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Chemical composition of water in the Czarna Wisełka and Biała Wisełka streams and the Wisła-Czarne dam reservoir

Skład chemiczny wody Czarnej Wisełki i Białej Wisełki oraz zbiornika zaporowego Wisła-Czarne

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Abstract: This article contains the results of research on the chemical composition of water in the Czarna Wisełka and Biała Wisełka streams and the trophic state of the Wisła-Czarne dam reservoir. Studies conducted in 1993 and 1994 revealed a strong acidification of the water in the Czarna Wisełka stream, especially in its upper course. It was acompanied by a high aluminium concentration which positively correlated with hydrogen ion concentrations. The influence of dolomite application in the middle course of the Czarna Wisełka on its water characteristics was also discussed.

In spite of the inflow of strongly acidified waters, intensive "water blooms" have been occurring in the Wisła-Czarne dam reservoir. The strong water alkalization (pH 9.4) in these periods is caused by the high intensity of algae photosynthesis and low concentration of calcium hydrocarbonates.

Acidification and eutrophication have been the main causes of the deterioration of the water quality in the Wisła-Czarne dam reservoir.

Key words: water acidification, dolomite application, eutrophication.

Treść: W artykule przedstawiono skład chemiczny wody Czarnej Wisełki i Białej Wisełki oraz stan troficzny zbiornika zaporowego Wisła-Czarne. W badaniach prowadzonych w latach 1993 i 1994 stwierdzono silne zakwaszenie wody Czarnej Wisełki, zwłaszcza w górnym jej biegu. Stwierdzono także wysokie stężenie glinu skorelowane dodatnio ze stężeniem jonów wodoru. Opisano ponadto wpływ dolomitu, zastosowanego w środkowym biegu Czarnej Wisełki, na wody tego potoku.

Mimo okresowego dopływu silnie zakwaszonych wód do zbiornika zaporowego, występują nim intensywne „zakwity wody". Duże natężenie fotosyntezy glonów i niskie stężenie kwaśnych węglanów wapnia są przyczynami silnej alkalizacji wody w zbiorniku (pH 9.4).

Zakwaszenie i eutrofizacja to główne przyczyny pogorszenia się jakości wody w zbiorniku Wisła-Czarne.

1. Introduction

The Vistula River originates at the confluence of two streams – the Czarna Wisełka and the Biała Wisełka, which is situated at an altitude of 524 m. The former, being the longest one, is regarded as the Vistula River origin while the latter as its tributary (Punzet 1998). Three hundred meters downstream from their confluence, a dam was constructed at the beginning of the seventies. The dam reservoir covers an area of 40 hectares with a maximum capacity of 5 mln m^3. This dam reservoir serves as a drinking water supply for the following neighbouring towns: Wisła, Ustroń, Goleszów and part of Skoczów.

Although the spring areas of the Czarna Wisełka and Biała Wisełka streams have not been paid particular attention to by specialists in water chemistry, they have been studied by specialists in hydrography (Barański 1994, Punzet 1998). A complete analysis of water in both streams was performed in the summer of 1952 (unpublished data). It constituted part of the preliminary investigations preceding the filling of the dam reservoir in Goczałkowice. The research revealed acidification in the Czarna Wisełka (pH 6.3) while the Biała Wisełka remained neutral. Differences in water chemistry were confirmed at the turn of the fifties and sixties by ichthyologic studies (Kołder 1964). Brown trout were found in both streams, but their population was found to be much poorer in the Czarna Wisełka stream.

Systematic studies of the lower courses of the Czarna Wisełka and Biała Wisełka streams and the Wisła-Czarne dam reservoir were initiated in 1974 (Magosz 1976) and continued until 1984 (Kasza 1986). The purpose of these studies was to observe water eutrophication in the dam reservoir.

At the beginning of the eighties, the sessile algae of both the Czarna Wisełka and Biała Wisełka streams were studied (Kwandrans 1989). The study showed significant differences in sessile algae composition and water chemistry. Subsequent investigations confirmed a water acidification in the Czarna Wisełka stream which was accompanied by a high aluminium level (Wróbel, Wójcik 1989). During research of the eighties and the nineties, on no occasion were any fish observed in the Czarna Wisełka. They were, however, found in the Biała Wisełka (Szczęsny, Kukuła 1998). It should be stressed that both the Czarna Wisełka and Biała Wisełka streams have been declared a nature reserve, created in 1959 with the aim of protecting the brown trout population. Furthermore, it should be noted that in the last century, a salmonid fish hatchery, belonging to the Polish Association of Anglers, was built in the village of Wisła-Czarne which is presently located downstream the dam.

This hatchery operated until the spring of 1985 when it was closed due to total fry mortality. Water to be used in the hatchery was supplied from the same source as the water treatment plant. In should be added here that water intakes in the dam reservoir are situated at 3 levels (at 6 m, 11 m and 16 m from the bottom).

In recent years, a deterioration of water quality in the dam reservoir has been observed in the water treatment plant. In the spring and after heavy rainfalls, water acidification has been noticed, while „water blooms" occurred in the summer.

The main aim of this survey was to determine the causes of water acidification in the Czarna Wisełka, in relation to water composition in the Biała Wisełka, and the eutrophication of the Wisła-Czarne dam reservoir. The evaluation of an influence of dolomite application on water composition in the Czarna Wisełka stream was an equally important goal of the study.

2. Study area

Both streams, the Czarna Wisełka and Biała Wisełka, run from Mt. Barania Góra (1220 m a.s.l.). The springs of the former are located on its southern slope and of the latter, on the north-western (Punzet 1998). Some characteristics of the streams and their catchments are given in Table 1.

Table 1. Characteristics of the Czarna Wisełka and Biała Wisełka streams and their catchments (according to various authors)

Tabela 1. Charakterystyka Czarnej i Białej Wisełki i ich zlewni (wg różnych autorów)

Characteristics Charakterystyki	Czarna Wisełka	Biała Wisełka
Spring altitude m Wysokość źródeł m npm.	1150	1100
Length km Długość km	9.6	6.6
Catchment area km^2 Powierzchnia zlewni km^2	12.23	16.54
Slope exposures: Ekspozycje zboczy:		
southern (południowa) %	31	27
northern (północna) %	20	39
Catchment land use: Zagospodarowanie zlewni:		
forest (lasy)	95	84
arable land (użytki rolne)	0	14

It is important to emphasize that the right-bank tributaries of the Czarna Wisełka stream drain from the southern slopes of Mt. Barania Góra while the left-bank tributaries of the Biała Wisełka stream drain from the northern ones. The Silesian Beskid and Mt. Barania Góra are built of Carpathian flysh. The Czarna Wisełka catchment is primarily covered with podsolic soils developed on sandstones of the Istebna beds which are poor in calcium and magnesium. On the other hand, brown soils, developed from sandstones and mud stones of the Godula beds, prevail in the catchment of the Biała Wisełka stream (Maciaszek, Zwydak 1998). Therefore, soils in the Czarna Wisełka catchment are more prone to acidification.

