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The use of diatoms to assess the water quality in the Wisłoka River in the town of Dębica and the surrounding area

by

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Abstract

The objective of this work was to examine the water quality using three diatom indices SPI, GDI and TDI. The material for the study was collected during four seasons from autumn 2010 to summer 2011, from four sampling sites located on the Wisłoka River, in the town of Dębica and the surrounding area. The Wisłoka at all selected sites was characterized by alkaline or close to neutral pH (pH 6.5-7.7). Electrolytic conductivity ranged from 364 to 480 μS cm^{-1}. The Wisłoka at the selected sites in the urban area and in the surrounding areas was characterized by high diatom species richness. The total of 238 taxa from 53 genera were recorded, of which the most numerous were: *Nitzschia* (44), *Navicula* (33) and *Gomphonema* (12). *Achnanthidium minutissimum* var. *minutissimum*, *Amphora pediculus*, *Navicula gregaria*, *N. lanceolata*, and *Nitzschia dissipata* ssp. *dissipata* were usually the dominant species. Chemical parameters indicated very good quality of water. However, the diatom indices used to assess the water quality, classified the studied water into a group corresponding to quality class III or IV.

Key words: diatom indices SPI, GDI; water quality; PCA, RDA; Wisłoka River; Dębica town; SE Poland

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Introduction

Diatoms (*Bacillariophyceae*) are characterized by a large variety of species and are also a very sensitive component of aquatic ecosystems on a wide range of environmental variability. Therefore, they are used, among others, in hydrobiological studies of water quality. The basis of these studies are lists of taxa and their assigned indicative values for the various environmental factors (Van Dam et al. 1994; Prygiel & Coste 1999; Rakowska 2001; Stoermer & Smol 2010). Monitoring studies using diatoms to assess the water quality are conducted in many countries on a large scale. The OMNIDIA software which contains taxonomic and ecological database with indicator values and degrees of sensitivity of individual diatom taxa was created for this purpose (Lecointe et al. 1993). Benthic diatoms are used to assess the water quality in many European countries (Prygiel & Coste 1993, 1999; Kelly & Whitton 1995; Kelly et al. 1995; Whitton & Rott 1996; Eloranta 1999; Prygiel 2002; Kelly 2003; Kelly et al. 2008; Stenger-Kovács et al. 2013; Bayene et al. 2014), as well as in Poland (Kwandrans et al. 1998; Kawecka & Kwandrans 2000; Bogaczewicz-Adamczak et al. 2001; Rakowska 2001; Kwandrans 2002; Bogaczewicz-Adamczak & Dziengo 2003; Zgrundo & Bogaczewicz-Adamczak 2004; Żelazowski et al. 2004; Dumnicka et al. 2006; Rakowska & Szczepocka 2011; Wojtal & Sobczyk 2012; Szczepocka et al. 2014).

The research on diatoms in the Podkarpacie Province has been conducted only in the last few years (Noga & Siry 2010; Tambor & Noga 2011; Bernat & Noga 2012; Noga 2012; Noga et al. 2012; Pajączek et al. 2012; Noga et al. 2013a; 2014a). Previously, individual studies were conducted only in the upper reaches of the San River, in connection with the massive growth of *Didymosphenia geminata* below the reservoirs "Solina" and "Myczkowce" (Kawecka & Sanecki 2003). In recent years, studies using diatoms as an indicator to assess the water quality were also conducted, but never in the cities (Noga et al. 2013b,c,d; 2014b, 2015; Peszek et al. 2015).

The objective of this work was to investigate the quality of water in the Wisłoka River in Dębica and the surrounding area using three diatom indices: SPI, GDI, TDI. The paper also attempts to assess the usefulness of the indices used in assessing the quality of water flowing through urban areas.

Study area

The urban area of Dębica covers 34 km^2 and is located on the border of two physico-geographical units – the Sandomierz Basin and the Carpathian Foothills. The town is divided into the northern part, which is part of the Subcarpathian Proglacial Valley and the Valley of the Lower Carpathian Wisłoka, while the southern part is part of the Dynowskie Foothills, which is spread mainly between the Wisłoka River and the Wielopolka River (Buszko & Kiryk 1995; Mendelowski 2007) (Fig. 1).

