ACTA HYDROBIOL.	22	3	249—262	KRAKÓW 1980

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Hydrochemical characteristics of the stream Drwinka and estimate of its self-purification ability

Hydrochemiczna charakterystyka Drwinki i ocena jej zdolności do samooczyszczania*

Wpłynęło 26 października 1978 r.

Abstract — The basic chemical composition and the concentration of Zn, Fe, Cu, Pb, Cd, Ni in the organically polluted stream Drwinka were described. The water and sediments samples from eight stations were studied during 1977 and analysed monthly. The kind of pollutions and their sources were discussed. On the basis of the decrease in the concentration of most elements in the ionic composition of Drwinka's water at successive stations, three distinctly differing zones of the stream were distinguished.

Introduction

The hydrochemical character of the stream Drwinka, the degree of its pollution, and the process of its self-purification are presented. The work was a part of complex investigations carried out by the Laboratory of Hydrobiology and the Jagiellonian University Institute of Environmental Biology, which also included the macro- and microfauna and algae of this river.

The Drwinka catchment basin with an area of 150.53 square kilometres (Lewiński, personal information) lies in the western part of the Sandomierz valley at the junction of the rivers Vistula and Raba. This small area of the catchment basin, and the clearly changing trophic

* Praca wykonana w ramach problemu węzłowego 10.2.07.05.01.

stages of the stream suggested that it might be used as a natural model in limnological investigations.

Chemical analyses were carried out in the sector between the 6th and 19th kilometres from the springs of the stream, i.e., from Niepołomice to Zielona, and in the final sectors of its two tributaries, the Ruski Potok and Lane Błoto streams.

Investigation area

The Drwinka basin lies in the River Vistula's dead channel (20°17'—20°27'E and 50°4'—50°8'N). In the relief of this area a distinct depression of the terrain is observed along the Drwinka course, parallel to the Vistula. The depression is 0.5—1.7 kilometres in length and it does not exceed 1.5 metre in depth (Bzowski 1973). It is lined with a layer of sandy-gravelly quarternary sediments covered with silts and with formations of marshy accumulation 0.4—1.6 metre in depth (Klimaszewski 1972). The ground water of the discussed area is very rich owing to the great thickness of quarternary alluvial sediments. They occur at depths of 0—110 cm (Bzowski 1973), this being connected

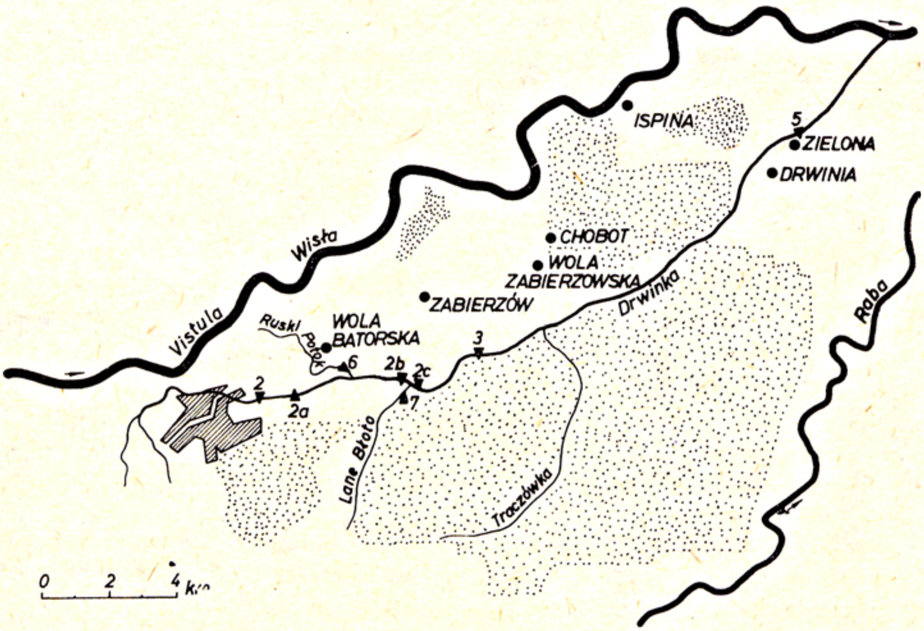

Fig. 1. Distribution of measurement stations on the Drwinka stream

Ryc. 1. Rozmieszczenie punktów pomiarowych na Drwince with the relative altitude of different parts of the valley. In the Drwinka basin the northern complex of the Niepołomice Forest which covers about $^{2}/_{3}$ of the whole area, clearly prevails while meadows make up the remaining part of the river basin (fig. 1).