The catchment of the Czarna Wisełka and Biała Wisełka differ in forest species structure. Spruce (*Picea abies*), introduced in the last century in lieu of an exploited mixed forest, is almost the exclusive constituent of forests overgrowing the Czarna Wisełka catchment, while mixed spruce-fir-beech forests cover the Biała Wisełka stream catchment. The catchment of the dam reservoir is also overgrown with forest.

In terms of altitude the Wisła-Czarne dam reservoir is one of the highest dam reservoirs in Poland; the maximum altitude of its water level is 551.2 m and its capacity equals 5 mln m^3. At a normal water level of 544.5 m, the capacity of the dam reservoir is 2.1 mln m^3 (Olszamowski 1995). The present study was conducted during normal water level.

Both catchments are sparsely populated. Tourist accomodation is located about 7 km from the dam reservoir in the catchment of the Czarna Wisełka, while in the lower course of the Biała Wisełka, there is a village with 1000 permanent inhabitants. The population doubles in the summer. Sewage from this village are partially disposed into the Biała Wisełka stream.

Precipitation level in the catchment of the Czarna Wisełka, as measured at the station in Przysłop, averaged 1400 mm per year while the yearly average value in the whole Barania Góra massif amounted to 1350 mm. In 1993 and 1994, when the survey was conducted, the average precipitation level at the two stations (Wisła-Malinka and Istebna-Stecówka) was 1080 mm and 1420 mm, respectively (the first year of research being much drier than the second).

3. Methods

Studies of chemical composition of water in the Czarna Wisełka and Biała Wisełka streams began in May 1993 and ended in May 1995. Every month, samples were collected at three stations on the Czarna Wisełka (Cz1, Cz2, Cz3) and at one station on the Biała Wisełka (B) (Fig. 1). Two stations on the stream Płony (P1, P2) were also studied. Sporadically, samples were collected from the Biała Wisełka stream near its inflow into the dam reservoir.

Chemical investigations of water in the Wisła-Czarne dam reservoir were conducted on the same experimental basis, in two vegetation seasons. Water samples were collected in the euphotic zone (at a depth equal to double the visibility of Sacchi disc), within the range 5–8 m. During „water blooms", water was collected at several depths (surface, 1.0, 2.5, 5.0, 10, 15 m). The vertical profile of temperature and oxygen content was determined during collection of each sample. Samples were collected at 3 stations: near the dam (R1), in the Biała Wisełka bay (R2) and in the Czarna Wisełka bay (R3) as well as at the reservoir's outlet. Additionally, water samples were taken twice from the springs of the Czarna Wisełka and Biała Wisełka streams. The first series was collected in May 1994, during spring thaw in the higher part of Mt. Barania Góra, while the second was taken in August in the same year, when the water level in the streams was very low. In addition, water samples were collected twice from several streams in the Silesian Beskid in 1993. Lastly, 4 samples of melted snow were collected in the catchment of the Czarna Wisełka stream and 14 rain samples collected in Water Treatment Plant in Wisła-Czarne were analysed in 1994.

This analysis of water samples was conducted according to the methods described by Hermanowicz et al. (1976). Nitrates were determined in conformity with the Polish Standard. Chlorophyll was measured by the method of Golterman and Clymo (1969). Samples collected at all stations on streams were studied by the ICP-AES in the Institute of Hydrogeology at the Technical University of Kraków. The water ion

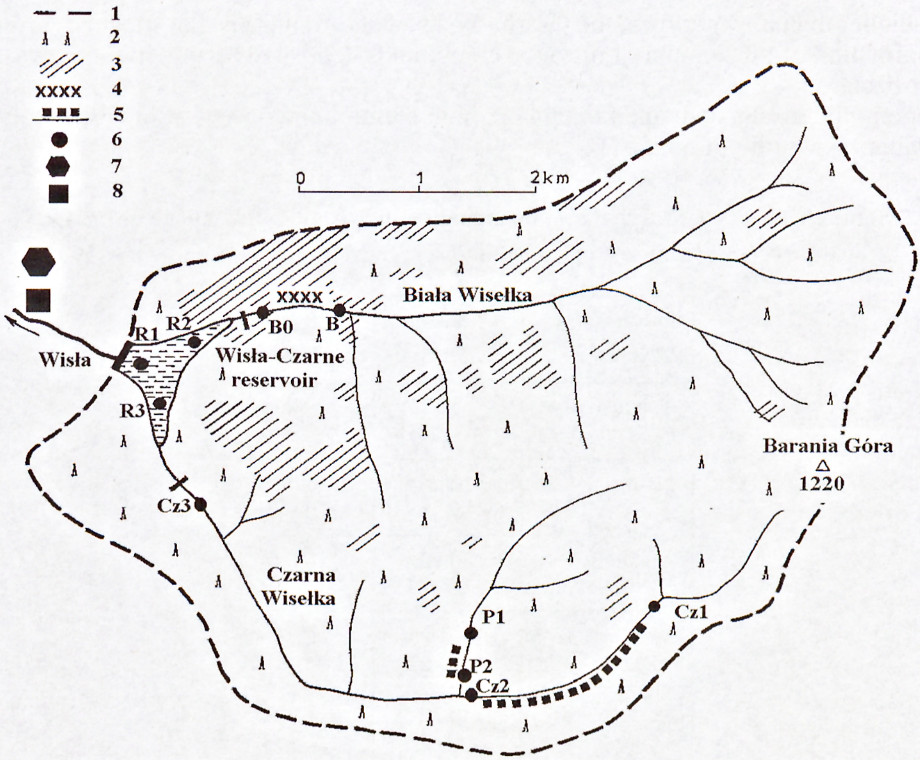

Fig. 1. Catchment of the Czarna Wisełka and the Biała Wisełka streams: 1 – boundary of the catchment, 2 – forest, 3 – arable land, 4 – buildings, 5 – dolomite application, 6 – stations, 7 – hatchery, 8 – water treatment plant. Desigrations of stations explained in the text.

Ryc. 1. Zlewnia Czarnej i Białej Wisełki: 1 – granica zlewni, 2 – las, 3 – użytki rolne, 4 – zabudowania, 5 – dolomitowanie, 6 – stanowiska, 7 – wylęgarnia, 8 – stacja uzdatniania wody. Oznaczenia stanowisk objaśnione w tekście.

content was analysed by using an original computer program titled „MauchaProg", written by Andrzej Wróbel.

Water in the Czarna Wisełka stream was neutralized with 230 t of dolomite gravel deposited in its middle course. Additionally, 50 t of dolomite gravel was deposited in the Płony stream, one of the Czarna Wisełka stream tributarties. Dolomite was deposited in a period from the 4th of September to the 7th of December 1993.