The Wisłoka is a right-bank tributary of the Vistula River, flowing through areas of the Low Beskids, the Jasło Foothills, the Jasło-Krosno Basin, the Strzyżów Foothills, the Lower Wisłoka Valley and the Vistula Plains. The length of the river is 164 km and its basin area covers 4110 km^2 (Buszko & Kiryk 1995). Dębica is located in the lower reaches of the Wisłoka River, which has a transitional nature in this section. A characteristic feature of the Wisłoka is a small amplification of its course and a considerable variability in the water level. This is the result of abundant, often torrential rain, causing sudden floods of water, especially during the summer months. The dominant role in the supply of the Wisłoka is played by the spring area of the basin – the Low Beskids. The Wisłoka has a rain-snow-groundwater type of hydrological regime along its entire length (Ziemońska 1973). The towns of Dębica and Mielec are located in the middle and lower section of the Wisłoka River, which could significantly affect the quality of water.

Materials and methods

The material for the study was collected during four seasons: autumn 2010 (October), winter 2011 (January), spring 2011 (May) and summer 2011 (August) from four sampling sites located on the Wisłoka River, in Dębica and the surrounding areas (Fig. 1), in the vicinity of large industrial plants, agricultural areas and housing estates. The material was collected always in periods of stable hydrological conditions. The first site was located in Podgrodzie – a village west of Dębica, near a plant producing bicycles and surrounded by agricultural land. The second and the third site were located in the urban area of Dębica, behind a tire company and in the vicinity of a large housing estate. The second site was commonly referred to as a "dam" and the third one was situated under a road bridge connecting the town with villages located north of the town. The last site was situated in the village Brzeźnica, located to the east of the town, within a short distance from a plant producing paint and varnish.

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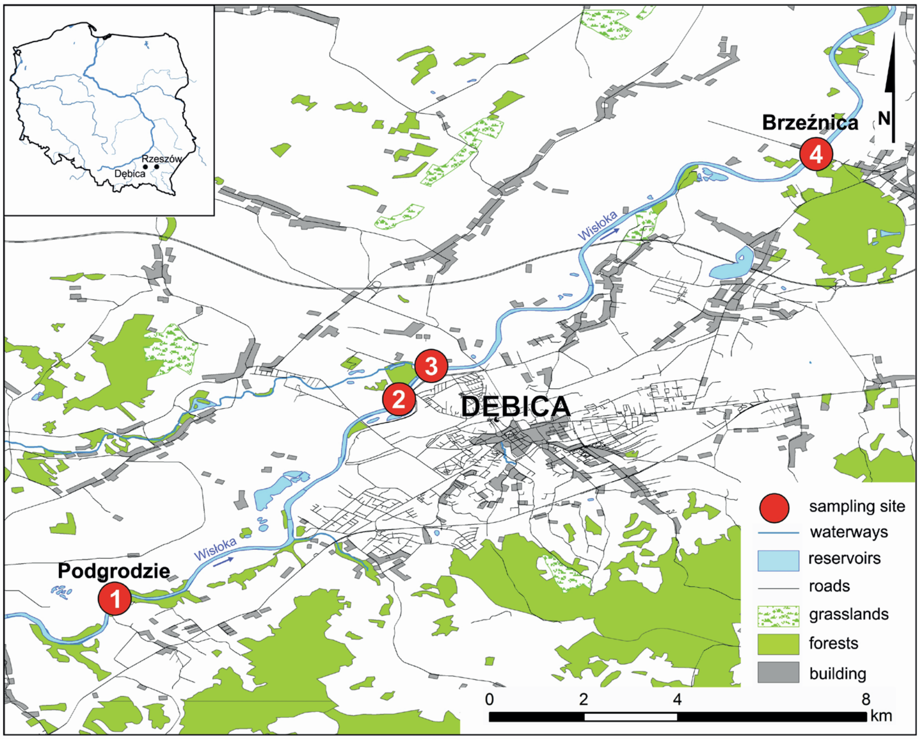

Figure 1

The location of sampling sites: 1 – site no. 1 in Podgrodzie village, 2-3 – sites in the Dębica town, 4 – site no. 4 in the Brzeźnica village (own study based on data from the Geodetic and Cartographic Documentation Centre in Rzeszów)

