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The structure of a diatom community in the spring sector of a stream with low pH (Biała Wisełka, Silesian Beskid, Poland)

Janina Kwandrans

Polish Academy of Sciences, Institute of Freshwater Biology
ul. Sławkowska 17, 31-016 Kraków, Poland

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Abstract — The work presents the structure of the diatom community developing in the spring sector of a mountain stream with low pH. A small species variety was observed in the community. The following species occurring in acid waters were of essential importance: *Eunotia exigua*, *E. tenella*, and *E. trinacria*. The effect of water acidity on the cell morphology of diatoms was noted. The changes concerned linear dimensions, the number of striae in 10 μm, and the shape of the valve. During the period of investigation no important seasonal changes were observed in the structure of the diatom community.

Key words: pH, mountain stream, diatom community.

1. Introduction

Water reaction as an important factor affecting organisms which live in water. Blum (1956), Backhaus (1968) stress the fact that, among numerous ecological factors, pH is decisive for the development of complexes of water organisms.

Low pH is usually a negative environmental factor and among numerous groups of water organisms algae tolerate it the best (Wehrle 1926/27).

The relation between the structure and occurrence of algal communities and acid water reaction has been investigated by many researchers. Cholnoky (1968), Nisbet, Verneaux (1970), Hargreaves et al. (1975), Fabri, Leclercq (1979) and many other authors have found that a low pH has a limiting effect on the number of species in the environment.

However, although floristically poor, the environment of acid waters is still ecologically interesting and the distinguishing of algal complexes with a specific composition may indicate acidity of the investigated environment (Del Prete, Schofield 1981).

The algae commonly used as pH indicators are diatoms. According to Hustedt's classification (1937/39) they are divided into 5 groups depending on their occurrence in relation to the pH:

1. Alkalibiontic — with pH above 7.0
2. Alkaliphilous — with pH about 7.0, prevailing with pH $>$ 7.0
3. Indifferent — with pH = 7.0
4. Acidophilous — with pH about 7.0, prevailing with pH $<$ 7.0
5. Acidobiontic — with pH below 7.0, optimum pH 5.5 or below.

The aim of the present work was to present the characteristics of a diatom community developing in the low pH sector of a mountain stream.

2. Study area

The Biała Wisełka stream is one of two springs streams of the River Vistula. It rises in the north-eastern slope of Mt Barania Góra (alt. 1214 above sea level) in the Silesian Beskids. There is no single main stream but a number of small springs in the rock debris at alt. 930 m. The spring outflows soon merge and the stream has originally a narrow bed in a gully and forms rapids and falls. Its bottom consists of numerous boulders, cobblestones, and partly of solid rock. In the middle course of the stream the bed becomes wider and it flows further through a broad, asymmetric valley. At the end of the village of Wisła-Czarne the Biała Wisełka joins the Czarna Wisełka stream flowing from the south-western slope of Barania Góra thus giving rise to the River Vistula.

Rain and snowfalls are frequent in the Beskids with their maximum in summer. The snow cover is long maintained, in the upper parts of the Beskids lying from November till April.

Geologically, the Biała Wisełka valley consists of a complex of sandstones, conglomerates, and shales which are described as Istebna and Godula layers. In the whole head section of the stream the chemically variable layers of Istebna sandstone are to be found (Pasternak 1962). Generally, they contain a small amount of calcium and abound in silica, potassium, and aluminium. Soils in the Silesian Beskids are highly differentiated. In the upper part the prevailing soil is rocky, intensely acid, deficient in calcium, phosphorus, and assimilable nitrogen (Pasternak 1962).

On the basis of the content of biogenic components, the stream waters may be classified as mezotrophic areas a characteristic feature, however, being the absence of biochemically active phosphorus, the run-off of orthophosphates being several times lower than the value adopted for oligotrophic areas (M a g o s z 1976). Nevertheless, the mineral composition of water abounds in silica and sulphates (P a s t e r n a k 1962).

The investigation was carried out on a flow one of the Biała Wisełka springs at an altitude of about 900 m, at a distance of more than 10 m from the actual outflow. The bottom in this place is stony and the bed 0.3 m wide. The station (covering a 1 m long section of the flow) is intensely forested (spruce with occasional fir) with moss and liverworts strongly developed on the bank. The station is poorly lighted and during summer it is increasingly shady. The water temperature ranged from 2.8°C in the autumn to 10.5°C in the summer. The stream waters, containing small amounts of calcium, are strongly acid. The water reaction measured in the investigated section in the middle course ranged from 3.5 in May when the snow was melting, to pH 5.0 in October. Further on, in the course of the stream and with the decreasing altitude the pH increases.