4. Results

4. 1. Some characteristics of chemical composition of precipitation

Snowmelt and rain water were analysed in 1994. The pH of snowmelt reached a value as low as 5.2, while pH-value of rain water dropped down to 4.1 (Tab. 2).

All constituents, including nitrogen compounds, reached their highest concentrations after long dry periods. Maximum ammonium concentrations in rain water were almost 10 times higher than in water from the Czarna Wisełka and Biała Wisełka streams. A rough approximation of the amount of nitrogen compounds deposited by precipitation was 18 kg per hectare.

Among the results contained in table 2, high aluminium concentration, especially in rain water, is worthy of notice.

Table 2. Some chemical characteristics of precipitation in Wisła-Czarne village in 1994

Tabela 2. Niektóre cechy chemiczne opadów atmosferycznych w Wiśle-Czarnem w 1994 r

Factor Czynnik	Snow Śnieg	Rain Deszcz
Conductivity (μS/cm, 25°C)	12.2 4.1–22.4	37.0 7.9–108
pH	5.5 5.2–5.9	4.9 4.1–6.0
Alkalinity mval/dm^3	0.10 0.08–0.12	0.09 0.02–0.22
Total hardness G.d.	0.08 0–0.22	0.33 0.11–1.00
Ca mg/dm^3	0.38 0–0.79	1.72 0–6.58
Mg mg/dm^3	0.18 0–0.48	0.31 0–0.95
N-NH_4 mg/dm^3	0.172 0.104–0.252	0.609 0.129–2.85
N-NO_3 mg/dm^3	0.327 0.111–0.564	0.836 0.139–3.00
P-PO_4 mg/dm^3	0.024 0.008–0.041	0.034 0.006–0.130
Al mg/dm^3	0.029 0–0.056	0.108 0.011–0.380

4. 2. Chemical composition of water of the springs of the Czarna Wisełka and Biała Wisełka streams

The chemical composition of water in one of the springs of the Czarna Wisełka stream („Pod Smrekiem") demonstrated characteristics of acidic waters. Its particular features were: low pH (Tab. 3), an alkalinity equalling zero and a low calcium concentration. Aluminium concentration, however, was high. A left-bank tributary of the Czarna Wisełka stream, which appears during the spring thaw above the aforementioned spring, is even more acidified. This

Table 3. Some chemical features of water in the Czarna Wisełka and Biała Wisełka springs
Tabela 3. Niektóre cechy chemiczne wody źródeł Czarnej Wisełki i Białej Wisełki

Parameter Czynnik	Czarna Wisełka				Biała Wisełka		
	"Pod Smrekiem" spring Źródło "Pod Smrekiem"		Drip Wykap		Spring Źródło		Spring near a trail Źródło przy szlaku
	May	August	May	August	May	August	August
Conductivity μS/cm, 25°C	61.3	39.7	70.5	76.4	70.6	82.7	65.0
pH	3.96	5.50	3.70	4.00	6.10	6.62	4.38
Alkalinity mval/dm^3	0	0.16	0	0	0.21	0.30	0.23
Total hardness G.d.	0.29	0.54	0.26	0.38	1.31	1.71	0.88
N-NH_4 mg/dm^3	0.52	0.12	0.82	0.46	0.13	0.21	0.15
N-NO_3 mg/dm^3	1.15	1.62	0.54	0.15	1.60	1.50	0.41
P-PO_4 mg/dm^3	0.168	0.027	0.033	0.012	0.052	0.015	0.014
SO_4 mg/dm^3	5.50	3.57	3.46	10.15	13.60	15.00	14.70
Cl mg/dm^3	1.40	1.70	1.40	1.85	1.80	2.00	2.00
Ca mg/dm^3	1.80	2.08	1.42	2.06	7.33	7.27	3.44
Mg mg/dm^3	0.63	1.21	0.25	0.71	2.60	2.92	1.35
Al μg/dm^3	505	65	379	325	51	–	358
Fe μg/dm^3	163	62	275	833	10	10	137
Mn μg/dm^3	64	37	8	94	4	5	78
Zn μg/dm^3	140	718	143	383	30	545	506
Ba μg/dm^3	217	148	167	176	112	89	117
Sr μg/dm^3	3	13	1	12	14	22	12
Hg μg/dm^3	2.3	–	1.6	–	1.0	–	–
DOC mg/dm^3	–	3.1	14.0	10.6	3.5	1.0	–
UV absorbance	–	44.0	92.50	46.00	3.28	1.06	–

stream dries completely during rainless periods and, its flow into the Czarna Wisełka stream only supplies it with negligible amounts of water. It should be added that this stream crosses a peatbog. An exceptionally characteristic phenomenon is a change in zinc concentration. An increase in this metal concentration was noted in the dry period in comparison with other metals – especially aluminium and iron whose concentrations were lower.

Ammonium concentrations were also high in the spring section of the Czarna Wisełka.

The chemical composition of the water in the spring of the Biała Wisełka stream differed from that of the Czarna Wisełka. The water pH value was higher than 6.0 and the calcium content exceeded 6.0 mg/dm^3. Nitrates prevailed over ammonium containing compounds.

The chemical composition of water in springs situated on the northern slopes of Mt. Barania Góra is similar to water characteristics in the tributaries of the Czarna Wisełka. On the other hand, water in some of the right tributaries of the Biała Wisełka stream was weakly alkaline whilst calcium concentration reached 21 mg/dm^3. This chemical composition suggests a wide diversity of substrata of the Biała Wisełka catchment.

4. 3. Chemical composition of water in the Czarna Wisełka and Biała Wisełka streams

The chemical composition of water in the Czarna Wisełka differs considerably from that of the Biała Wisełka. A comparison with several other streams in the Silesian Beskid (Fig. 2) indicated that the chemical composition of water in the Biała Wisełka stream is typical of this part of the Western Carpathians. Water in these streams belongs to a bicarbonate-calcium type, with a relatively high sulphate concentration and a pH value at about 7.0.

Yet the Czarna Wisełka stream is markedly different. The main features of water chemical composition in this stream are low calcium concentration, low water alkalinity, and low pH-value; the latter resulting from a high concentration of aluminium (Fig. 3). The right tributary of the Czarna Wisełka stream belongs, as well as its springs, to the strongest at the acidified streams. This stream serves as water supply for a tourist accomodation in Przysłop. Its water contains not only excessive amounts of aluminium but iron as well (sometimes up to 1.80 mg/dm^3).

