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The effect of dolomite on the sessile algae communities in an acidic mountain stream (Czarna Wisełka)

Wpływ dolomitowania na zbiorowiska glonów osiadłych w kwaśnym górskim potoku (Czarna Wisełka)

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Abstract: The influence of dolomite application on sessile algae communities in the Czarna Wisełka, an acidic stream which is one of the two headwaters of the Vistula River, was studied. Changes in the chemical composition of water after dolomite application resulted in modified species composition and structure of the diatom communities. An increase in the number and abundance of diatom taxa, and a changed domination structure were observed. The dolomite effect consisted in a decreased share of acidobiontic and acidophilous species of the genus *Eunotia* in favour of neutral and alkaliphilous species, such as *Achnanthes minutissima* var. *minutissima* and *Fragilaria capucina*. The spring thaw, accompanied by a decrease in the pH of water, made the neutralization of water with dolomite unsuccessful and affected colonization and development of the algae communities. During that period, the community „returned" to the type which developed before dolomite application.

Key words: sessile algae communities, water pH, acidic stream, dolomite application.

Treść: Przeprowadzono badania nad wpływem dolomitowania kwaśnego potoku Czarna Wisełka – jednego z dwóch źródłowych potoków rzeki Wisły – na zbiorowiska glonów osiadłych. Po dolomitowaniu, w wyniku zmian w składzie chemicznym wody, nastąpiły zmiany w składzie gatunkowym i strukturze zbiorowisk okrzemek. Wyrażały się one wzrostem liczby i liczebności gatunków oraz zmianami w układzie dominacji. W konsekwencji oddziaływania dolomitu zmniejszał się udział acydobiontycznych i acydofilnych gatunków z rodzaju *Eunotia* na korzyść gatunków neutralnych i alkalifilnych, jak: *Achnanthes minutissima* var. *minutissima* oraz *Fragilaria capucina*. Wiosenny okres roztopów i towarzyszące mu obniżenie pH wody miało negatywny wpływ na skuteczność zabiegu neutralizacji wody oraz kolonizację i rozwój zbiorowisk glonów. W tym okresie obserwowano w strukturze zbiorowisk okrzemek tendencję „powrotu" do sytuacji początkowej przed dolomitowaniem.

1. Introduction

The acidification of surface waters, as caused by air pollution, have become a serious ecological problem due to the extent of this phenomenon and its disadvantageous effect on water organisms.

Experiments involving the neutralization of acidic waters with lime and studies of the effects of liming on water biocenoses have been carried out for several years, mainly in lakes. These studies were primarily concerned with fish populations and the possibilities of their re-introduction into improved conditions of chemical composition in the water after its enrichment with $CaCO_3$. Some articles describe the effect of liming on other trophic levels, including phytoplankton (Hillbricht-Ilkowska et al. 1977, Erikson et al. 1983), periphyton and benthic algae in lakes and moorland pools (Lazarek 1982, Simola 1986, Ohl et al. 1990, Round 1990, Bellemakers, van Dam 1992).

Fewer studies concerned algae communities in running waters, which are quick as well as sensitive indicators of anthropogenic changes throughout the entire catchment (Herrmann et al. 1993). The effect of the neutralization of running waters may be different to some extent because of the larger periodical and spatial variability of physico-chemical conditions, continuous restoration of water masses, and pulsation of water pH value.

Successful trials involving dolomite application in acid mountain streams (Wróbel, Wójcik 1989) prompted the author to make a similar attempt in conjuction with a complex research of the Czarna Wisełka – an acidic stream which is one of the two headwaters of the Vistula River. These streams – Biała Wisełka and Czarna Wisełka – feed into the Wisła-Czarne dam reservoir which, in turn, supplies drinking water for Silesia. The Czarna Wisełka stream also provides drinking water for the tourist hostel on Mt. Barania Góra. Unfortunately, this stream is deteriorating the water quality of the dam reservoir (Bucka 1998).

The aim of this research was to investigate the changes in species composition and the structure of sessile algae communities in the Czarna Wisełka after dolomite application. Furthermore, the ecological characteristics of sessile algae communities in the Biała Wisełka of higher pH value were evaluated. This has served as a reference point in the comparison of both stream's algal communities.

2. Research area, materials and methods

The object of the study were headwaters of the Vistula River: the Czarna Wisełka and the Biała Wisełka which both originate on the slopes of Mt. Barania Góra, in the Silesian Beskid at an altitude of 1150 and 1100 m. The streams join at an altitude of 524 m and fall now into the Wisła-Czarne dam reservoir (Fig. 1). The Czarna Wiselka spring flows out of several marshes of peatbog type while the Biała Wisełka stream originates from typical rock springs. These streams flow on a base formed of sandstones of Istebna and Godula layers constituting the Carpathian Flysch, originating from the Cretaceous period (Burtan 1973). The spring area of both streams was formed as a whole by Istebna layers which are characterized by a low calcium concentration. Istebna layers occur on the largest area in the Czarna Wiselka catchment; they produce skeletal-sandy and skeletar-loamy weathering covers of acidic and strongly acidic pH. But in the lower section of Biała Wisełka, rock formations of the upper Godula layers occur and the stream flows over a 2 km distance over a base containing more calcium and magnesium (Maciaszek, Zwydak 1998). In general, the soil in the area does not contain carbonates. It is strongly acidic and poor in phosphates and assimilable nitrogen compounds while rich in silica, potassium, iron and sulphates (Pasternak 1962). The catchment of the Biała Wisełka stream is covered, mainly, by beech-fir and spruce forests. In the Czarna Wisełka catchment spruce forest prevail while meadows and cultivated soils cover much less area (Fig. 1). The area is situated in the montane climatic zone which is characterized by long period of snow coverage and high precipitation. There are two maxima of water levels which are significant to living organisms and water pH: in spring – in April and May, as caused by snow melting, and in summer – in June and July, as caused by heavy rainfalls. Both streams are characterized by high slopes, strong current, and low water temperature.