The acid reaction of the stream waters in the investigated section is mainly connected with natural conditions in the area (the character of the substratum — decalcified rocks of Istebna sandstone, strongly acid wood soils, pH from 3.0 to 4.0).

However, the effect of increasing atmospheric pollution (emission of sulphur dioxide and nitric oxide) on acidification of surface waters (the lowest pH in May, during the thaw) may also be suggested.

3. Material and methods

The investigated material was collected from the station situated on a spring flow once a month from May to October 1981.

Taking into account the variety of habitats, samples were taken from stones, moss, and large grained sand found in small quantities near the bank.

During sampling the water temperature was measured and its reaction determined by means of the colorimetric method.

The collection and description of the material was based on algological methods according to S t a r m a c h (1969) and K a w e c k a (1980). Part of the material was used for making solid diatom preparations. In order to obtain them the material was macerated twice in a chromic acid cleaning mixture for 48 hours from the moment of digestion of the inner content of the cell. Deprived of their inner content, the cells were protected from contamination by sedimentation and centrifugation in a centrifuge, and after being washed with distilled water they were enclosed in the synthetic resin "Pleurax". Microscopic examination was carried out with an Amplival-type microscope with fixed micrometric net.

The diatom community was characterized by the number of taxa, their abundance, coverage coefficient, and the index of their biomass. The number of species was determined by means of the estimation method. This method involves counting the individuals of a given species in the microscope in 10 fields of vision which are limited by the contour of the micrometric net, with lens magnification of 40× and ocular magnification of 10×. If the species was present in the preparation but not found during counting it was given the agreed value 0.1. Then, according to the percentage share of the particular species dominants and adominants were determined. The species described as dominant reached at least a 5% share in the community. All species below that value were considered as adominants. Next, the size of the cell was determined by comparing it with that of the micrometric net mesh, this value being given in fractions or multiplies of net squares. By multiplying the number and cell magnitude of a given species the coverage coefficient was obtained which conventionally determines the area occupied by the species in the community. Then, when multiplied by 2, this value allows the determination of the alga's approximate assimilative surface.

The value of the coverage coefficient was used to characterize the dominant species and by summing the values of the coefficient the index of the diatom biomass was obtained.

4. Results

4.1. Description of the community

The distinguished community is characterized by a small species variety. In the examined material 20 diatom taxa were determined. The number of species was constant throughout the period of investigation (fig. 1). The number of individuals within the species and therefore the index of their biomass was low or average (fig. 1). The main role in the community was played by the acidophilous species of the *Eunotia* genus and to a smaller degree the *Pinnularia* genus. The dominant species throughout the period of investigation were *Eunotia exigua*, *E. tenella*, and *E. trinacria* (fig. 1).

Changes were observed in the cell morphology of diatoms. Apart from typical forms, cells of different linear dimensions, number of striae in 10 μm, and shape of valve were found (fig. 2—7).

In the cell population of *Eunotia tenella* there appeared cells with an asymmetric shape of the shell and a smaller number of striae in relation to

Months	V	VI	VII	VIII	IX	X
Water temperature °C	9,0	10,2	10,5	8,5	8,9	2,8
pH	3,5	4,5	4,0	4,2	4,5	5,0
Number of species	19	20	20	19	20	19

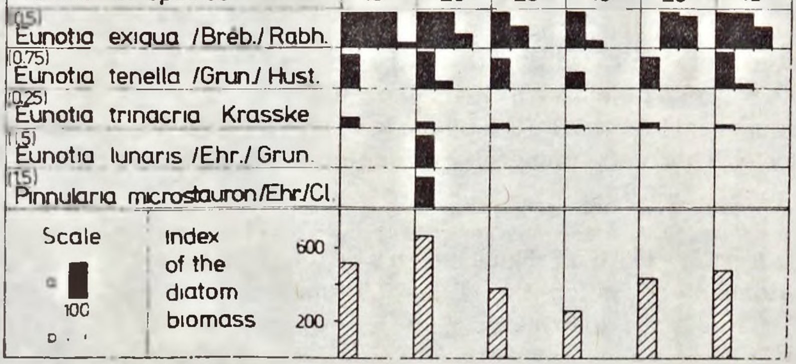


Fig. 1. Dominating species in the head water section of the stream. a — coefficient of coverage; b — cell dimensions. Adominants: *Eunotia bigibba*, *E. bigibba* var. *pumila*, *E. fallax*, *E. diodon*, *Pinnularis interrupta* var. *minutissima*, *P. molaris*, *P. borealis*, *P. subcapitata*, *P. viridis*, *P. viridis* var. *sudetica*, *Frustulia rhomboidea* var. *saxonica*, *Navicula contenta*, *N. söhrensis*, *Navicula* sp., *Cymbella ventricosa*