The Drwinka, which is a large lowland stream, begins at 194 m above sea level, southwest of Niepołomice. Below Niepołomice it changes its course from north to northeast, flows along the northern border of the Niepołomice Forest and then into the River Vistula a few kilometres above the mouth of the River Raba, at 180 m above sea level. Three larger tributaries flow into the Drwinka: the left-bank Ruski Potok stream at a distance of 10 kilometres from the springs, and two right--bank tributaries: the Lane Błoto stream at a distance of 11 kilometres and the Traczówka stream at a distance of 16 kilometres from the springs (fig. 1).

The present river bed of the Drwinka and its tributaries are modified by trimming and by land reclamation of the neighbouring areas. Owing to a small river gradient, not exceeding 0.5‰ on the average, and to the growth of *Myriophyllo-Nupharetum* vascular plant association on the bottom and at the banks (D u b i e l 1973), the river is characterized by small yields ranging from 0.7—0.1 cu.m/sec. The affluents do not bring large amounts of water either, the yields of the mouth sectors of the streams Lane Błoto and Ruski Potok amounting to 0.05 cu.m./sec at average water levels. In some periods the Drwinka is supplied with water from the drainage ditches.

The chief and constant sources of pollution of the Drwinka aquatic environment are municipal sewage and wastes from a poultry farm at Niepołomice. Both are fed directly to the stream through 5 collectors located in Niepołomice. The last collector is situated 100 metres above station 2.

Climatic factors are responsible for the fact that the Niepołomice Forest lies in the region of the greatest pollution emitted by the Lenin Steel Works (G r o d z i ń s k i 1976). In the Kraków region west and southwest winds predominate in the annual cycle while the annual mean number of rainy days amounts to 170 (H e s s 1974). Atmospheric pollution decisively affects the chemical composition of fallout which introduces great amounts of chemical compounds into soils and waters. Among them are also toxic substances.

In 1976, from the total emission of dusts from the Lenin Steel Works, a fraction of the diametre $< 60\ \mu m$ contained 11 thousand tons of iron, 2977 tons of calcium, 982 tons of magnesium, 880 tons of zinc, 478 tons of potassium, 360 tons of copper, and 235 tons of lead (Z a j ą c 1977).

Similar emission values were found in 1977 (W i l c z y ń s k a--M i c h a l i k 1978). X-ray radiographic analyses determining the phase composition of these dusts showed that the following minerals were most readily dissolved in water: gypsum, sylvine, halite, calcite, hexahydrite, and melanterite (Wilczyńska-Michalik 1978). In the several-year investigation on the chemical composition of rain waters in Poland, Chojnacki (1970) found that in industrial regions the annual inflow of nitrogen compounds with rain was 20 kg/ha. These compounds can enter the Drwinka and its tributaries directly, i.e., with the fallout on the water surface, or indirectly with surface drainage waters.

Method

Six investigation stations were appointed on the Drwinka and one on the mouth sectors of the Lane Błoto and Ruski Potok streams (Table I). Chemical analyses were carried out on the following dates: January 10, February 28, April 27, May 30, June 19, July 18, September 12, Octo-

Table I. Characteristics of sampling stations on the Drwinka stream
Tabela I. Charakterystyka stanowisk na Drwince

Sampling stations Stanowiska	Distance from the spring Odległość od źródła km	Width of the river bed Szerokość koryta m	Depth at an average water level Głębokość przy średnim poziomie wody cm	Percentage of bottom covered with higher plants; the dominating taxons Procent pokrycia dna przez rośliny wyższe i takson dominujący	The prevailing type of bottom Dominujący typ podłoża
2	6.0	2.1	30	Potamogeton 10%	black slime czarny szlam
2a	7.5	2.4	23	Potamogeton Nuphar 40%	black slime czarny szlam
2b	11.3	4.3	40	Potamogeton Nuphar 80%	dark sand ciemny piasek
2c	11.7	4.0	40	Potamogeton Nuphar 80%	sand piasek
3	13.5	3.9	32	Potamogeton Nuphar 80%	sand and gravel piasek i żwir
5	25.0	5.3	30	Potamogeton Nuphar 70%	sand and gravel piasek i żwir

ber 11, November 11, and December 15, 1977. From May, on the river trimming work carried out on the Drwinka near Chobot made further investigations at station 5 at Zielone impossible. For this station, the results of analyses refer to the first three dates (January, February and March).