The material for the study was collected near the river bank, at a depth of 20 to 50 cm, from all available habitats (i.e. cobbles, mud, sand and aquatic macrophytes). A total of 48 samples were collected. In the calculation of the diatom indices and in PCA and RDA analysis, 16 samples collected from cobbles were used. Simultaneously with diatom sampling, pH, electrolytic conductivity and temperature of water were measured. Additionally, during the last two seasons (spring and summer 2011), water samples were collected for chemical analysis carried out in the Departmental Laboratory of Analysis of Environment Health and Materials of Agricultural Origin at the University of Rzeszów. Chemical analysis was performed by means of a liquid chromatography apparatus (PeakNet Dionex 2001-2006, version 6.80). The content of chlorides, nitrates, nitrites and sulfates, phosphates and ammonium nitrogen was determined. The content of phosphates and ammonium nitrogen was below the limit of quantification (<0.05 mg l^{-1}). Water quality classes were determined according to the Regulation of the Minister of the Environment from 22 October 2014 (Dz. U. 2014 No. 0, pos. 1482).

The material was prepared according to the methods applied by Kawecka (1980). To obtain pure diatom valves, part of each sample was subjected to maceration in sulfochromic mixture (mixture of concentrated sulfuric acid and chromic acid in proportion 3:1), then washed in a centrifuge (at 2500 rpm). The diatoms were mounted in permanent diatom slides with Pleurax (refractive index 1.75). Diatoms were identified and counted under a Nikon ECLIPSE 80i light microscope, using the following identification keys: Krammer & Lange-Bertalot (1986; 1988; 1991a,b), Krammer (2000; 2002; 2003), Lange-Bertalot (2001), Hofmann et al. (2011).

Species composition was determined by counting specimens on randomly selected transects under a light microscope. The number of diatoms was obtained by counting all species in randomly selected microscopic fields of view, up to a total

Table 1

The range of indices values and corresponding ecological status according to Dumnicka et al. (2006)

Water Quality Class*	Ecological status	SPI	GDI	TDI	Trophic state
I	high	> 17	> 17	<35	oligotrophic
II	good	15-17	14-17	35-50	oligo/mesotrophic
III	moderate	12-15	11-14	50-60	mesotrophic
IV	poor	8-12	8-11	60-75	eutrophic
V	bad	<8	<8	>75	hypertrophic

* according to the Regulation of the Minister of the Environment from 22 October 2014 (Dz. U. No 0, pos. 1482).

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number of 400 valves. Species with a content of 5% or more in a given diatom assemblage were defined as dominant.

The OMNIDIA software (Lecointe et al. 1993, version 4.2), which also includes the taxonomic and ecological database, was used to calculate diatom indices (Prygiel & Coste 1993).

In order to determine the ecological status of the Wisłoka River, the structure of diatom assemblages was analyzed. The results of the analysis were presented using the selected diatom indices: SPI, GDI and TDI (Table 1), for which the range of ecological classes of water quality and the ecological status was adopted (according to Żelazowski et al. 2004; Dumnicka et al. 2006).

SPI – Specific Pollution Sensitivity Index is an index of organic pollution (Coste in CEMAGREF 1982), similar to an index based on genera GDI – Generic Diatom Index (Coste & Ayphassorho 1991). The indices are scaled from 1 to 20 (an increase in the value of an indicator reflects an increase in the water quality). TDI – Trophic Diatom Index (Kelly & Whitton 1995), which is scaled from 1 to 100 (the higher the value, the higher the trophic status of water). The percentage of species characteristic of organic pollution (PT) must be taken into account in the interpretation of the TDI index. There is a possibility of organic pollution if the values of PT are > 20% and < 40%. If the range of PT values is above 40%, it is likely that organic pollution significantly contributes to eutrophication of a site.

Statistical calculations and graphical interpretations were performed using the Canoco 5.03 software. The dominant species were selected for the analysis. In order to investigate the variability at individual sampling sites and during the study periods, PCA (Principal Component Analysis) was used. To determine the effect of water chemical parameters on the diatom species composition, the redundancy analysis (RDA) was used, with centering and standardization by response variables. The RDA method was selected on the basis of the detrended correspondence analysis (DCA), which had a linear character (gradient length: 1.51). The statistical significance of the canonical axis was determined based on the Monte Carlo test (Ter Braak & Šmilauer 2012). Data were considered statistically significant if the level of significance was below 0.05. PCA was performed for all research seasons, while RDA for May and August 2011 when chemical analysis of water was performed.