the typical diagnosis for the species. Among the cells of *Eunotia lunaris* the prevailing forms had curved valve edges, wider than those in the species description. High morphological variability in the linear dimensions was also observed in the cell population of *E. exigua* and *Pinnularia microstauron*. During the investigation period the community showed strong stability. Species composition and the system of dominant species remained without much change. In June there occurred an increase in *Pinnularia microstauron* and *Eunotia lunaris* leading to a periodical domination but throughout the rest of the period they appeared in small, constant numbers. However, quantitative differences were observed. Species abundance and hence the biomass index reached their maximum values in May and June. During the summer the index value fell, reaching its minimum in August, after the period of increased water level. In the autumn a tendency towards stabilization in the community and a renewed rise in species abundance were noted.

4.2. Taxonomy and ecology of some diatom species in the opinion of other authors

Eunotia exigua (Bréb.) Rabh. Siemińska (1964) fig. 2
Dimensions of cells: length: 8.8—32 μm; width: 2.0—4.2 μm; 15 –20 striae in 10 μm

Some cells have a slightly smaller number of striae and are wider than is given in the diagnosis of the species.

According to Siemińska (1964) the number of striae is 16—24 in 10 μm, and the width of the cell 2.0—3.5 μm. However, van Dam et al. (1981) found cells which were 2.0—3.5 μm wide. According to Patrick, Reimer (1966) the upper limit of width is 4.0 μm. A species strongly connected with acid waters (Patrick, Reimer 1966), described as acidobiontic (Jørgensen 1948, Foged 1964, Merilainen 1969). Numerous at pH 5.2—5.3 (Cholnoky 1968). In the examined material the species was very numerous throughout the investigation period, at a pH range 3.5—5.0.

Eunotia tenella (Grun.) Hust. Hustedt (1932) fig. 3
Dimensions of cells: length: 11.5—29.5 μm; width: 2.5—4.5 μm; 13—16 striae in 10 μm

Hustedt (1932) gives the following dimensions: length: 6.0—35.0 μm; width: 3.0—4.0 μm; 16—20 striae in 10 μm.

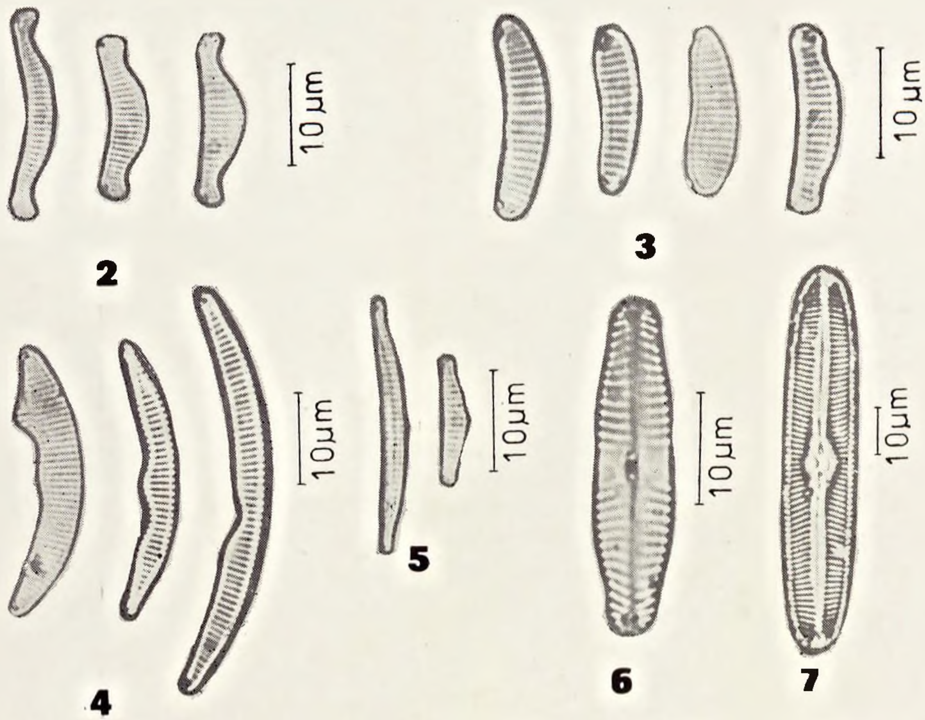
Some of the cells are wider than is given in the description of the species and their striae number is smaller. However, according to Patrick, Reimer (1966) there are 14—16 striae in the middle part of the cell and up to 20 at its ends. Cholnoky (1958) found cells with a smaller number of striae: 13 in 10 μm. The species is difficult to identify. Apart from the typical forms, cells with a different number of striae and an asymmetric shape of valve (fig. 3) were frequently found. *E. tenella* prefers acid waters (Patrick, Reimer 1966) and is described as acidophilous (Jørgensen 1948, Foged 1964, Merilainen 1969). It comes to its optimal stage of development at pH 5.5—6.0 (Cholnoky 1968), and is numerous at pH 3.5—7.0 (Van der Werff, Hulls 1974).