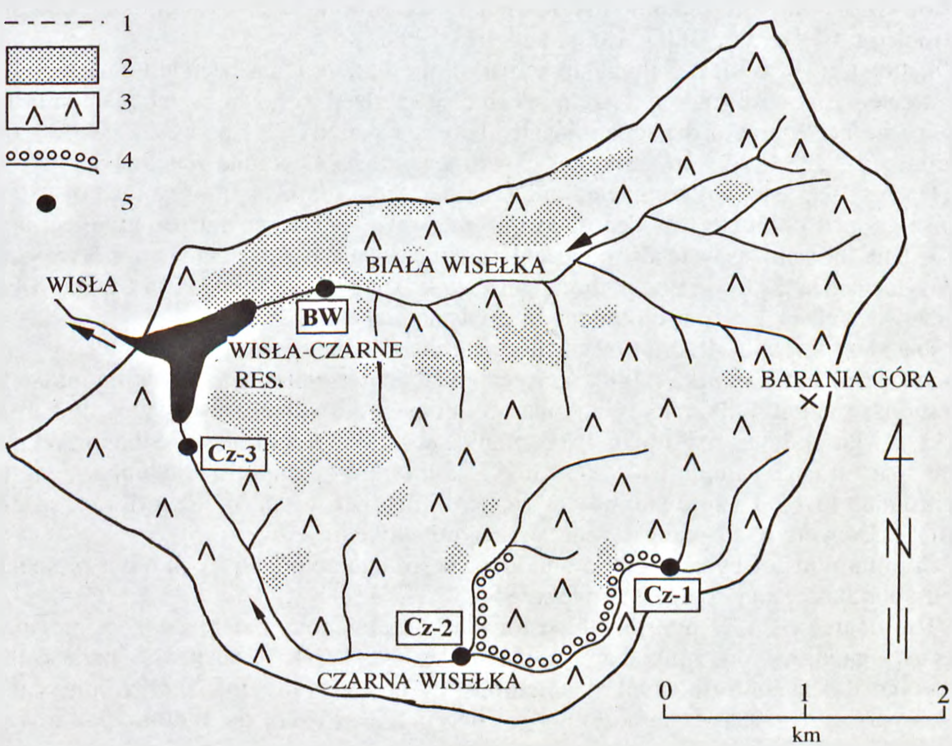

Fig. 1. Map of the study area: 1 – borderline of the catchment basin, 2 – meadows and fields, 3 – forests, 4 – liming zone, 5 – stations: BW – at the Biała Wisełka stream; Cz-1, Cz-2, Cz-3 – at the Czarna Wisełka stream.

Ryc. 1. Mapa badanego terenu: 1 – granica zlewni, 2 – łąki i pola uprawne, 3 – lasy, 4 – odcinek dolomitowany, 5 – stanowiska: BW – w potoku Biała Wisełka, Cz-1, Cz-2, Cz-3 – w potoku Czarna Wisełka.

Differences in the geological structure of both valleys result from differences in the chemical composition of the water. The Czarna Wisełka water contains a low calcium concentration, and low pH, especially in its upper part, where, in the period studied, the pH ranged from 3.9 to 5.5. In the middle part of the stream the pH fluctuated in the range 4.7–5.7 before dolomite application, while in the lower part of the stream pH registered at 5.8–6.1. The Biała Wisełka water contains more calcium and the pH value of water is higher, particularly in its lower part, near Wisła-Czarne village, where pH oscillated around 7.0.

It should be stressed here that the naturally acidic waters of the Czarna Wisełka are subject to further acidification resulting from air pollution and acid precipitation, as indicated by the lowest pH period occurring during snow melting (Wróbel, Wójcik 1989, Wróbel 1998).

The detailed characteristics of the research area were given by Punzet (1998) and Maciaszek, Zwydak (1998), while hydrochemical description of both streams was provided by Wróbel (1998).

Samples were collected at three stations on the Czarna Wisełka stream (Cz-1, Cz-2, Cz-3) on the following dates: 14.04, 26.06, 3.09, 18.10, 3.11.1993, with the exception of station Cz-1 (where the sample had not been taken on the first research date) and at all stations on: 6.05, 9.06, 12.07, 18.08, and 7.11.1994.

Station Cz-1 was located in the upper part of the stream; it has been left unchanged and was treated as control station, it having been characterized by acidic waters. Dolomite was applied in the section of the stream located between stations Cz-1 and Cz-2 (Fig. 1), thus, stations Cz-2 and Cz-3 were treated as experimental ones. Dolomite was first applied on 4 September 1993 and was completed in December, 1993. In this section, a total of 280 t of coarse-grained dolomite was deposited into the water. For comparative purposes, on the same dates the samples were also collected from the Biała Wisełka, at the station BW. Station BW is located in the lower part of the stream (while being upstream of Wisła-Czarne village) which was treated as a control station, due to its neutral waters.

The sampling and description of the material was based on methods given by Starmach (1969) and Kawecka (1980) concerning algae in running water. Taking into consideration a habitat's diversity, algae was collected from stones, river bank sludge, and mosses. Material was fixed with 4% formaline solution. To obtain solid diatom preparations, part of each sample was macerated in a mixture of sulphuric acid and potassium dichromate (3:1). Then, material was rinsed in distilled water and centrifuged at 3000 rpm. Slides were made using „Pleurax", a synthetic resin.

Communities of cyanobacteria and algae were characterized by number of species, their abundance, and degree of coverage.

The degree of coverage for algae forming homogenous macroscopic aggregations was estimated over determined area of the streambed (1–10 m^2), using a 5-grade scale of coverage: 1 – algae form small aggregations, 2 - covering less than 25% of the bottom, 3 – covering 25–50% of the bottom, 4 – covering 50–75% of the bottom, 5 – covering 75–100% of the bottom. The species were regarded as abundant if they obtained 3 degrees or higher on the coverage scale.

Abundance of microscopic forms (mainly of diatoms and desmids) was determined by counting the cells of a particular species in 10 fields of vision under the microscope. If a species occurred in a sample but was not found in the counting, it arbitrarily was given the value of 0.1. Next, the percentage share of each species in the community was calculated. The species attaining more than a 10% share within a community were regarded as dominants, while 1–10% were considered as accompanying species, and these remaining as sporadic species.

Algae and cyanobacteria identification and autecological characterization, including diatom classification into groups according to their pH preferences, was performed after

Hustedt (1937-1939), Cholnoky (1968), Starmach (1966, 1972), van Dam et al. (1981), Krammer and Lange-Bertalot (1986–1991), Anagnostidis and Komárek (1988) and Hakansson (1993), Coring (1996). The nomenclature of diatoms was used according to Krammer and Lange-Bertalot (1986–1991).

Algae communities were compared using Pearson's correlation coefficient and grouped using the average linkage method.

3. Results

In general, 110 cyanobacteria and algae taxa were discovered in the studied material (Tab. 1). Most of them occurred sporadically.