Water samples were collected with a modified Żukrowski sampler (Żadin 1966) at a depth of 15—20 cm below water surface, and kept in 1- and 2-litre plastic containers. The microelement content in sediments was found by Matis and Cummings method (1973). Water temperature and ionic reaction were measured at the stations, using a sampler thermometer and a N-511 battery operated pH-meter which was standardized with pH 4 and pH 6,88 buffers before measurement. Analyses of the free CO_2 content in water were carried out in the laboratory on the sampling day. Electrolytic conductance was measured in the laboratory using an „Oxytester". The content of macroelements was determined according to Standard Methods (1955) or to those given by Golterman (1969) and Just and Hermanowicz (1955). The content of microelements in water was determined by spectral emission analysis according to the method described by Pasternak (1973).

In order to prevent changes in the ionic concentration, the chemical analysis of water was always carried out in a time interval not exceeding 48 hrs after the samples were transported to the laboratory.

Means ($\bar{x}$) and standard deviations ($\pm$ SD) were chiefly used in the statistical evaluation of results. The standard error (SE) was also found. Relations between mean BOD_5 and oxidation values, and the distance between stations were described using semi-logarithmic regression equations according to Oktaba (1974).

As all vascular plants growing in river beds of the Drwinka and its tributaries were cut in September in connection with the preservation works of land reclamation ditches, the decomposition processes which usually occur in this type of streams were almost wholly eliminated and, therefore, the native matter was not taken into account in the study.

Results

Even the preliminary analysis of the measurements suggests considerable pollution of the Drwinka waters. This was indicated by a changed ionic composition of water, characterized by an increased amount of chlorides, sulfates and sodium, and a decreased amount of calcium carbonates (Table II). It was manifested in the general proportions of ions, which were chiefly represented by carbonates (21.4—30.5%), calcium (27.2—35.2%), sulfates (8.8—21.9%), chlorides (3.8—9.9%), sodium (4.9—12.9%), magnesium (6.3—11.1%) and potassium (0.9—2.5%).

The wastes fed to the river were of an organic character. At station 2, this was indicated by a high content of dissolved organic nitrogen (2.99—11.51%), coloration in the range of 110—180° Pt, biochemical oxygen demand of 10—70 mg O_2/l, and also by the amount of volatile organic matter which constituted 38% of the dry residue, on the average. The greatest load of sewage in the Drwinka water was noted in December, the highest content of dry residue (659 mg/l), organic nitrogen (11.51 mg/l), and oxidation (32.08 mg O_2/l) being found then at station 2.

In day time, water in the Drwinka grew warmer fairly rapidly. In

Table II. Some elements of the chemical compositions of water of the Drwinka stream
Computations of: mean values ($\bar{x}$); standard deviation ($\pm SD$); standard mean error (SE)

Tabela II. Wybrane czynniki składu chemicznego wody Drwinki
Obliczono: wartości średnie ($\bar{x}$); odchylenie standardowe ($\pm SD$); błąd standardowy średniej (SE)