In the examined material the species was numerous throughout the investigation period, reaching its maximum development at pH 4.5—5.0.

Eunotia lunaris (Ehr.) Grun. Cleve-Euler (1953) fig. 4
Dimensions of cells: length: 28.0—62.5 μm; width 3.0—5.5 μm; 13—16 striae in 10 μm

Some of the cells are wider than is given in the diagnosis of the species. According to Cleve-Euler (1953) the width is 3—5 μm. In the examined material, regarding the typical forms, cells with curved valve edges prevailed (fig. 4). This species is often found in peat bogs with its anomalous forms with curved valve edges (Siemińska 1964).

The species *Eunotia lunaris* is connected with weakly acid waters (Patrick, Reimer 1966). It is also described as indifferent (Jørgensen 1948, Merilainen 1969). Optimum pH: 5.5—6.0 (Chol-



Figs 2—7. Species of algae. 2 — *Eunotia exigua*; 3 — *E. tenella*; 4 — *E. lunaris*; 5 — *E. trinacria*; 6 — *Pinnularia microstauron*; 7 — *P. viridis*

n o k y 1968). In the examined material it reached its maximum stage of development at pH 4.5.

Eunotia trinacria Krasske Siemińska (1964) fig. 5
Dimensions of cells: length: 6.0—24.5 μm; width: 2.5—3.0 μm; 16—18 striae in 10 μm

Some of the cells have a smaller number of striae than that given in the species description. According to Siemińska (1964) the number of striae is 17—20. The species prefers acid, cold waters (Patrick, Reimer 1966) and is characteristic for peat bog waters (Siemińska 1964). It is described as acidophilous (Jørgensen 1948). Optimum pH 5.0 (Cholnoky 1968).

In the examined material it was fairly numerous throughout the investigation period, at pH 3.5—5.0.

Pinnularia microstauron (Ehr.) Cl. Siemińska (1964) fig. 6
Dimensions of cells: length: 26.5—48.2 μm; width: 5.5—7.5 μm, 10—13 striae in 10 μm

Some of the examined cells are narrower than is given in the species description. According to Siemińska (1964), Patrick, Reimer (1966) the width is 7—11 μm.

However, forms which were 5.6—7.0 μm wide (Starmach 1973) or even 5.3 μm, were also found (*Pinnularia microstauron* fo., Foged 1964).

A species characteristic for weakly-acid waters, described as indifferent (Merilainen 1969), as acidophilous (Jørgensen 1948). Optimum of occurrence at pH below 7.0 (Cholnoky 1968), numerous at pH 4.3—6.5 (Jørgensen 1948).

In the examined material the maximum stage of development was reached in June at pH 4.5.

Pinnularia viridis (Nitzsch) Ehr. Siemińska (1964) fig. 7
Dimensions of cells: length: 68.0—125.0 μm, width: 10.0—19.0 μm; 6—9 striae in 10 μm

A species described as indifferent (Jørgensen 1948, Foged 1964). Optimum occurrence at pH 5.6—6.0 (Cholnoky 1968).

In the examined material the species was found together with the variety *P. viridis* var. *sudetica* and was scarce throughout the investigation period, with a distinct tendency to increase in number along with rising pH. The maximum stage of development was reached during the investigation at pH 5.0.