The structure of the bottom communities developing in the Biała Wisełka (at control station BW with a water pH of 6.8–7.3) changed with the seasons (Fig. 2). The cyanobacteria species *Phormodium subfuscum* (Agardh) Kütz. and *P. corium* (Agardh) Gomont prevailed in both spring and autumn and *Hydrurus foetidus* of chrysophytes in spring. In the summer, filamentous chlorophytes were abundant with a predominance of *Ulothrix zonata* (Weber et Mohr) Kütz., *U. variabilis* Kütz and *Klebsormidium rivulare* Morison and Sheat. Diatoms formed numerous populations, with the exception of spring water flow, when a considerable decrease in their abundance was noted. The number of diatom species was highest in comparison with the remaining groups of communities and remained at constant level (Fig. 3). With respect to preferences towards water pH, circumneutral and alkaliphilous species constituted the highest share (Fig. 4). *Achnanthes minutissima* Kützing var. *minutissima* was clearly the most frequent (46.6%) and species of *Fragilaria* genus and *Cocconeis placentula* Ehrenberg var. *euglypta* dominated temporarily (Fig. 2).

The structure of algae communities in the Czarna Wisełka (control station Cz-1 were acidic water's with a pH of 3.9-5.5) were shown to be less dependent on seasons (Fig. 2). The *Klebsormidium rivulare* of chlorophytes developed abundantly during almost the entire research period as accompanied by *Microthamnion strictissimum* Rebenh., *Microspora floccosa* (Vauch.) Thur., *Spirogyra* sp., and *Mougeotia* sp. Diatoms were represented by low number of species – approximately 20 (Fig. 3). A decrease in coverage level and algae abundance had been noted in the period of spring run-off, which was followed by a quick community restoration. Acidobiontic and acidophilous species prevailed in the diatom population, while the contributions of the remaining groups were low (Fig. 4). Among diatoms, *Eunotia exigua* (Breb.) Rabh., *E. rhomboidea* Hust., and *E. tenella* (Grun.) Hust., dominated. Acompanying species belonged to *Anomoeoneis brachysira* (Breb.) Grun. and *Pinnularia subcapitata* Greg. (Fig. 2).

The middle part of the stream (station Cz-2), before dolomite application (IV–IX 1993, water pH equalling 4.7–5.7), was distinquished by a remarkedly low development of diatom population. Macroscopic aggregations were formed mainly by *Klebsormidium rivulare*, which showed their maximum development in summer. There were accompanied by *Microspora floccosa, Microthamnion strictissimum, Spirogyra* sp., *Mougeotia* sp., and cyanobacteria *Phormidium kuetzignianum* (Kütz.) Kirch. (Fig. 2).

Diatoms occurred in low numbers, thus their abundance was low as well (Fig. 3). Acidobiontic and acidophilous species prevailed. The following species dominated prior to the experiment: *Eunotia exigua, E. tenella* and *Pinnularia subcapitata* (Fig. 2).

Table 1. List of cyanobacteria and algal taxa found in Biała Wisełka and Czarna Wisełka before and after dolomite application (among systematics groups in alphabetical order). Stations designated as in Fig. 1.

Tabela 1. Lista taksonów sinic i glonów znalezionych w Białej i Czarnej Wisełce przed oraz po dolomitowaniu (w obrębie grup taksonomicznych kolejność taksonów podano w porządku alfabetycznym). Oznaczenia stanowisk jak na ryc. 1.

Taxon Takson	Stations Stanowiska					
	BW	Cz-1	Cz-2 before przed	Cz-2 after po	Cz-3 before przed	Cz-3 after po
Cyanobacteria						
Chamaesiphon polonicus (Rostaf.) Hansg.	+					
Homoeothrix janthina (Boret et Flahault) Starmach	+					
Phormidium kuetzingianum) Kirchn.			+	+	+	+
P. subfuscum (Agardh) Kützing	+		+	+	+	+
P. corium (Agardh) Gomont	+					
Oscillatoria limosa Agardh	+					
Chrysophyceae						
Hydrurus foetidus (Villars) Trevisan	+			+		+
Bacillariophyceae						
Achnanthes biasolettiana Grunow var. *biasolettiana*	+		+	+	+	+
A. flexella (Kütz.) Brun var. *flexella*	+			+		+
A. kriophila Petersen	+		+	+	+	+
A. lanceolata (Bréb.) Grunow var. *lanceolata*	+	+	+	+	+	+
A. marginulata Grunow	+	+	+			
A. minutissima Kützing var. *minutissima*	+	+		+	+	+
Achnanthes sp.	+				+	+
Amphora pediculus (Kütz.) Grunow	+			+		+
Anomoeoneis brachysira (Bréb.) Grunow	+		+	+	+	+
A. serians (Breb.) Cleve		+				
A. vitrea (Grun) Ross	+				+	
Caloneis molaris (Grun.) Krammer			+	+	+	+
Cocconeis placentula Ehrenberg var. *placentula*	+					+

Table 1 cont.

Taxon Takson	Stations Stanowiska					
	BW	Cz-1	Cz-2 before przed	Cz-2 after po	Cz-3 before przed	Cz-3 after po
C. placentula Ehrenberg var. *euglypta* (Ehr.) Grun.	+			+	+	+
Cymbela cesatii (Rabh.) Grunow	+					
C. gracilis (Ehr.) Kützing	+			+	+	
C. minuta Hilse	+	+	+	+	+	+
C. naviculiformis Auerswald	+			+		
C. silesiaca Bleisch	+		+	+	+	+
C. sinuata Gregory	+			+		+
Denticula tenius Kützing	+					+
Diatoma hyemalis (Roth) Heinberg	+	+	+	+	+	+
D. mesodon (Ehr.) Kützing	+			+	+	
D. vulgaris Bory	+					+
Diploneis sp.	+					+
Eunotia bilunaris (Ehr.) Mills		+	+	+	+	
E. diodon Ehrenberg		+		+	+	
E. exigua (Bréb.) Rabenhorst	+	+	+	+	+	+
E. incisa Gregory var. *incisa*				+	+	+
E. meisteri Hustedt		+				
E. minor (Kütz.) Grunow				+		+
E. nymanniana Grunow		+	+		+	
E. paludosa Grunow		+	+			
E. paludosa Grunow var. *trinacria* (Krasske) Nörpel et Alles		+				
E. praerupta Ehrenberg var. *bigibba* (Kütz.) Grunow			+			
E. rhomboidea Hustedt		+	+	+		+
E. tenella Grun. Hustedt	+	+	+	+	+	+
Fragilaria arcus (Ehr.) Cleve	+		+	+	+	+
F. capucina Desmazieres	+	+	+	+	+ -	+
F. capucina Desmazieres var. *vaucheriae* (Kütz.) Lange-Bertalot	+			+	+	+
F. constricta Ehrenberg	+					
F. pinnata Ehrenberg	+			+		

Table 1 cont.