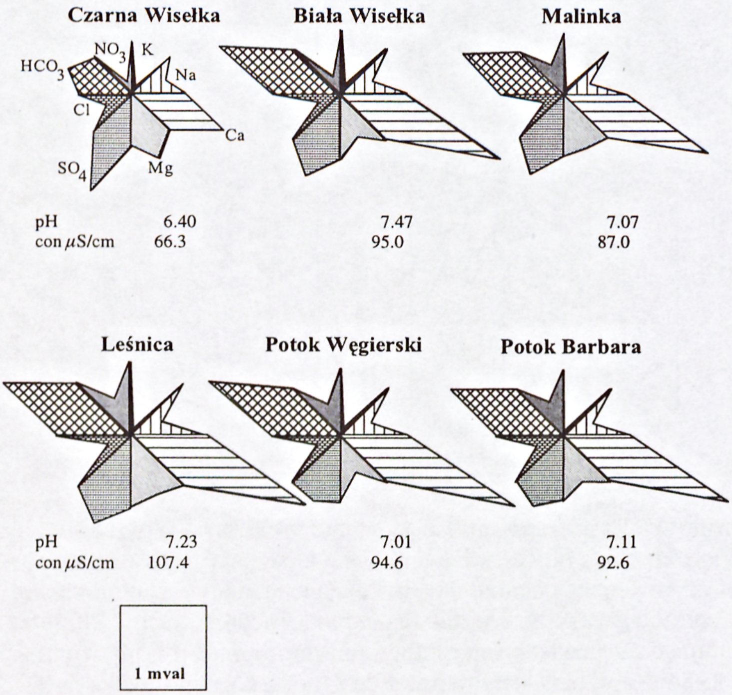

Fig. 2. Ionic composition, pH and conductivity of water in several streams in Beskid Śląski.

Ryc. 2. Skład jonowy, pH i przewodnictwo wody w niektórych potokach Beskidu Śląskiego.

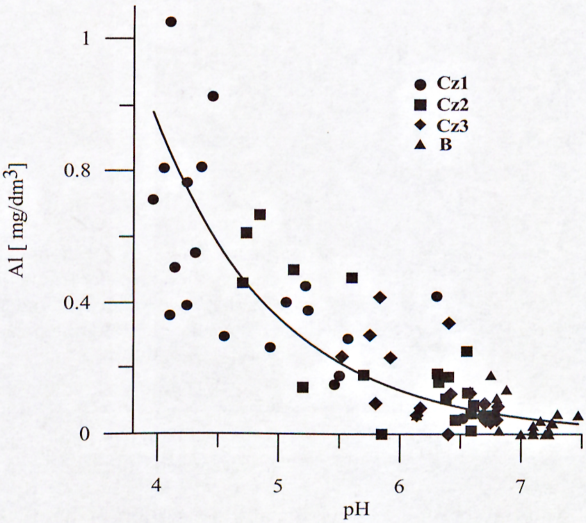

Fig. 3. Dependence of aluminium concentrations on pH value of water in the Czarna Wisełka and Biała Wisełka streams. Designations of stations explained in the text.

Ryc. 3. Zależność stężeń glinu od odczynu wody Czarnej Wisełki i Białej Wisełki. Oznaczenia stanowisk objaśnione w tekście.

The chemical composition of the water in the Czarna Wisełka stream changes downstream (tab. 4). Concentrations of calcium and magnesium hydrocarbonates increase whereas hydrogen and aluminium ion concentrations decrease. In spite of these advantageous alterations, the water pH of the Czarna Wisełka stream at its inflow into the reservoir did not reach a neutral value.

Chemical conditions in the Biała Wisełka stream differed. There, the water's pH never dropped below 6.75, while water alkalinity was always higher than 0.25 mval/dm^3. This is a testimony to a higher buffer capacity of water in this stream.

4. 4. The influence of dolomite application on the chemical composition of water in the Czarna Wisełka stream

Field experiments were preceded by thorough laboratory investigations consisting of a filtration of water collected in the Czarna Wisełka stream through a dolomite percolating filter. As can be seen in Fig. 4, the short-term contact of water with dolomite caused significant changes in the water's chemical composition. Similar changes were observed in the Czarna Wisełka stream just after dolomite application. The following parameters increased: water alkalinity, from 0.11 meq/dm^3 to 0.20 meq/dm^3, pH from 4.21 to 6.02, magnesium concentration from 1.0 mg/dm^3 to 2.0 mg/dm^3, whereas aluminium concentration decreased from 0.49 mg/dm^3 to 0.32 mg/dm^3. The advantageous influence of dolomite, however, diminished with time, due to the precipitation of iron and aluminium hydroxides on the surface of the dolomite. The effect of dolomite, collected in the Czarna Wisełka stream two months after its application, was lower than 50–60% in comparison with the freshly deposited dolomite. According to an analysis performed in the Institute of Refractory Materials in Gliwice, the cover of dolomite gravel contained 15.4% of Al_2O_3 and 5.17% Fe_2O_3. The positive effect of dolomite on the chemical composition of the Czarna Wisełka stream water was difficult to ascertain throughout the year's study since an increase in calcium and magnesium concentration and a decrease in hydrogen, aluminium and iron ion content occurred naturally along the stream. The influence was obvious in the short section of the Płony stream (Fig. 5).

In the spring of 1994, a massive thaw dissolved the aluminium and iron hydroxides deposited on the surface of the dolomite. After the thaw's runoff, dolomite pebbles bu-

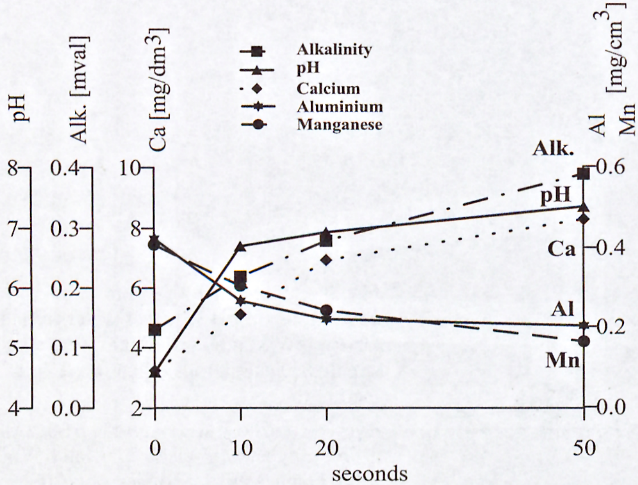

Fig. 4. Changes in chemical composition of water from the Czarna Wisełka stream under an influence of dolomite in laboratory conditions.

Ryc. 4. Zmiany składu chemicznego wody Czarnej Wisełki pod wpływem dolomitu w warunkach laboratoryjnych.