5. Discussion

The present work characterizes a diatom community developing in the environment of a mountain stream unmodified by human activity, in its low pH sector. A characteristic feature of this community is the small variety of species. It is stressed in the literature that a low pH has a limiting effect on the number of species in the environment. Bennet (Hargreaves et al. 1975) gives 25 algal species present at pH below 4.0, Fabri, Leclercq (1979) 40 species at pH 3.4—5.6, and Lackey (Hargreaves et al. 1975) gives the highest of algae and protozoa at pH below 4.0 as 76.

The abundance of the species, and hence the index of their biomass, was low or average.

The main role in the community was played by diatoms, described in Hustedt's system (1937/39) as acidobiontic and acidophilous (*Eunotia exigua, E. tenella, E. trinacria* and, to a smaller degree, *E. lunaris* and *Pinnularia microstauron*). The most abundant during the period of investigation was *Eunotia exigua*. This is a strongly dominant species in acid waters and its abundance rises with increasing acidity (Fabri, Leclercq 1979, van Dam et al. 1981).

Although *Eunotia exigua* is a species strongly connected with natural acid, oligotrophic waters, it also develops well in acid mine waters with a high content of mineral components and a large amount of heavy metals (Hargreaves et al. 1975). It is probably the diatom most resistant to concentrations of heavy metals (van Dam et al. 1981).

It was established that a low pH is a stress-inciting environmental factor and affects the morphology of diatom cells. In the investigated population forms were found whose linear dimensions, number of striae, and the shape of valve did not correspond with the species description. Asymmetric cells of *Eunotia tenella* were numerous. Asymmetric forms of the *Eunotia* genus have been described by many authors: *Eunotia faba* fo. *rhomboidea* (Foged 1972), *E. veneris* (Merilainen 1969), and *E. tenella* (Cholnoky 1958). Hustedt described the asymmetric forms as *Eunotia rhomboidea* species (Foged 1974, Pl. IV, fig. 14—16), while van Dam et al. (1981) included it in *E. tenella* species. Changes in the linear dimensions and the shape of valve of diatoms in streams with low pH were observed by Hargreaves et al. (1975) and van Dam et al. (1981) in moorland pools.

The lower the pH became, the greater the changes taking place (Hargreaves et al. 1975). Hargreaves, Whitton (1976) also give species from other algal groups which underwent considerable morphological differentiation when affected by a strong acid reaction of the water.

During the investigation period no basic differences in seasonal development of the community were noted. F a b r i, L e c l e r c q (1979) showed that seasonal changes in streams with a low pH (3.4—5.6) were practically non-existent, whereas in the other type of investigated streams, with a higher pH (about 6.0—7.4) and richer in minerals, such changes were distinct.

6. Polish summary

Struktura zbiorowisk okrzemek w źródłowym odcinku potoku o niskim pH (Biała Wisełka, Biskid Śląski, Polska)

Celem przeprowadzonych badań była charakterystyka zbiorowiska okrzemek rozwijających się w środowisku górskiego potoku na odcinku o niskim pH.

Obiektem badań było stanowisko położone na obszarze źródliskowym potoku Biała Wisełka, wypływającego ze stoków Baraniej Góry w Beskidzie Śląskim.

Wyróżnione zbiorowisko scharakteryzowano przez liczbę taksonów, liczebność gatunków, wskaźnik rozmieszczenia przestrzennego oraz wskaźnik biomasy okrzemek.

Stwierdzono małą różnorodność gatunkową zbiorowiska (20 gatunków na stanowisku). Liczba gatunków była mniej więcej stała w ciągu badanego okresu (ryc. 1). Liczebność gatunków, a stąd i wskaźnik biomasy okrzemek, utrzymywały się na poziomie niskim i średnim. Największe liczebności osiągały kwasolubne gatunki z rodzaju *Eunotia*. Dominowały: *Eunotia exigua, E. tenella, E. trinacria*, a okresowo również *E. lunaris* i *Pinnularia microstauron* (ryc. 1).

Stwierdzono znaczny wpływ kwasowości wody na morfologię komórek okrzemek. W stosunku do opisu gatunku, obserwowano różnice dotyczące wymiarów liniowych, liczby prążków i kształtu okryw (ryc. 2—7).

W sezonowym rozwoju populacji okrzemek struktura zbiorowiska nie zmieniała się w sposób istotny. Skład gatunkowy i układ gatunków dominujących pozostawał bez większych różnic, wystąpiła natomiast tendencja do zmian ilościowych.

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