Factors / Czynniki \ Sampling station / Stanowisko		2			2a			2b			2c			3			5		
		$\bar{x}$	$\pm SD$	SE	$\bar{x}$	$\pm SD$	SE	$\bar{x}$	$\pm SD$	SE	$\bar{x}$	$\pm SD$	SE	$\bar{x}$	$\pm SD$	SE	$\bar{x}$	$\pm SD$	SE
Conductance of electrolytes Przewodnictwo	uS 20°C	539.9	59.3	19.7	523.4	64.3	22.7	459.9	28.4	10.0	456.4	36.3	12.8	442.2	78.7	26.2	379.0	94.0	54.3
Turbidity Mętność	SiO_2 mg/dm^3	234	77.5	27.4	119	38.5	15.7	64	26.4	10.8	45	15.1	6.1	40	12.3	4.6	40	11.9	4.3
Colour Barwa	°Pt	126	28.1	8.8	88	18.2	6.4	57	9.6	3.4	49	6.2	2.2	47	6.2	2.0	41	5.7	1.3
pH		7.1	0.03	0.05	7.2	0.2	0.08	7.4	0.3	0.09	7.5	0.2	0.08	7.4	0.2	0.08	7.1	0.3	0.2
Total hardness Twardość ogólna	°G °n	16.7	0.8	0.2	15.7	0.5	0.1	14.7	0.5	0.2	13.7	0.7	0.2	13.5	0.7	0.2	9.7	1.1	0.6
Carbonate hardness Twardość węglanowa	°G °n	11.4	1.0	0.3	10.9	1.2	0.4	9.7	1.3	0.4	9.6	1.3	0.4	8.9	1.3	0.4	5.6	1.6	0.9
CO_2 -free -wolny	mg/dm^3	15.6	1.5	0.5	12.7	1.4	0.4	9.8	2.9	0.9	6.5	3.0	1.0	5.8	2.8	1.0	4.1	2.6	1.1
Chlorides Chlorki	Cl mg/dm^3	41.9	12.2	3.8	33.1	9.8	3.2	22.3	3.4	1.1	20.7	3.0	1.0	20.5	3.9	1.3	11.2	1.4	0.8
Calcium Wapń	Ca mg/dm^3	91.6	7.2	2.3	87.1	5.8	1.9	79.5	6.0	2.0	76.7	6.6	2.2	75.2	6.4	2.1	52.6	4.6	2.6
Magnesium Magnez	Mg mg/dm^3	14.9	1.9	0.6	13.3	1.2	0.4	12.1	1.2	0.4	11.7	1.1	0.4	11.1	1.0	0.3	8.4	1.3	0.8
Potassium Potas	K mg/dm^3	12.9	2.4	0.8	10.0	1.6	0.5	6.7	1.2	0.4	5.3	0.7	0.2	4.9	0.7	0.2	3.9	0.1	0.09
Sodium Sód	Na mg/dm^3	36.5	10.7	3.5	27.1	10.9	3.8	17.7	3.8	1.3	16.8	3.5	1.2	16.5	3.0	1.0	12.4	2.2	1.3
Sulphides Siarczany	$S-SO_4$ mg/dm^3	30.3	5.3	1.8	26.1	8.7	3.1	24.5	7.3	2.6	23.7	7.5	2.6	22.0	5.2	1.7	21.7	6.7	3.9
Phosphates Fosforany	$P-PO_4$ mg/dm^3	0.26	0.12	0.04	0.19	0.1	0.04	0.12	0.07	0.03	0.08	0.04	0.01	0.07	0.02	0.0	0.03	0.0	0.0
Total nitrogen Azot ogólny	N mg/dm^3	10.6	5.0	1.6	8.0	4.1	1.4	5.6	3.0	1.1	4.8	3.0	1.1	4.3	2.1	0.7	2.2	0.3	0.1
Silica Krzemionka	SiO_2 mg/dm^3	7.1	1.3	0.4	6.9	0.5	0.2	5.9	1.7	0.6	5.8	1.4	0.5	5.8	1.2	0.4	5.2	1.7	1.0
Dry residue Sucha pozostałość	mg/dm^3	497.0	57.5	20.3	438.5	32.2	13.1	398.2	34.5	14.1	390.9	30.6	12.5	373.0	23.5	8.9	293.5	31.0	17.9
Loss on ignition Strata przy prażeniu	mg/dm^3	164.8	61.5	21.7	148.9	44.4	18.1	140.5	46.4	18.8	132.0	47.3	19.3	123.1	42.6	16.1	115.6	17.3	10.0
Total fixed residue Pozostałość po prażeniu	mg/dm^3	332.2	59.7	21.1	292.6	40.3	16.4	257.7	22.9	9.4	250.1	27.8	11.4	246.5	29.7	11.2	177.9	32.8	18.9
Sum of electrolytes Suma elektrolitów	me/dm^3	15.5	1.3	0.4	13.8	0.9	0.3	11.9	0.6	0.2	11.5	0.7	0.2	11.1	0.8	0.3	7.9	0.4	0.2

Table III. Water temperatures in the Drwinka stream as found in 1977 investigations (h - hours; t.w. - water temperature in °C)

Tabela III. Wartości temperatury wody Drwinki z terminów badań w 1977 r. (h - godziny; t.w. - temperatura wody w °C)

Stations Stanowiska	Dates - Daty																			
	10.1.		28.2.		27.4.		30.5.		16.6.		18.7.		12.9.		11.10.		16.11.		15.12.	
	h	t.w.	h	t.w.	h	t.w.	h	t.w.	h	t.w.	h	t.w.	h	t.w.	h	t.w.	h	t.w.	h	t.w.
2	9^{00}	3.7	9^{00}	3.5	9^{00}	10.8	9^{00}	15.9	10^{00}	20.2	9^{00}	11.5	9^{00}	12.8	9^{00}	11.6	9^{00}	7.7	9^{00}	3.4
2a	10^{00}	1.9	10^{00}	3.3	10^{00}	10.8	10^{00}	15.9	11^{30}	20.4	10^{00}	12.7	10^{00}	12.9	10^{00}	11.6	10^{00}	5.8	10^{00}	1.2
2b	11^{00}	0.1	11^{30}	2.8	13^{00}	11.1	11^{30}	15.9	12^{30}	20.6	13^{30}	16.1	14^{00}	17.2	13^{00}	12.5	11^{30}	5.2	11^{00}	1.1
2c	12^{00}	0.1	12^{30}	1.9	12^{00}	11.0	14^{00}	16.4	9^{30}	20.2	12^{30}	15.1	12^{30}	16.0	12^{30}	12.3	12^{00}	5.0	12^{30}	0.8
3	13^{00}	0.1	13^{30}	1.1	11^{00}	10.9	13^{00}	16.0	9^{00}	20.1	11^{30}	15.1	11^{30}	14.0	11^{00}	11.6	13^{00}	4.9	13^{30}	0.4
5	14^{00}	0.1	14^{00}	0.4	14^{00}	11.1														