Table 4. Some chemical characteristics of water in the Czarna Wisełka at three stations: Cz1, Cz2 and Cz3 and the Biała Wisełka (B) during high (a) - 6 May 1994 and low (b) - 10 August 1994 water level

Tabela 4. Niektóre cechy chemiczne wody Czarnej Wisełki na trzech stanowiskach: Cz1, Cz2 i Cz3 oraz Białej Wisełki (B) przy niskim (a) - 10.08.1994 i wysokim (b) - 6.05.1994 stanie wody

Parameter		Cz1	Cz2	Cz3	B
Conductivity	a	64.8	44.0	46.5	81.3
μS/cm 25 °C	b	46.3	59.8	67.5	1037
pH	a	4.05	4.73	5.83	6.77
	b	5.46	6.36	6.40	7.20
Alkalinity	a	0	0.12	0.15	0.35
mval/dm³	b	0.21	0.23	0.23	0.57
Total hardness	a	0.28	0.54	0.80	1.66
G.d.	b	0.82	1.23	1.35	2.40
Ca mg/dm³	a	1.21	2.38	3.64	10.00
	b	3.43	5.72	5.93	13.40
Mg mg/dm³	a	0.48	0.91	1.26	1.13
	b	1.47	2.00	2.26	2.30
Al mg/dm³	a	0.807	0.610	0.417	0.05
	b	0.147	0.042	0	0
$N-NH_4$	a	0.529	0.271	0.194	0.086
mg/dm³	b	0.154	0.055	0.103	0.123
$N-NO_3$	a	0.653	0.557	0.669	0.892
mg/dm³	b	0.488	0.562	0.750	0.969
$P-PO_4$	a	0.005	0.003	0.004	0.003
mg/dm³	b	0.005	0.003	0.003	0.005
Oxidability	a	7.40	5.10	4.00	1.52
O_2 mg/dm³	b	4.56	3.36	3.12	2.08
DOC mg/dm³	a	9.5	–	7.0	4.5
	b	7.4	–	2.5	3.2
UV absorbance	a	44.00	–	25.40	5.50
	b	8.90	–	5.08	5.76

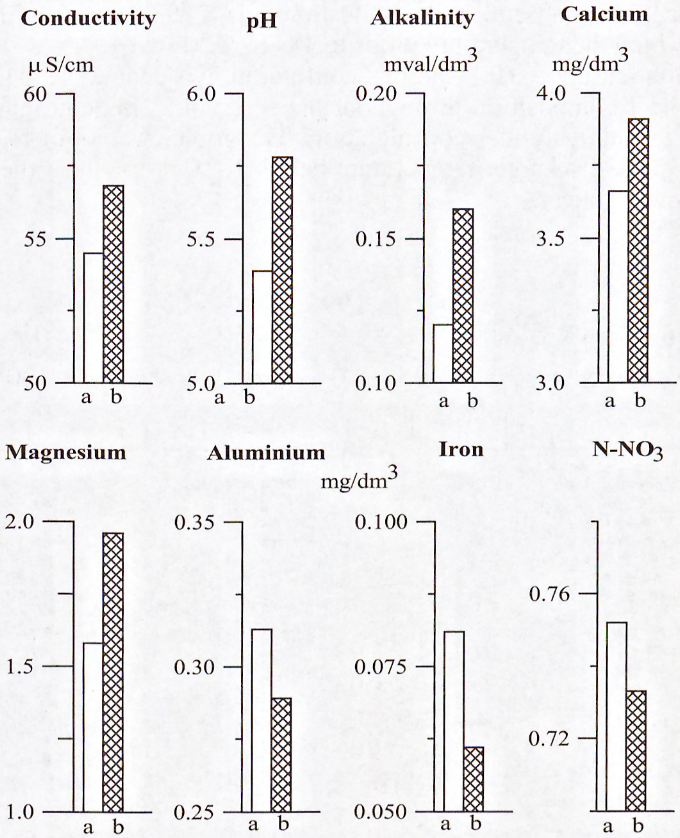

Fig. 5. Changes in chemical composition of water (average values in 1994) in the Płony stream after dolomite application: (a) upstream of dolomite application, (b) downstream of dolomite application

Ryc. 5. Zmiany chemiczne wody w potoku Płony pod wpływem dolomitu (wartości średnie z 1994 roku): (a) powyżej miejsca dolomitowania, (b) poniżej miejsca dolomitowania.

ried in the bottom of the stream appeared rusty in colour while surfaces washed with water were devoid of precipitated compounds. Favourable environmental conditions and the subsequent fate of communities of living organisms depend on high river levels. Large amounts of water in comparison with the amount of the dolomite applied weakens its advantageous action.

4. 5. Chemical composition of water in the Wisła-Czarne dam reservoir

In terms of altitude, the Wisła-Czarne dam reservoir is the highest dam reservoir in Poland (above 500 m). The reservoir, the area of which is small, is relatively deep (22 m during the period of the research). These characteristics, in addition to its lower sluice and lower outlet determine water circulation in the reservoir. These features are typical of all dam reservoirs in Poland.

At the station near the dam, measurements of water temperature and of the concentration of dissolved oxygen were conducted several times, indicating that the thermal stratification typical of lakes is absent. In the hottest months (1993), a thin epilimnion layer develops, under which the temperature drops to 14–15^{o} C (Fig. 6).

In the vegetation season, a stable thermal configuration is conducive to the uniformity of water chemical composition throughout the reservoir. This configuration is not disturbed by the tributaries under consideration. The cooler waters of the tributaries, especially during peak discharge (temperature below 10^{o} C), flow near the bottom and out through the lower sluice.