Taxon Takson	Stations Stanowiska					
	BW	Cz-1	Cz-2 before przed	Cz-2 after po	Cz-3 before przed	Cz-3 after po
F. ulna (Nitzsch.) Lange-Bertalot	+					+
F. virescens Ralfs	+	+		+	+	+
Frustulia rhomboides (Ehr.) De Toni var. *saxonica* (Rabh.) De Toni		+	+	+	+	+
F. vulgaris (Thwaites) De Toni	+				+	+
Gomphonema acuminatum Ehrenberg	+					
G. angustatum (Kütz.) Rabenhorst	+				+	+
G. angustum Agardh				+		+
G. constrictum Ehrenberg	+				+	
G. gracile Ehrenberg	+					
G. olivaceum (Hornemann) Brébbisson var. *olivaceum*	+			+		+
Hantzschia ampioxys (Ehrb.) Grunow	+				+	+
Meridion circulare (Greville) Agardh	+		+	+	+	+
Navicula contenta Grunow	+	+	+	+	+	+
N. cryptocephala Kützing	+			+		
N. mediocris Krasske		+				
N. radiosa Kützing	+					+
N. soehrensis Krasske		+			+	
N. subtilissima Cleve		+				
Navicula sp.	+					
Neidium affine (Ehr.) Pfitzer	+			+	+	+
Neidium sp.						+
Nitzschia amphibia Grunow	+					+
N. capitellata Hustedt	+			+	+	
N. dissipata (Kütz.) Grunow	+			+		+
N. hantzschiana Rabenhorst	+				+	+
N. linearis (Ag.) W. Smith.	+		+	+	+	+
Pinnularia borealis Ehrenberg	+				+	+
P. interrupta W. Smith	+					+
P. microstauron (Ehr.) Cleve	+		+	+		+
P. subcapitata Gregory		+	+	+	+	+
P. sudetica (Hilse) Peragallo	+		+	+	+	+
P. viridis (Nitzsch) Ehrenberg	+			+	+	

Table 1 cont.

Taxon Takson	Stations Stanowiska					
	BW	Cz-1	Cz-2 before przed	Cz-2 after po	Cz-3 before przed	Cz-3 after po
Rhoicosphenia abbreviata (Ag.) Lange-Bertalot	+					+
Stauroneis phoenicenteron (Nitzsch) Ehrenberg				+	+	
S. smithii Grunow	+					
Stephanodiscus hantzschii Grunow	+				+	+
Surirella angusta Kützing	+			+	+	+
S. brebissonii Krammer & Lange-Bertalot	+			+		+
S. brebissonii var. *kuetzingii* Krammer & Lange-Bertalot					+	
S. linearis W. Smith	+	+	+	+	+	+
S. ovalis Brebisson	+					+
Tabellaria flocculosa (Roth) Kützing		+	+	+	+	+
Chlorophyta						
Binucelaria tectorum (Kütz.) Berger			+			
Klebsormidium flaccidum Kütz. Morison & Sheath		+	+	+	+	+
K. rivulare Kütz. Morison & Sheath		+	+	+	+	+
Microspora floccosa (Vauch.) Thur.	+	+	+		+	+
M. lauterbornii Schmidle		+				
Microthamnion strictissimum Rabenhorst		+	+	+	+	+
Mougeotia sp.		+	+	+	+	+
Spirogyra sp.		+	+	+	+	+
Oedogonium sp.	+				+	+
Ulothrix zonata (Weber et Mohr) Kützing	+					
U. variabilis Kützing	+			+		
Closterium acerosum (Schrank) Ehrenberg	+			+	+	+
Closterium sp.			+	+	+	+
Cosmarium circulare Reinsch	+		+	+		+
Cosmarium sp.	+		+	+	+	
Cylindrocystis spp.						+
Penium spp.			+	+	+	+
Staurastrum spp.			+	+		+
Rhodophyta						
Audouinella chalybaea (Roth) Fries	+				+	+