winter, almost the entire length of the investigated sector was covered by a 10-centimetre ice sheet, only the most polluted sector remaining free of ice. From November to March the highest water temperatures were noted in this sector (Table III). In July during sunny weather, daily water temperatures in the transverse profile were examined at station 2. It was found that the highest temperatures (23.0—23.2°C) occurred between 2 p.m. and 4 p.m. while the lowest temperature (14.5°C) was noted at 6 a.m. Neither the ionic composition nor the water hardness changed much throughout the year (Table II). Changes in the water hardness were chiefly related to the variation in calcium content, while pollution had only a small effect on them. In February, at a clearly increased

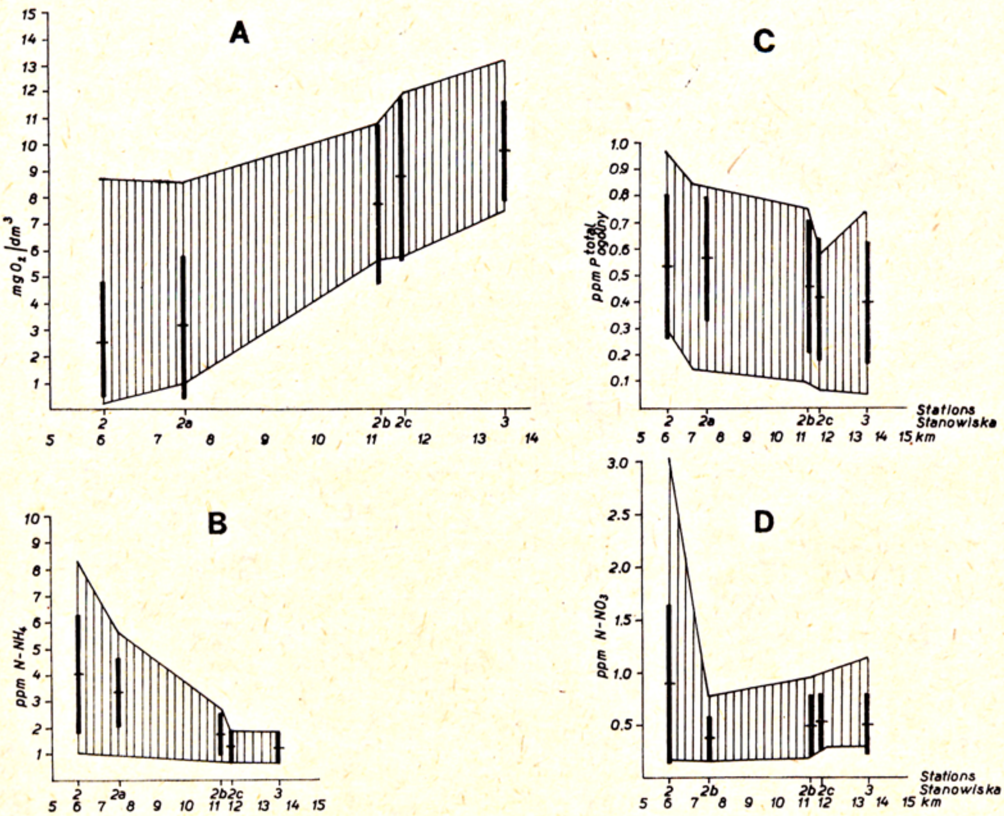

Fig. 2. Variations in concentration in the Drwinka water: A — oxygen; B — ammonia nitrogen; C — total phosphorus; D — nitrate nitrogen. Thick lines denote mean concentrations (x) with standard deviation (± SD)

Ryc. 2. Zakres wahań koncentracji w wodzie Drwinki: A — tlenu; B — azotu amonowego; C — fosforu ogólnego; D — azotu amonowego: Linie pogrubione oznaczają średnie koncentracje (x) wraz z odchyleniem standardowym (± SD)