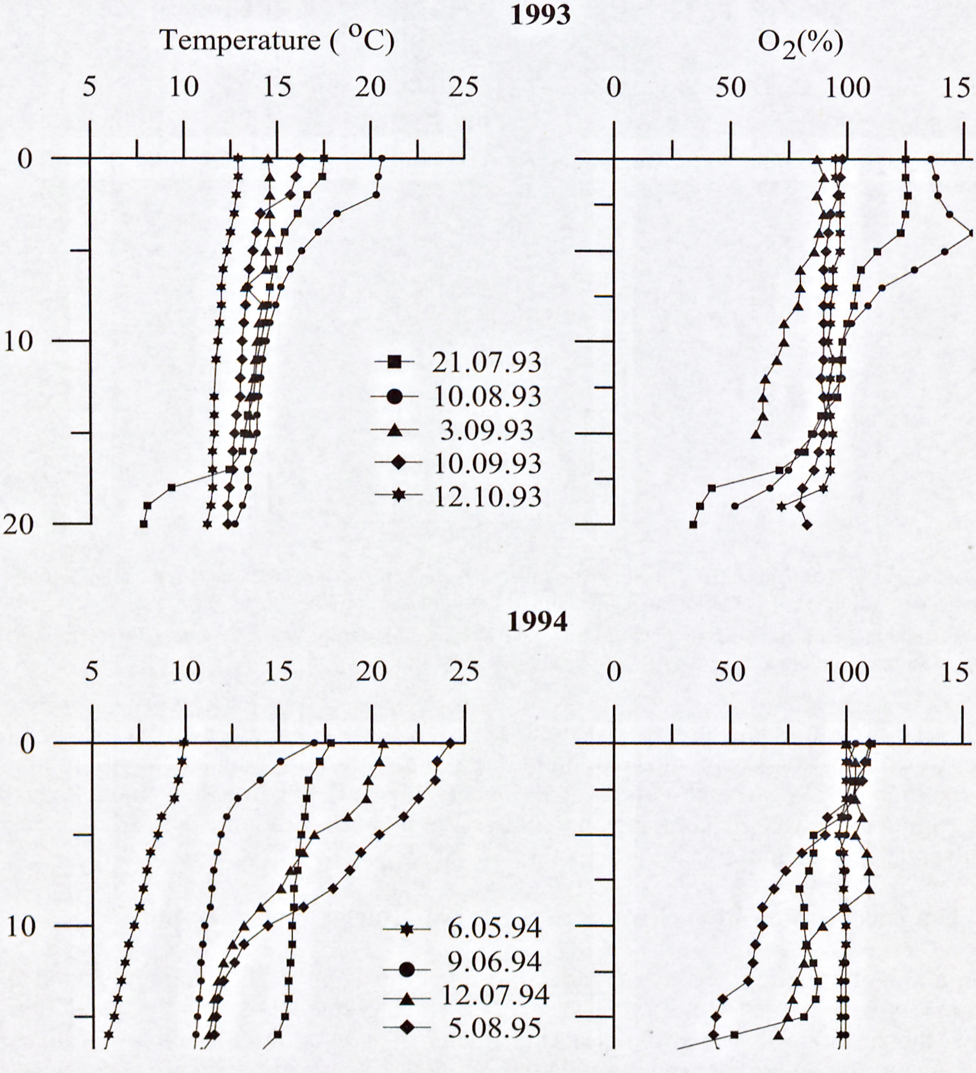

Fig. 6. Stratification of water temperature and oxygen saturation in the Wisła-Czarne dam reservoir in 1993–1994.

Ryc. 6. Stratyfikacja temperatury wody i nasycenia tlenem w zbiorniku zaporowym Wisła-Czarne w latach 1993–1994.

The ionic composition of water in the reservoir depends mainly on the Biała Wisełka stream (the ratio of catchment areas of the Czarna Wisełka and Biała Wisełka streams equals 3 : 4). Thus, its water belongs also to a bicarbonate-calcium type.

Water softness in the dam reservoir combined with a weak buffering capacity results in strong alkalization during „water bloom" (*Planctococcus sphaerocystiformis*) similar to that which occurred in August 1993 (Figs 7 and 8). An even stronger „water bloom" in 1994, as caused by the massive development of dinophytes (*Ceratium hirundinella*), did not foster any drastic changes in the chemical composition of the water in the reservoir.

The trophic state of this reservoir is quite characteristic. During the vegetation season, algae development was rather weak since chlorophyll content did not exceed 5mg/dm^3. However, in the hottest months, one or two algae species grew prolifically. The period in which „water bloom" occurs depends on the intensity of algae development and the level of photosynthesis as well as the consequences of this phenomenon, i.e. strong water alkalization.

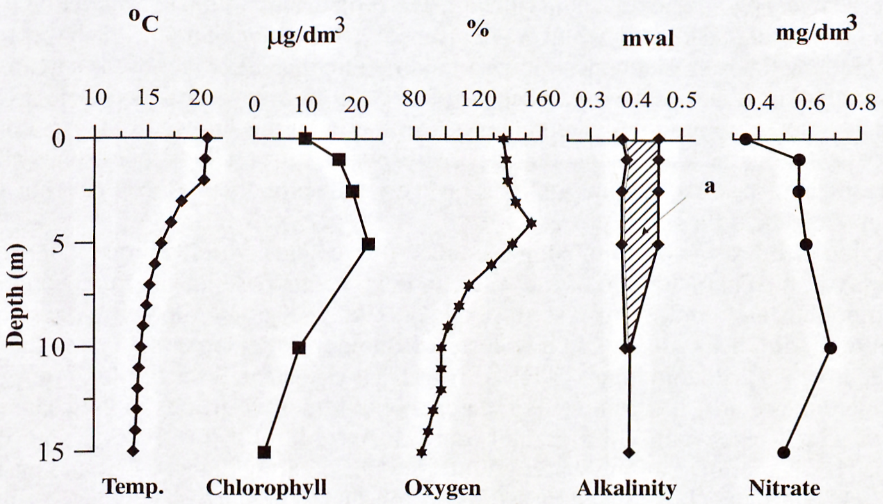

Fig. 7. Stratification of some chemical water characteristics during „water bloom" in the Wisła-Czarne dam reservoir: a – carbonate alkalinity.

Ryc. 7. Uwarstwienie niektórych czynników podczas „zakwitu wody" w zbiorniku zaporowym Wisła-Czarne: a – zasadowość węglanowa.

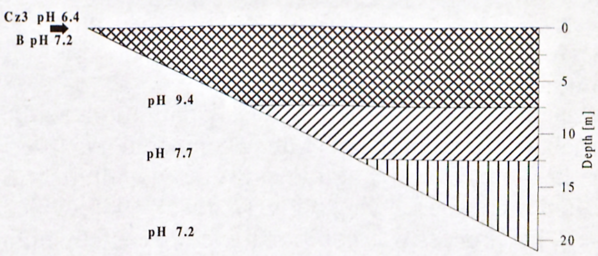

Fig. 8. Water pH-value during mass development of *Planctococcus sphaerocystiformis* in the Wisła-Czarne dam reservoir.

Ryc. 8. Odczyn wody podczas masowego rozwoju *Planctococcus sphaerocystiformis* w zbiorniku zaporowym Wisła-Czarne.

It should be emphasized that the highest chlorophyll concentration was determined in the Czarna Wisełka bay, although concentrations of mineral nitrogen and phosphorus compounds were higher in the water of the Biała Wisełka stream.

5. Discussion

The Czarna Wisełka and Biała Wisełka – originating on the Mt. Barania Góra slopes – differ considerably in bicarbonate content, mainly in amounts of calcium. The differences which disadvantage the Czarna Wisełka stream result from low calcium stores in soils within its catchment.

The spring area of the Czarna Wisełka stream shows the highest acidification. Downstream, calcium concentration increases and water pH approaches neutral value whereas aluminium concentration and dissolved organic carbon content decrease. This beneficial change in the chemical composition of water is caused by an inflow of water from the lower-course tributaries which are more abundant in calcium. The drop in aluminium concentration is also an effect of another phenomenon. Soft water promotes a formation of foam which was found to contain many times greater concetrations of aluminium than the water of the stream. The bottom portions of stones on the streambed are often covered with white deposits of $Al(OH)_3$. A certain portion of aluminium precipitates is also found on the surface of the stream bed. The photosynthesis of sessile algae changes pH of water surrounding stones; thus, aluminium precipitation occurs. Attempts undertaken to estimate primary production did not allow for a proper quantitation of this process.