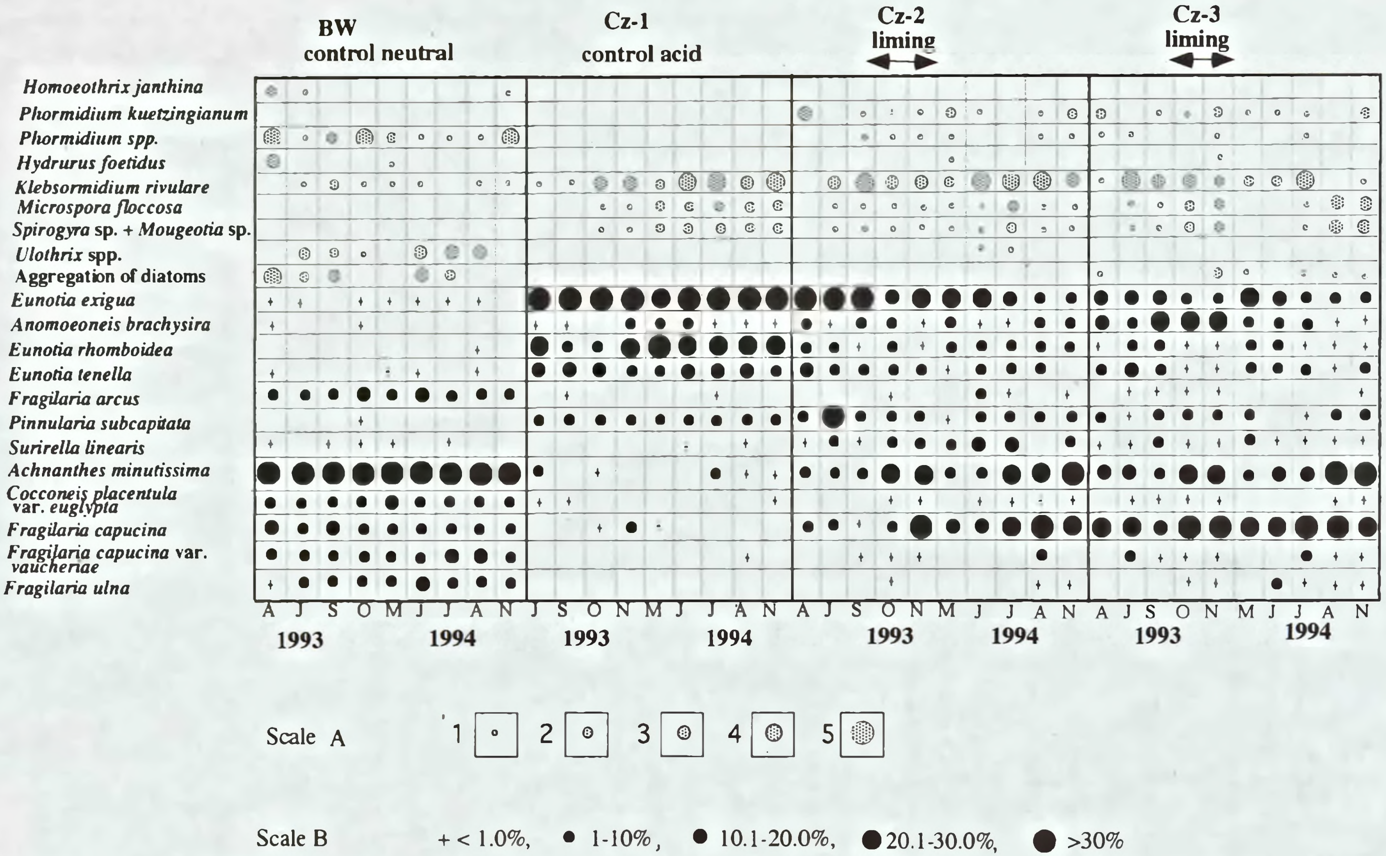

Fig. 2. Communities of algae at the control and liming stations in the studied period: scale A – coverage of the bottom surface by algae occurring in macroscopic aggregations (1 – algae form small aggregations, 2 – they cover less than 25% of the bottom, 3 – 25–50 %, 4 – 50–75%, 5 – 75–100%), scale B – share (%) of dominating diatom species.

Ryc.2. Zbiorowiska glonów na stanowiskach kontrolnych i dolomitowanych w badanym okresie: skala A – pokrycie powierzchni dna przez glony występujące w postaci makroskopowych skupień (1 – glony tworzą drobne skupienia, 2 – pokrywają mniej niż 25% dna , 3 – 25–50 %, 4 – 50–75%, 5 – 75–100%), skala B – procentowy udzial dominujących gatunków okrzemek.

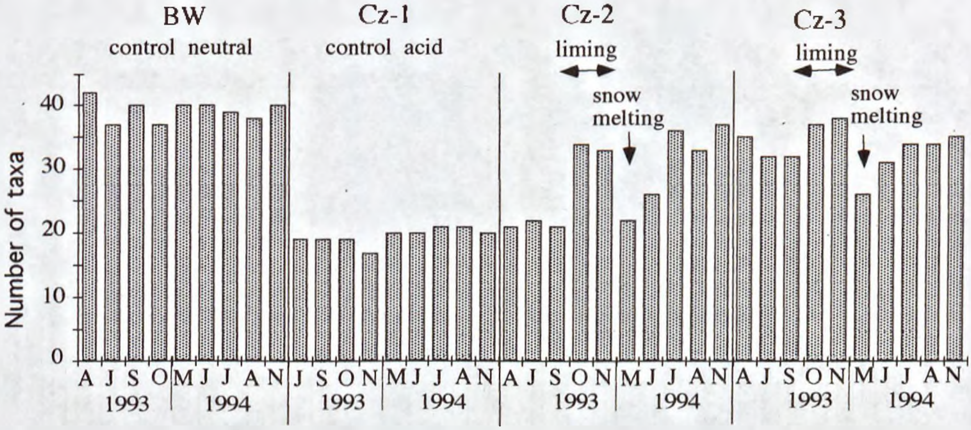

Fig. 3. Number of diatom taxa at the control and liming stations.

Ryc. 3. Liczba taksonów okrzemek na stanowiskach kontrolnych i dolomitowanych.

In the lower part of the stream (station Cz-3), the water's pH ranged from 5.9 to 6.1 before the experiment, algae community was quantitatively richer and more diverse. Among algae forming macroscopic aggregations, the most abundant species was *Klebsormidium rivulare* in association with other chlorophytes and blue-green *Phormidium kuetzingianum* (Fig. 2). Desmids of the genera *Penium* and *Cosmarium* appeared quite often at that station. Diatoms were represented by higher number of species than those of the previous station (Fig. 3). Beside acidophilous species, alkaliphilous and circumneutral ones represented a greater number, while acidobiontic participation was much lower than at stations Cz-1 and Cz-2 (Fig. 4). Before the experiment, acid-water taxa: *Eunotia exigua, Anomoeoneis brachysira* (Breb.) Grun. and *Eunotia tenella*, along with species characteristic of a higher water pH such as *Achnanthes minutissima* var. *minutissima* and *Fragillaria capucina* dominated (Fig. 2).

In diatom communities at this station, teratologic cells were found; being particularly numerous in *Fragilaria capucina* population.

The water's neutralization and a change in its chemical composition caused an alteration in species composition and the structure of the diatom communities. It was especially evident in the first period after dolomite application, i.e. in October and November 1993 (Figs 2, 3, 4).

Those changes at station Cz-2 were significant. An increase in pH (pH 6.3–7.1) was accompanied by higher numbers and abundance of diatom species, and decrease in acidobiontic and acidophilous diatom species towards neutral and alkaliphilous forms. *Eunotia exigua* still dominated but *Achnanthes minutissima* var. *minutissima* and *Fragilaria capucina*, previously rare at this station, became the dominant species.

At Cz-3 station, in general community appearance, the tendency of changes was similar to the first period after dolomite application (pH 6.6–6.7). The changes, however, were not so pronounced. An increase in a number of diatom species and minor augmentation of their abundance had been observed. In the first period after dolomite application, the abundance of *Eunotia exigua* and *E. tenella* fell, while *Anomoeoneis brachysira, Achnanthes minutissima* var. *minutissima* and *Fragillaria capucina* were numerous.