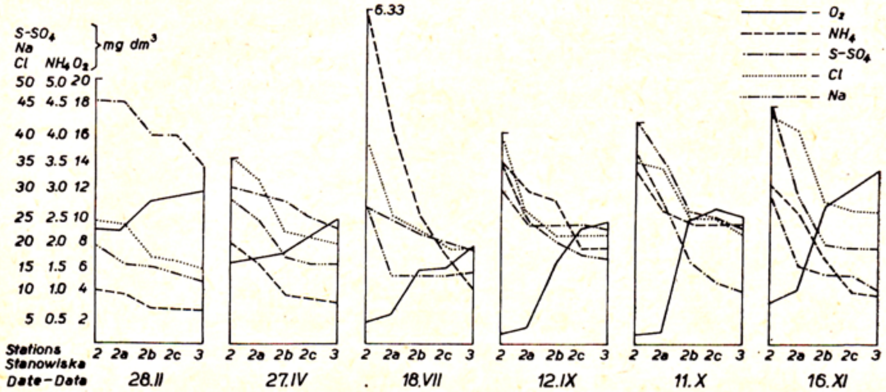

Fig. 3. Content curves of some elements of the ionic water composition of the Drwinka stream on several investigation dates

Ryc. 3. Krzywe wartości niektórych elementów składu jonowego wody Drwinki w wybranych terminach badań

water level, a decrease in salinity from 3.0 to 1.6 me/l and a simultaneous increase in sulfate content were noted at all stations. At stations 2 and 2a, most seriously affected by wastes, a very low concentration of oxygen was usually observed (fig. 2A). Only in February the oxygenation increased to above 6 mg O_2/l in this station and improved at stations located at greater distances from the inflow of wastes. In June and July, oxygen content below 6 mg/l was noted at station 2b, while at station 2c this was observed only in June.

Throughout the year a distinct increase in oxygen content occurred at the first three stations during summer months, while at stations 2c and 3 a much more uniform level of oxygen concentration was observed (fig. 3). At low water oxygenation mineral nitrogen compounds occurred, mainly in the form of ammonium ions (fig. 2B). Variation in the content of this nitrogen form was in accordance with changes in the oxygen

Table IV. Mean concentrations of important heavy metals in water and bottom sediments of the Drwinka stream

Tabela IV. Średnie wartości koncentracji ważniejszych metali ciężkich w wodzie i w osadach dennych rzeki Drwinki

Metals / Metale — Sampling stations / Stanowiska	Water – woda – ppb						Bottom sediments – osad denny – ppm					Fe %
	Cd	Pb	Cu	Ni	Zn	Fe	Cd	Pb	Cu	Ni	Zn	
2	0.8	15	16	162	618	2049	1.3	37	68	91	460	3.71
2a	0.0	6	5	32	428	1672	1.2	31	63	76	383	3.51
2b	0.0	10	16	23	509	1296	1.1	32	32	75	274	2.59
2c	0.0	9	8	20	464	950	0.8	19	31	75	262	2.09
3	0.0	6	7	16	358	785	1.2	18	30	71	236	1.75

content. With satisfactory oxygenation the amount of ammonia ions distinctly decreased while that of nitrates increased (fig. 2D). For precise determination of this variation, the NH_4/NO_3 ratio was computed. At the successive stations, the values of this index were: station 2 — 10.97, station 2a — 10,46, station 2b — 5.16, station 2c — 2.68, and station 3 — — 2.17.

The content of total phosphorus greatly differed on the individual dates of sampling: however, on all dates high concentrations of this element were noted on the entire length of the investigated stream (fig. 2C). When the oxygen conditions grew worse, phosphorus from bottom sediments contributed to an increase in the concentration in the water.

The analysis of microelement content in water and bottom sediments of the Drwinka showed that most metals did not occur at critical concentrations (Table IV). Conditions prevailing in this aquatic environment were favourable for the precipitation of these elements from the water. Only the concentration of iron was maintained at a very high level. The highest concentration of heavy metals in water was found at station 2, with the content of different elements decreasing along the river course (Table IV). The smallest differences were noted in the concentration of cadmium (0.0—10.0 ppb), lead (0.0—40.0 ppb) and copper (0.0—70.0 ppb), while the content of nickel (0.0—497.0 ppb), zinc (15.0—1480.0 ppb) and iron (343.0—3695.0 ppb) greatly varied. This strong variation and an irregular decrease in the concentration of microelements in the water suggest a variable inflow of heavy metals to the river.

An analysis of the ion-equivalent composition of water from the Lane Błoto stream showed that it strongly differed from the Drwinka water. As in most unpolluted surface waters of our climatic zone, their chief components are calcium and magnesium carbonates. Several biochemical processes occurring in the environment of this small tributary of the Drwinka were detected by water analysis. In summer, intense photosynthetic processes resulted in the depletion of free CO_2 and in a constant saturation of water with oxygen (up to 140%), this bringing about the precipitation of iron which readily oxidized, and an increase in water alkalinity to pH 8.5.