A high concentration of humic compounds – fulvic acids – amidst high water levels is an unfavorable characteristic of the water in the Czarna Wisełka stream. Though humic compounds are a buffering system (Dickson 1980) serving to decrease the toxicity of aluminium and heavy metals in a water environment (Petersen et al. 1982), they are also precursors of trihalomethans (THMs) if water is chlorinated for drinking purposes.

Humic compounds, including fulvic acids, contain methyl groups in their chemical structure which react with chlorine and easily form chloroform ($CHCl_3$ – one of the THMs). The danger of drinking water pollution with trihalomethans, which are harmful for human health, may be reduced by removing the THMs precursors with active carbon or through the elimination of chlorine from the water treatment process.

The chemical composition of water in the Biała Wisełka stream is typical of the Silesian Beskid. The Biała Wisełka stream improves the water quality in the dam reservoir. However, it supplies waters more abundant in nitrogen and phosphorus compounds which cause eutrophication.

The comparison of the chemical composition of water in the Czarna Wisełka at present and from 1976–1984 (Tab. 5) provides evidence that a considerable worsening of water quality has occurred in the last 10–12 years. It should be mentioned that dust emission into the atmosphere significantly decreased in Poland in that period while sulphur dioxide and nitrogen oxides emission remained unchanged.

As mentioned above, soils in the catchment of the Czarna Wisełka are more acidic than in the catchment of the Biała Wisełka. The main cause of this phenomenon is forest management. As early as in the first half of the last century, spruce monoculture was introduced in lieu of the greatly exploited mixed beech-fir woods (Denisiuk 1985) which accelerated present soil podsolization. This process was additionally quickened by high

Table 5. Comparison of some chemical characteristics of water in the Czarna Wisełka and the Biała Wisełka and the Wisła-Czarne dam reservoir in the period 1978–1984 (after Kasza 1986) and 1993–1994 (average and variability range)

Tabela 5. Porównanie niektórych cech chemicznych wody Wisełek i zbiornika zaporowego Wisła--Czarne w latach 1976–1984 (wg Kaszy 1986) i 1993–1994 (średnie i zakresy wartości)

Parameter	Research period Okres badań	Czarna Wisełka	Biała Wisełka	Dam reservoir Zbiornik Wisła-Czarne
Alkalinity mval/dm^3	1976-1984	0.35 (0.09-0.90)	0.51 (0.20-0.85)	0.44 (0.16-0.85)
	1993-1994	**0.2 0 (0.10-0.28)**	**0.47 (0.28-0.62)**	**0.39 (0.16-0.56)**
Ca mg/dm^3	1976-1984	6.8 (3.2-13.2)	12.7 (4.7-17.5)	10.2 (7.6-13.6)
	1993-1994	**5.4 (3.6-8.5)**	**11.4 (8.3-14.4)**	**9.4 (3.6-13.8)**
Mg mg/dm^3	1976-1984	4.0 (0.4-6.9)	3.8 (2.0-9.5)	3.8 (2.0-8.2)
	1993-1994	**2.2 (1.3-3.2)**	**2.2 (1.1-3.1)**	**2.2 (0.3-4.7)**
$N\text{-}NH_4$ mg/dm^3	1976-1984	0.100 (0-0.400)	0.076 (0-0.295)	0.103 (0-0.305)
	1993-1994	**0.189 (0.104-0.289)**	**0.128 (0.062-0.221)**	**0.147 (0.055-0.240)**
$N\text{-}NO_3$ mg/dm^3	1976-1984	1.28 (0.145-2.700)	1.656 (0.675-2.580)	1.368 (0.710-2.35)
	1993-1994	**0.738 (0.334-1.625)**	**0.936 (0.557-1.598)**	**0.719 (0.062-1.274)**
$P\text{-}PO_4$ μg/dm^3	1976-1984	5 (0-35)	8 (0-31)	6 (0-20)
	1993-1994	**10 (0-47)**	**14 (0-52)**	**5 (0-14)**
Chlorophyll μg/dm^3	1976-1984	–	–	4.5 (1.0-13.6)
	1993-1994	**–**	**–**	**7.4 (1-30.3)**

precipitation (above 1300 mm). Shallow soils, washed by large amounts of water, were leached of cations (Gesser, Edwards 1988), thereby becoming more and more sensitive to airborne acid compounds. Similar changes have been described in other parts of Europe as well (Feger 1994).

Therefore, water acidification in the Czarna Wisełka is a consequence of the exposure of its catchment, the change in species composition of forests, and the deposition of sulphur compounds derived from industrial emission. The mechanism of water acidification in this stream was shown in Fig. 9. In this regard, slope exposure in the catchment of the Czarna Wisełka stream is especially important. The springs of this stream and its tributaries are situated mainly on the southern slopes of Mt. Barania Góra. The waters flowing down these slopes contain less calcium and magnesium, and therefore are more prone to acidification.

Water eutrophication in the dam reservoir has also intensified in the last 12 years. The highest chlorophyll concentration which was formerly recorded 13 $\mu g/dm^3$, presently amounts to 30 $\mu g/dm^3$.

An increase in water eutrophication is caused, apart from an enhancement of nutrient load, by the heating of surface layers of water in the summer (up to 24°C) due to a discharge of cool water which flows close to the bottom through the lower sluice. Stepanek et al. (1963), after analysing various factors influencing the development of „water bloom" in Czechoslovakia, claimed that they do not occur in reservoirs situated at altitudes higher than 500 m.

In dam reservoirs similar to that of the Wisła-Czarne, the period of total water exchange loses its significance as an index of susceptibility to eutrophication. In the summer, the cool waters of tributaries flow close to the bottom and then out through the lower sluice, while surface layers undergo stagnation and strong heating.

The occurrence of "water bloom" in the Wisła-Czarne dam reservoir, supplied periodically with acidified water, indicates that acidification does not limit eutrophication. An increase in water eutrophication in the reservoir as accompanied by an enhancement of acidification suggests that the latter promotes strong development of some algae species. Water acidification has caused a decrease in biodiversity (Pająk 1998, Bucka 1998) which in turn creates a kind of free space for species more resistant to unfavorable environmental conditions.