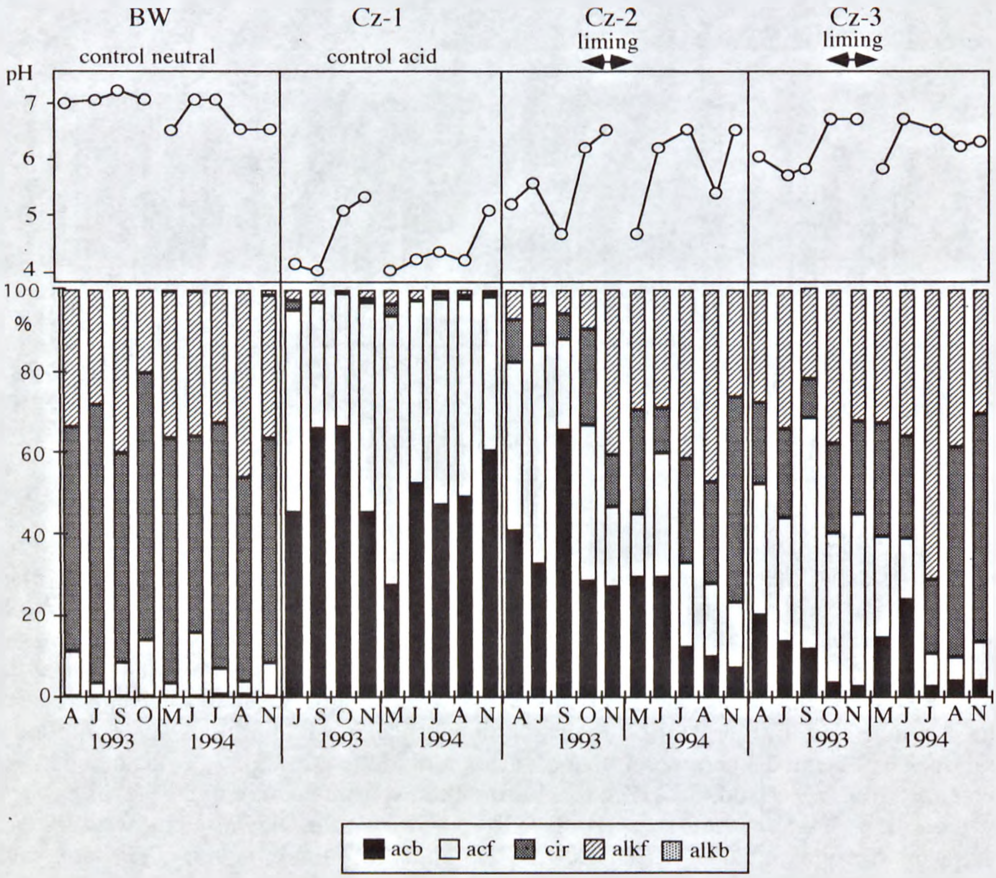

Fig. 4. Relative abundance of diatom pH-groups at the control and liming stations in relation to change in pH in the studied period (pH measurment according to Wróbel 1997, pH groups of diatom: acb – acidobiontic, acf – acidophilous, cir – circumneutral, alk – alkaliphilous, alkb – alkalibiontic).

Ryc. 4. Procentowy udział ekologicznych grup okrzemek na tle zmian pH wody, na stanowiskach kontrolnych i dolomitowanych w badanym okresie (pH wody według Wróbla 1998, podział okrzemek na grupy w odniesieniu do pH wody: acb – acydobionty, acf – acydofile, cir – neutralne, alk – alkalibionty, alkb – alkalibionty).

A period of spring thaw (May 1994) brought a decline in water pH (station Cz-2 – pH 4.7, and Cz-3 – pH 5.8), which caused changes in algae communities, namely the number of species, and in the abundance of diatoms (Figs 2, 3, 4). In contrast to natural stations – where the colonization of an environment was as rapid as samples studied in the preceeding collection (June 1994), at experimental stations, algae development was inhibited, and the community „returned" to the type developed before dolomite application. This situation began to improve in July 1994. Water pH oscillated around pH 7. Filamentous chlorophytes, particularly *Klebsormidium rivulare* – as well as diatoms – appeared in great numbers. Desmids were often moderately observed. There was an increase in the number of diatom species in addition to an abundance of neutral and alkaliphilous forms (Figs 3, 4).

In the course of time, the abundance of *Eunotia exigua* decreased, while the share of *Achnanthes minutissima* var. *minutissima* and *Fragillaria capucina* increased (Fig. 2).

The diatom communities studied can be divided, using cluster analysis, into several groups differing in structure type (Fig. 5), the differences being expressed mainly by

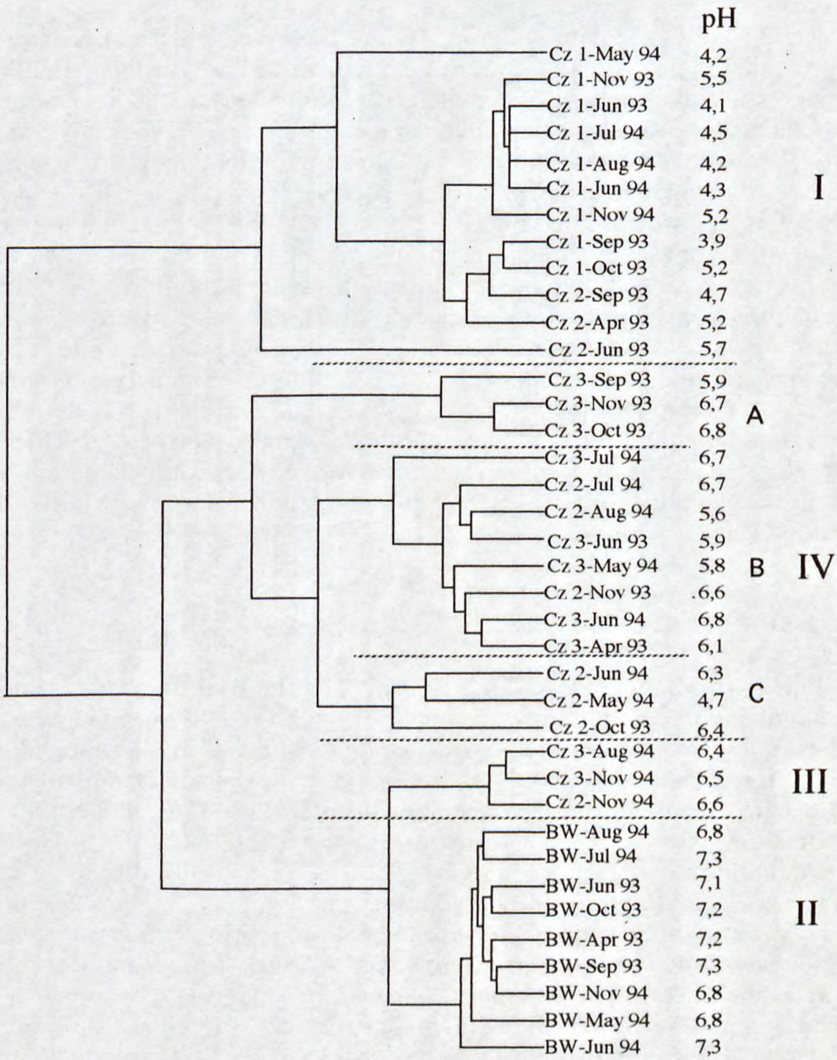

Fig. 5. Comparison of algae communities at the control and liming stations according to Pearson's correlation coefficient, and the average linkage clustering. I–IV – types diatom communities devoloping at the studied stations, A–C – subgroups distinguished among type IV of the diatom community. Stations designated as in Fig.1.

Ryc. 5. Porównanie zbiorowisk glonów na stanowiskach kontrolnych i dolomitowanych z zastosowaniem korelacji Pearsona i metody łączenia średnich. I–IV – typ zbiorowisk okrzemek rozwijające się na badanych stanowiskach A–C – podgrupy wyróżnione w obrębie typu IV. Stanowiska oznaczone jak na ryc. 1.

a quantitative proportion within the dominants which depended on changes in pH values after dolomite application and the spring thaw.