Organic pollution was fed into the other investigated tributary, the Ruski Potok stream from a dairy in Wola Batorska. It distinctly affected the chemical composition of the water in the mouth sector of this stream. During the investigation period, water oxygenation did not exceed 50%, the concentration of organic nitrogen was 3.3 mg/l on the average and the concentration of sulfates and of sodium was also increased. However, because of small water yields, this tributary did not markedly influence the chemical composition of the Drwinka waters.

Discussion

As it is known, the self-purification process of rivers occurs constantly, its intensity and rate resulting from the intensity and character of pollution. Results of experiments (Mc Coll 1973) showed that with a natural low level of biogenes dissolved in water the process of purification of the inflowing compounds was effective and rapid.

The self-purification of the River Drwinka mainly occurred in a 5-kilometre sector below Niepołomice, between stations 2 and 2b. In the first kilometres below the inflow of wastes, the biochemical oxidation of

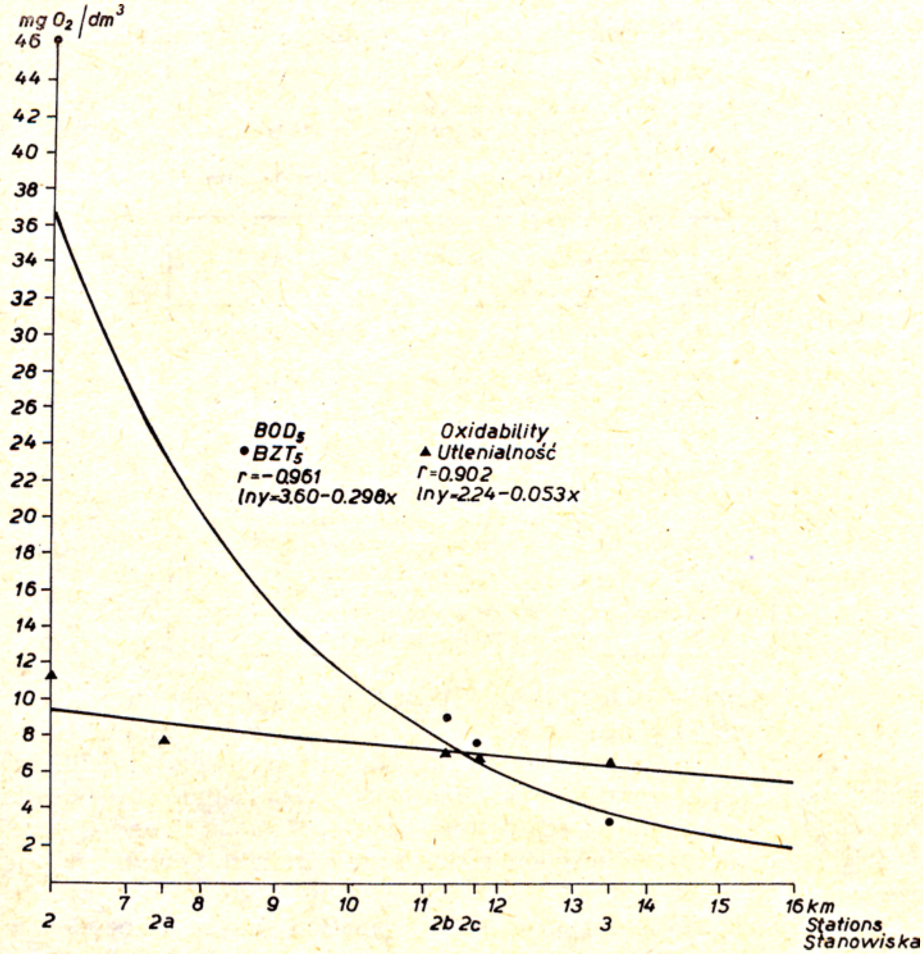

Fig. 4. Distribution of mean values of BOD_5 (mg O_2/dm^3) and of oxidability (mg O_2/dm^3) along the Drwinka course (km)

Ryc. 4. Rozkład średnich wartości BZT_5 (mg O_2/dm^3) i utlenialności (mg O_2/dm^3) wzdłuż biegu Drwinki (km) organic matter chiefly occurred, being particularly distinct in the sector between stations 2 and 2a. This was indicated by the high values of the biochemical oxygen demand and frequent oxygen deficits at these stations (fig. 4). From station 2b, vascular plants played a marked role in the purification of the Drwinka, assimilating great amounts of nutritive compounds.