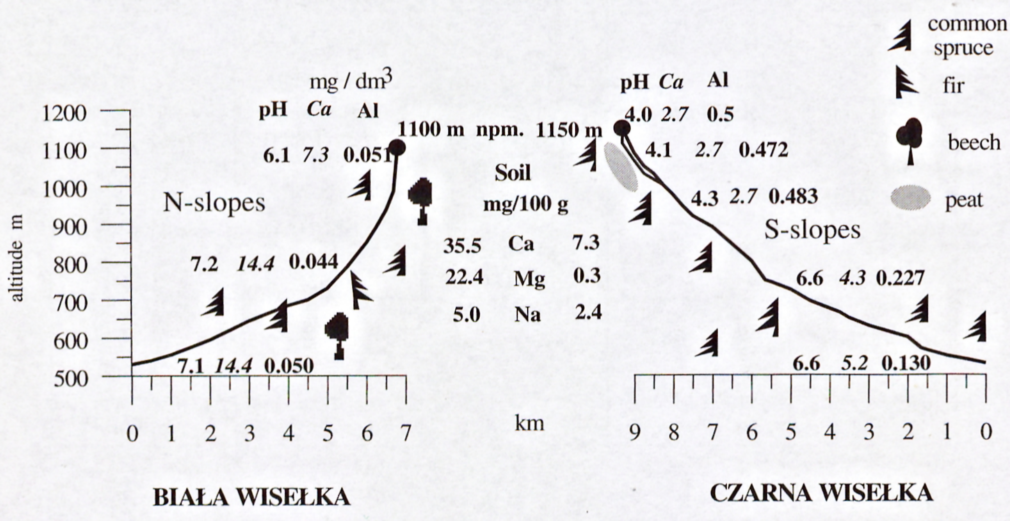

Fig. 9. Vertical cross sections of the Czarna Wisełka and Biała Wisełka streams and some characteristics of their waters and catchments.

Ryc. 9. Profile podłużne Białej i Czarnej Wisełki oraz niektóre cechy ich wody i zlewni.

Previously recognized disadvantageous changes in water chemical composition and in the population of water organisms in the Czarna Wisełka have prompted attempts to neutralise its water with dolomite. A simple method of dolomite gravel application into the streambed as a single dose, despite its known shortcomings (Olem 1991), was chosen. Some authors (Arnold et al. 1988), using calcium or sodium carbonate in addition to various barriers, emphasized that more precise methods consisting of automatic dosing of finely ground carbonate rocks require appropriate equipment, properly prepared material, and constant attendance. The lack of these benefits was a decisive factor in our choice of the method of water neutralization in the Czarna Wisełka stream.

Therefore, a search for other methods of water neutralization was required. One of the possibilities implemented was the application of partially decarbonated dolomite ($CaCO_3 \cdot MgO$, dolomite roasted at 750^{o}C) which is used in water treatment plants for water neutralization (Kowal, Kowalski 1991). However, it cannot be used without prior grinding and the use of automatic feeders. Water neutralization with dolomite-burnt was also attempted in laboratory conditions ($CaO \cdot MgO$ roasted at 1200 ^{o}C) having proved effective at quantities as low as 20 g/m^3. Its field application, however, needs further studies.

When discussing the direct neutralization of water in acidified streams, it is necessary to note that liming or dolomite application in streams and lakes is only a temporary measure. It leads to the alleviation of harmful consequences of water acidification without the elimination of causes which lie in severe soil degradation within the catchment. Though dolomite application in forest soils would present obvious difficulties, the hypothesis of pedologists (Maciaszek, Zwydak 1998) involving dolomite application for the purpose of soil neutralization in stream valleys appears to be worth considering. However, it is commonly known that true improvement will result primarily form a decrease in emissions of sulfur dioxide, nitrogen oxides and ammonia, i.e. a reduction in air pollution.

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Streszczenie

Czarna Wisełka i Biała Wisełka spływają ze stoków Baraniej Góry. Oba te potoki objęto w 1959 roku ochroną rezerwatową w celu zabezpieczenia siedlisk pstrąga potokowego.

Od roku 1974 Czarna Wisełka i Biała Wisełka uchodzą do zbiornika zaporowego Wisła-Czarne (Ryc. 1), z którego czerpie się wodę dla zaopatrzenia Wisły, Goleszowa i części Skoczowa.

Od kilkunastu lat następowało pogorszenie jakości wody w zbiorniku. Wyniki analizy chemicznej wody, prowadzonej w Stacji Uzdatniania Wody w Wiśle-Czarnem świadczyły o okresowym (podczas roztopów i po deszczach) wzroście zakwaszenia, utlenialności i barwy wody. W okresach letnich zaczęły występować „zakwity wody".

Znane wcześniej z prac innych autorów i wyników własnych badań zakwaszenie wody w Czarnej Wisełce skłoniło autora do przeprowadzenia prób neutralizacji wody za pomocą dolomitu. Kamienny dolomit, w ilości 280 t, wsypano (w miesiącach wrzesień – grudzień) do koryta Czarnej Wisełki w środkowym jej biegu (230 t) oraz przy ujściu potoku Płony – jednego z jej dopływów (50 t).

Badania Czarnej Wisełki i Białej Wisełki prowadzono od maja 1993 do maja 1995. Należy dodać, że zlewnie obu potoków różnią się przede wszystkim ekspozycją stoków oraz stopniem zalesienia (Tab. 1). W badaniach obu Wisełek oraz innych potoków Beskidu Śląskiego stwierdzono duże podobieństwo składu jonowego wody Białej Wisełki i innych potoków beskidzkich (Ryc. 2). Różni się od nich natomiast woda Czarnej Wisełki. Stwierdzono silne zakwaszenie wody, zwłaszcza w źródliskowej partii Czarnej Wisełki (Tab. 2, 3). Zakwaszeniu temu towarzyszyły wysokie stężenia zjonizowanego glinu (Ryc. 3). Oba te czynniki były przyczyną wyginięcia ryb w tym potoku.

W pracy podano przyczyny zakwaszenia Czarnej Wisełki (Ryc. 9). Tkwią one w budowie geologicznej i ekspozycji stoków zlewni oraz małej zdolności buforowej gleb zlewni Czarnej Wisełki.

Okresowy dopływ wód zakwaszonych do zbiornika zaporowego Wisła-Czarne nie hamuje jego eutrofizacji. W latach, w których prowadzono badania, występowały silne „zakwity wody", spowodowane rozwojem zielenicy *Planctococcus sphaerocystiformis* w roku 1993 i bruzdnic (głównie *Ceratium hirundinella*) w roku następnym. Przyczyną „zakwitów wody", obok stosunkowo wysokich stężeń związków azotu i fosforu w wodzie dopływów, jest specyficzny układ krążenia wody w zbiorniku, uwarunkowany dolnym jej odpływem. Chłodne wody dopływów w sezonie wegetacyjnym płyną przy dnie i odpływają dolnym upustem. Woda w zbiorniku nie ulega zatem mieszaniu, a powierzchniowa warstwa silnie się nagrzewa (do 24^{o} C; Ryc. 6)), co sprzyja rozwojowi glonów.

Zastosowany sposób neutralizacji wody w Czarnej Wisełce nie spełnił pokładanych w nim nadziei. Największe zakwaszenie i zanieczyszczenie wody związkami humusowymi występuje podczas wiosennych roztopów i po większych opadach deszczu (Tab. 4) i wtedy wpływ dolomitu jest niewielki. Aby zneutralizować wodę podczas wezbrań, konieczne jest zastosowanie wapna dolomitowego (dolomit prażony w temperaturze 1200^{o} C). Dawka 20 g/m^3 skutecznie neutralizuje wodę.