A separate group (group I) consisted, firstly, of communities developing at a low water pH surrounding control station Cz-1, and secondly, of algae communities grown at station Cz-2 before dolomite application. The communities were characterized by a prevalence of acid-water taxa: *Eunotia exigua*, *E. rhomboidea*, *E. tenella* and *Pinnularia subcapitata*.

The second clearly distinguished group (group II) was composed of communities in the vicinity of the Biała Wiselka – control station. It should be noted that the BW is at a higher water pH. The characteristic feature of this group was a high amount of neutral and alkaliphilous forms, *Achnanthes minutissima*, and species of the genus *Fragilaria*.

Group III-communities, developed at Cz-2 and Cz-3 after application and a prolonged influence of dolomite resembled, to a high degree, those of group II.

Group IV, which was divided into 3 subgroups (A, B, C) was composed of communities developing at experimental stations Cz-2 and Cz-3. Subgroup A contained communities grown at station Cz-3 before and throughout the first period following dolomite application – the following species which dominated were: *Anemoeoneis brachysira*, *Fragilaria capucina*, *Achnanthes minutissima*. Communities of subgroup B showed individual character. They were composed primarily of communities developing after the experiment. Their characteristic feature was a dominance of both neutral and alkaliphilous, and acidophilous species, the share of which varied intermittently depending on fluctuations in pH value. Subgroup C containing communities developed at station Cz-2 after dolomite application, was similar to those of subgroup IV B.

4. Discussion

Two adjacent streams – the Czarna Wisełka and the Biała Wisełka – both differing in chemical composition of water, especially with regard to calcium concentration and pH value, exert significant influence on differences in the characteristics of developing algae communities (Kwandrans 1989). In the lower part of the Biała Wisełka stream, in which leading neutral, well-buffered waters were not influenced by acidification (Wróbel 1998), algae flora was characteristic of Carpathian streams. The dominating algae species were typical of pure, well-oxygenated, mountane streams: *Hydrurus foetidus* of chrysophytes and diatoms: *Achnanthes minutissima* var. *minutissima*, *Cocconeis placentula* (with its variety *euglypta*), *Fragilaria arcus*, *F. capucina*, *F. ulna*, and chlorophytes of *Ulothrix* genus, and the ubiquitous species as cyanobacteria *Phormidium subfuscum*, *P. corium*.

In contrast, the Czarna Wisełka stream, particularly in its upper and middle sections, had a much less effective buffer system, and was characterized by temporarily high states of acidification, high levels of aluminium, and dissolved organic contents (Wróbel 1998). The acidification process and the presence of humic compounds was caused by the geology of the catchment area. The southern exposition of the slopes, where peat-bogs are located, differ in the natural type of forest and also in effects resulting from industrial pollution. Flora developing in those sectors was typical of acidic waters; a low number of species and acidobiontic and acidophilous diatoms coupled with a predominance of *Eunotia* genus and green alga *Klebsormidium rivulare* appeared in mass along the course of the stream. *Klebsormidium rivulare* is a species that commonly occurs in acidic waters which are poor in electrolytes (Hargreaves, Whitton 1976) and are highly resistant to extreme environmental conditions. Its resistance to toxic substances (Say et al. 1977), as well as to freezing and drying (Morison, Sheath 1985) are commonly recognized. *Eunotia exigua* – the most numerous diatom in the Czarna Wisełka – belongs to an algae commonly found in strongly acidic waters. It is able to tolerate a high concentrations of heavy metals and aluminium (Cholnoky 1968, Round 1990, Kwandrans 1993, Hargreaves et al. 1975, van Dam et al. 1981), and is one of the most resistant species to acidic water conditions (van Dam, Buskens 1993). This diatom species has been found in waters with a pH as low as 2.5 (Hargreaves et al. 1975). According to many authors it is described as acidobiontic. However, according to Alles et al. (1991), Alles and Nörpel-Schempp (1992), *Eunotia exigua* coincides with the less effective buffer system of aluminium and silicon. This species tolerates wide and abrupt variations of pH-values and is a typical indicator of anthropogenic acidification, known as "indifferent-acidophilous". The aformentioned authors suggest a new system of a diatom pH-grouping contrary to the traditional one. According to behaviour in „different" types of waters, the genus *Eunotia* can be distinguished in four ecologically different groups with respect to pH and to buffer systems. The species of group I (e.g. *Eunotia paludosa*), group II (e.g. *E. minor*), and group III (e.g. *E. bilunaris*) are considered as indicators for an effective buffer system. The species in group IV (e.g. *Eunotia exigua*) are appropriate indicators for a less effective bufer system and anthropogenic acidification.

The species composition and structure of diatom communities developing in the lower part of the stream are indicative of waters richer in nutrients resources and higher water pH (pH was 5.8–6.4 before the experiment, Wróbel 1998). According to character of developing bottom flora, the waters of this sector can be considered as less buffered or, „episodically mild acidity" (see Coring 1996). In addition to representatives of the genus *Eunotia*, and *Anomoeoneis brachysira* species – typical of acidic, oligotrophic waters (van Dam et al. 1994, Hofmann 1994) – the following eurytopic species were abundantly observed: *Fragilaria capucina* – oligo-mesotrophic, as classifed with regard to the water's trophic state (Hofmann 1994, van Dam et. al 1994), and alkaliphilous, with regard to water's pH (e.g. van Dam et al. 1981, Hakansson 1993), in addition to *Achnanthes minutissima* var. *minutissima* (with a wide spectrum of trophic state), which is considered oligo-eutrophic and circumneutral in regards to pH (Whitmore 1989, Hofmann 1994, van Dam et al.1981, 1994). According to Flower (1986), a pH lower than 5.0 limits this species growth, while its abundance increases at a pH between 5.0–6.0. van Dam et al. (1981,1988) observed this species in weakly acidic to alkalic waters. The optimum pH for its development is estimated at a pH of 6.8. After liming, it is a pioneer species of epiliton and epiphyton in lakes and streams as well as moorland pools (Lazarek 1982, Round 1990, Bellemakers, van Dam 1992).

Dolomite application in the acidic waters of the Czarna Wisełka stream caused an increase in calcium and magnesium concentration, its alkalinity, water neutralization, and a considerable rise in ionised aluminium concentration (Wróbel, Wójcik 1989, Wróbel 1998).

As a concequence of changes in the chemical composition of the water, there was a modification of species composition and structure in algae communities, which affected mainly diatoms – the most sensitive group to chemical changes in water environment. A similar tendency towards an increase in the abundance and structure of epiphytic algae communities in limed lakes was observed by Lazarek (1982).