Marsh components which enter the Drwinka water were also partly eliminated and accumulated in bottom sediments. Due to the beneficial oxygen conditions at slightly polluted stations only a small part of these components returned from sediments to the water.

A 35% decrease in the mean concentrations of most macroelements occurred between stations 2 and 3 (Table V) while water yields increased

Table V. Percentage changes in mean concentrations in mean concentrations of macroelements in the Drwinka stream water

Tabela V. Zmiany w średnich koncentracjach makroelementów w wodzie Drwinki wyrażone w procentach

Sampling stations / Stanowiska — Factor / Czynnik	2	2a	2b	2c	3	5
NH_4	100	78.8	52.4	39.7	33.7	20.2
NO_2	100	38.8	29.1	28.1	28.1	15.3
NO_3	100	62.4	96.7	132.6	106.8	91.3
N-org.	100	71.5	67.5	59.3	55.3	37.0
N-tot.	100	75.5	61.0	51.8	45.6	30.4
Cl	100	78.3	55.6	52.2	49.4	39.2
SO_4	100	84.1	77.6	73.8	68.9	64.5
Ca	100	95.4	86.5	83.6	82.4	59.5
Mg	100	89.9	80.2	77.3	73.5	49.6
K	100	79.3	53.8	42.2	38.9	36.6
Na	100	71.4	53.5	51.2	47.7	46.5
PO_4	100	60.3	42.6	29.6	24.3	20.6
P-tot.	100	93.7	78.3	64.9	56.5	55.1
Si	100	93.8	85.3	82.0	80.8	80.1

by about 30% in this sector of the stream. Therefore, the diluting effect of the inflows only slightly influenced the trophic level of water.

The mean concentrations of the investigated elements at different stations suggest the occurrence of three basic zones in the course of the Drwinka below the inflow of wastes: zone 1, stations 2 and 2a, the strongly polluted zone; the regeneration zone within station 2b, and the pure water zone at stations 2c, 3 and 5. This division is based on a pronounced improvement of water oxygenation and on a decrease in the concentrations of most investigated compounds (Table II and V). However, in spite of a distinct improvement, the content of nutritive compounds in the water of the last stations was much higher than the limits of nitrogen and phosphorus concentrations in natural waters which were quoted by Vollenweider (1968).

I am highly indebted do Dozent Dr. Hab. Ryszard Sowa for his personal guidance during the studies and for his patient perusal of the manuscript.

STRESZCZENIE

W pracy przedstawiono ogólną charakterystykę hydrochemiczną i stopień zanieczyszczenia nizinnego strumienia Drwinki, prawostronnego dopływu Wisły poniżej Krakowa, na podstawie badań przeprowadzonych w 1977 r. W tym samym czasie prowadzone były na tym odcinku strumienia badania biologiczne obejmujące glony, mikro- i makrofaunę. Badania chemiczne obejmowały odcinek Drwinki, leżący między 6 a 19 km od jej źródeł, tj. od Niepołomic do Zielonej, wraz z przyujściowymi odcinkami dwóch dopływów: Ruskiego Potoku i Lanego Błota (ryc. 1). Koryto Drwinki i jej dopływów jest zmodyfikowane poprzez przeprowadzone regulacje i bujnie porośnięte przez rośliny naczyniowe.

Próby wody i osadów pobierano na sześciu głównych stanowiskach (tabela I) w odstępach miesięcznych pomiędzy godziną 9 a 14 (tabela III). Przy opracowaniu wyników badań posługiwano się głównie wartościami średnimi ($\bar{x}$) i odchyleniem standardowym ($\pm$ SD).

Analiza dokonanych pomiarów wskazuje na zmieniony skład jonowy wody, który pozostaje pod znacznym wpływem dochodzących zanieczyszczeń organicznych i charakteryzuje się zwiększoną zawartością chlorków, siarczanów i sodu przy malejącym udziale węglanów wapnia (tabela II). Na najsilniej zanieczyszczonym odcinku Drwinki notowano przeważnie bardzo niskie stężenia tlenu (ryc. 2A) przy jednoczesnej bardzo wysokiej koncentracji większości analizowanych czynników (ryc. 3), nie stwierdzono w czasie badań krytycznych stężeń większości mikroelementów (tabela IV).

Na podstawie spadku koncentracji na kolejnych stanowiskach większości elementów składu jonowego wody wyróżniono w Drwince trzy strefy: silnego zanieczyszczenia, odnowy i czystej wody. Spadek ten jest wynikiem procesu samooczyszczania się strumienia dokonującego się w dużym stopniu na odcinku 5 kilometrów poniżej Niepołomic pomiędzy stanowiskami 2 i 2b (tabela V).

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