer a decrease was noticed in the concentration of phosphorus, sodium, and most of the microelements. It was caused by the development of vascular plants. At no date any loss in mineral nitrogen compounds, so characteristic of small flows (Kaushik, Robinson 1976, Vitousek 1977) was found in the whole course of the stream. This suggests that at an impeded surface run off, especially during the vegetation period and at small differences in water inflow at particular stations a decrease in the concentration of nitrates and ammonia nitrogen, caused by physico-chemical processes and plant demand for these compounds, must be made up for by an inflow of these forms with rainfalls. The mineral forms of nitrogen can also be supplied from bottom sediments, but according to Fillos and Molof (1972) transmission of mineral and organic forms of biogenous substance into water takes place only at oxygen concentration in the layer close to the bottom equaling 2 mg $O_2/dm^3$.

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The results of daily investigations of water oxidation served for the determination of primary production by the diurnal oxygen curve method (O d u m 1956). The total primary production measured in May was 4.6 g $O_2/m^2$/day; this proves a high productivity of this small flow. A similar value of total production was obtained for May by D e L a C r u z and P o s t (1977) for a forest stream of increased trophic level. An intensive increase in vascular plants was conditioned by a great amount of mineral compounds deposited in the sediment and a low relation of C/N. The dependence of organic matter decomposition rate on C/N relation, i.e. on nitrogen concentration in the decomposing material (P a r n a s 1975) is a known phenomenon. Low values of C/N ratio are specially favourable for microorganism decomposing organic matter and those "mineralizing" nutrient elements; as a result, the sediment contains considerable amounts of readily absorbable mineral nutrient substances which are a factor of increase in autotrophs.

The basin of the stream Lane Błoto is situated in that part of the Niepołomice Forest which is most intensively contaminated with heavy metals (M a k o m a s k a 1979). The contamination of that territory is mainly caused by the dusts from the Lenin Steel Works at Nowa Huta, containing large amounts of lead, zink, cadmium, copper, and iron (Z a j ą c unpubl.). Many authors have drawn attention to the fact that the atmospheric influx of heavy metals is the main source of a slow contamination the aquatic environment and its pollution with these elements (K e m p, T h o m a s 1976, F o r s t e r, W i t t m a n n 1979, J o p 1980). Their harmful influence on biocenoses is of long-term character.

Physico-chemical properties of the water and great sorption ability of bottom sediments of the stream create favourable conditions for arresting the major part of immitted microelements in that environment (fig. 4a). Heavy metals present in the stream bottom sediment are reflected especially by the amount of organic matter at the station and by the intensity of the iron oxidation process. They are also manifest, though to a smaller extent, in the actual concentration of metals in the water. The ability to absorb great amounts of heavy metals on the surface of organic matter (C o o p e r, H a r r i s 1974) or around organic particles (G i b b s 1973) is a known phenomenon. The exceptionally small amount of metals deposited in the sediment at station 4 can be explained by the small amount of organic matter in this sector of the stream and by a simultaneous great participation of sand in the sediment which (according to G r i e v e, F l e t c h e r, 1977) makes accumulation of metals more difficult. A sandy bottom permits a fast migration both of microelements and mineral compounds which are taken up by the root system of the trees on the banks of the stream.

Occurrence of free forms of heavy metals in natural waters is connected mainly with acidic reaction, low alcalinity, and total hardness

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(H a r t u n g 1976). Chemical analyses show that in the environment of the stream Lane Błoto metals occur mainly in tied-up bound form. Free metal ions are much more toxic for aquatic organisms than their compounds (F l o r e n c e 1977); hence, in spite of relatively high concentrations of metals, especially in bottom sediments of the stream, their influence on benthos animals is of a slow, long-term character.

**Acknowledgment**

I am highly indebted to Dozent Dr. Hab. R y s z a r d S o w a for his personal guidance during studies and for his patient examination of the manuscript.

## 6. Polish summary

**Ekologia strumienia leśnego Lane Błoto w Puszczy Niepołomickiej**

1. Zmiany w chemizmie wody i osadów dennych pod wpływem zanieczyszczeń przemysłowych

Badania prowadzono w strumieniu Lane Błoto, który jest prawobrzeżnym dopływem Drwinki (ryc. 1), przepływa przez południową część Puszczy Niepołomickiej. Na całej długości strumienia wyznaczono pięć stanowisk badawczych różniących się charakterem dna, składem porastających je roślin naczyniowych (tabela I), a także przepływem (ryc. 2).

Rozkład temperatur wody w strumieniu był typowy dla małych cieków, o czym świadczą duże różnice temperatury w ciągu doby (ryc. 3), odpowiadające zmianom temperatury powietrza.

Wodę Lanego Błota i jego dopływów (tabela II) można zaliczyć do typu węglanowo-wapniowego, charakterystycznego dla wód czystych naszej strefy klimatycznej. Jednak stały dopływ z opadem atmosferycznym znacznych ilości związków mineralnych i metali ciężkich, przy niewielkim ich odpływie (tabela III), wpływa na zanieczyszczenie tego niewielkiego cieku. Znaczna akumulacja metali ciężkich w osadzie strumienia (ryc. 4a), przy niewielkiej mobilności podłoża, staje się istotnym zagrożeniem dla organizmów bentosowych. Akumulacji metali sprzyja duża zdolność sorbcyjna osadów dennych (ryc. 4b), w skład której wchodzi łatwo rozkładalna materia organiczna (tabela IV) oraz proces utleniania żelaza, z którym wytrącane są inne metale (tabela V). Porównanie średnich wartości koncentracji żelaza w wodzie z wartościami liniowej zależności pomiędzy koncentracją żelaza a natlenieniem (ryc. 5A) i stężeniem jonów wodorowych (ryc. 5B) świadczy, iż woda strumienia odznaczała się właściwościami umożliwiającymi stałe utlenianie żelaza, przez co jego koncentracja w wodzie utrzymywana była w dolnych granicach możliwych stężeń.

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