The comparatively small degree of water neutralization in the Czarna Wisełka has been noted in the case of other algae groups when quantitative changes were caused, most likely, by a seasonally developmental rhythm of selected species and groups throughout the year.

In the first stage, dolomite application exerted a stimulating effect by increasing the number of the diatom taxa and their abundance, and decreasing the share of acidobiontic and acidophilous forms in favour of those of an alkaliphilous and neutral species. These tendencies became more pronounced after an elongation of the period of dolomite influence at both stations. A quantitative increase in algae, changes in floristic composition of diatom communities, which were particularly poor at station Cz-2, indicated a raise in water pH and an increase in the level of nutrients after dolomite application. Bellemakers and van Dam (1992) reported that after liming in some moorland pools, the floristic composition of diatom assemblages indicated an increase in the bioavailability of nutrients as having resulted from the mineralization of accumulated organic matter. The chemical analyses, however, did not reveal an increased nutrient concentration.

In general, the results of the present study, including a cluster analysis, showed that dolomite application caused a kind of transition in the Czarna Wisełka's „acidic communities" to the natural phytocenoses of the Biała Wisełka waters. Simultaneously, a comparatively high share (which persisted after dolomite application) of acidobiontic diatom *Eunotia exigua* and other acidophilous diatoms was caused by a decrease in pH extremes and alkalinity fluctuations which were observed during precipitation, especially in a period of snow melting (Wróbel 1998). At the same time, the occurring, numerous teratological forms of the *Fragilaria capucina* population reflected the stressfully acid conditions.

The inhibition of quantitative algae development during the period of spring thaw (May, June 1994) was caused not only by spring's high level of water and subsequent destruction of algae, but also by the dolomite itself since it has been washed out, with it's finely-grained stones having been covered with a thick coat, thereby preventing the access of light. Similarly, unfavourable phenomena during floods and the unsuccessful effect of dolomite on the bottom fauna was also observed (Szczęsny 1998). As reported by Wróbel (1998) during this time, it first took place in the dissolution of iron compounds (being previosly precipitated on dolomite) followed by a release of hydrogen, aluminium and humic substances. Moreover, in these periods, too great a difference exisited between the mass of water compared to the amount of dolomite. This diminished any favourable chemical effect on the aquatic environment.

Preliminary results of the present research indicate both positive and negative effects of dolomite application on the phytocenoses of Czarna Wisełka stream. However, similar to the opinions of many other authors (e.g. Bellemakers, van Dam 1992, Erikkson et al. 1983, Herrmann et al. 1993), the seasonal changes, especially during the spring have a decisive influence the effectiveness of neutralization as well as the intensity of the colonization and types of interspecial competition between many groups of water organisms. A long-term influence of dolomite application has not been established so far and the specificity of numerous processes taking place in running waters leaves many questions without answer. It seems that the assessment the effectiveness of dolomite use in acidic waters will only be possible after long-term monitoring studies.

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Streszczenie

Niniejsze badania miały na celu określenie wpływu dolomitowania kwaśnego potoku Czarna Wisełka (jednego z dwóch źródłowych potoków Wisły) na zbiorowiska glonów osiadłych. Materiały do badań zbierano na 3 stanowiskach w potoku Czarna Wisełka: stanowisko Cz-1, odznaczające się silnie kwaśnym odczynem wody, pozostawiono w stanie naturalnym i traktowano jako stanowisko kontrolne; odcinek potoku między stanowiskami Cz-1 i Cz-2 poddano zabiegowi dolomitowaniu (Ryc.1); stanowiska Cz-2 i Cz-3 położone poniżej tego miejsca, traktowano jako

eksperymentalne. Ponadto dla celów porównawczych przeprowadzono badania w dolnym biegu sąsiedniego potoku Biała Wisełka – stanowisko BW, o neutralnym odczynie wody.

W badanym materiale znaleziono łącznie 110 taksonów sinic i glonów (Tab. 1). W potoku Biała Wisełka rozwijała się flora glonów typowa dla potoków karpackich, z przewagą złotowiciowica *Hydrurus foetidus*, zielenic z rodzaju *Ulothrix*, sinic z rodzaju *Phormidium* oraz neutralnych i alkalifilnych okrzemek: *Achnanthes minutissima, Cocconeis placentula* var. *euglypta*, oraz gatunkami rodzaju *Fragilaria*.

W potoku Czarna Wisełka obserwowano przestrzenne różnicowanie się zbiorowisk glonów (Ryc. 2). W górnym i środkowym biegu (stanowiska Cz-1, Cz-2) o niskim pH wody i przy dużych jego wahaniach, rozwijała się flora charakterystyczna dla wód kwaśnych, o małej liczbie gatunków, z przewagą acydobiontycznych i acydofilnych okrzemek z rodzaju *Eunotia* oraz zielenicy *Klebsormidium rivulare*. W dolnym biegu potoku (stanowisko Cz-3), wraz ze wzrostem pH wody obserwowano wzrost liczby i liczebności gatunków glonów. Obficie rozwijały się zielenice oraz desmidie. Wśród okrzemek, obok gatunków kwasolubnych, jak *Anomoeoneis brachysira* i gatunków z rodzaju *Eunotia*, licznie występowały okrzemki związane z wodami o wyższym pH, jak: *Achnanthes minutissima* i *Fragilaria capucina*.

Po zastosowaniu dolomitu i zmianach w składzie chemicznym wody, stwierdzono również znaczące zmiany w zbiorowiskach okrzemek. Wyrażały się one wzrostem liczby i liczebności gatunków, zmianami w strukturze dominacji i w proporcji grup ekologicznych, wyróżnionych w odniesieniu do pH (Ryc. 2, 3, 4). Zmniejszył się udział acydobiontycznych i acydofilnych gatunków z rodzaju *Eunotia* na korzyść gatunków neutralnych i alkalifilnych, jak *Achnanthes minutissima* i *Fragilaria capucina*. Zmiany te były szczególnie widoczne w pierwszym okresie zastosowania dolomitu oraz na najuboższym pod względem rozwoju glonów stanowisku Cz-2. W miarę dłuższego okresu oddziaływania dolomitu obserwowano tendencję przebudowy zbiorowisk okrzemek i ich „podobieństwo” do typu zbiorowisk glonów Białej Wisełki (Ryc. 5).

Wiosenny okres podwyższonych stanów wody i towarzyszące im obniżenie odczynu wody miało negatywny wpływ na ilościowy rozwój glonów, szczególnie na odcinku dolomitowanym, gdzie obserwowano powrót do typu zbiorowisk „kwaśnych”. Ponadto wypłukany dolomit w postaci drobnoziarnistej frakcji pokrywał dno potoku utrudniając osiedlanie się i rozwój glonów.