Results

During the research conducted in 2010-2011, the Wisłoka River in the town of Dębica and the surrounding areas were characterized by alkaline or close to neutral pH of the water (pH 6.5-7.7). Electrolytic conductivity ranged from 364 to 480 μS cm^{-1}. Average water temperature was 2°C in winter and 21°C in summer. Values of most chemical parameters studied (Cl^-, NO_2^-, NO_3^-, SO_4^{2-}) indicated very good quality of water. The content of phosphates and ammonium nitrogen was below the limit of quantification. Only the concentration of nitrite and nitrate indicated good water quality (Table 2).

The Wisłoka at four selected sampling sites was characterized by high species richness of diatoms. A total of 238 taxa from 53 genera were identified, including *Nitzschia* (44), *Navicula* (33) and *Gomphonema* (12) represented by the largest number of taxa. This was also confirmed by high values of the Shannon-Wiener (H') species diversity

Table 2

Values of physicochemical water parameters with description of sampling sites (1-4) in the Wisłoka River

Parameter	Unit	Site			
		1 50° 0'56.8" N 21° 19' 59.6" E	2 50° 3' 27.8" N 21° 23' 25.2" E	3 50° 3' 50.3" N 21° 24' 13.2" E	4 50° 6' 14.9" N 21° 28' 8.6" E
Insolation		high	high	high	high
Bottom		stony	stony	stones and silt	stones and silt
Width	m	ca 35	ca 60	ca 50	ca 35
Temperature	°C	2-20	3-21	2-21	2-22
pH		6.5-7.7	6.7-7.6	6.6-7.5	6.6-7.5
Conductivity	μS cm^{-1}	364-463	404-451	372-450	423-480
Cl^-	mg l^{-1}	9.43-9.54	5.70-10.31	6.78-10.29	7.80-11.45
NO_2-N		0.18-0.22	0.12-0.25	0.11-0.19	<0.15
NO_3-N		1.41-3.83	1.61-2.20	1.65-2.69	1.51-2.82
SO_4^{2-}		33.54-33.90	21.85-35.96	25.35-35.81	27.51-38.31

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index (4.1-5.8). All the studied sites were characterized by similar species richness of diatoms. A total of 139 taxa were identified at the study site in Podgrodzie, 149 taxa at the second site, 133 taxa at the third site, and 149 taxa at the site in Brzeźnica. Twenty nine dominant taxa were identified (i.e. those that accounted for min. 5% of a given assemblage), including *Amphora pediculus* and *Navicula lanceolata* which occurred most frequently at most of the sites (Fig. 2). The largest number of dominants (10 taxa) was found at site 1 in the spring season and the smallest one at site 3 during the summer season (4 taxa). The most common dominant species at all sampling sites and in all seasons were as follows: *Achnanthidium minutissimum* var. *minutissimum*, *Amphora pediculus*, *Navicula gregaria*, *N. lanceolata* and *Nitzschia dissipata* ssp. *dissipata*.

The study of the water quality was performed using diatom indices in order to determine the ecological status of the Wisłoka River based on the structure of identified diatom assemblages.

GDI index values at most sites in all seasons showed a moderate ecological status of waters, corresponding to the third quality class. The exception was the first site where a good ecological status was determined in the spring. The SPI index always indicated a moderate or poor ecological status in the range of values from 9.9 to 12.7. The trophic index TDI obtained the highest values (72.5-88.6) indicating a bad ecological status. Values were slightly lower (56.4-72.3) only in the spring season and indicated a poor or moderate ecological status. The TDI index value was indicative of eutrophic or hypertrophic waters of the Wisłoka River in Dębica and in the surrounding areas. The PT value ranged from 10.4 to 30.8% and indicated minor organic pollution, especially in the autumn and winter season (Table 3).

Figure 2

Dominance structure (%) in diatom assemblages and Shannon-Wiener (H') diversity index values at the sampling sites in the Wisłoka River

Statistical analysis performed with the use of CANOCO software was based on two methods: PCA and RDA. PCA analysis showed that all the studied sites were similar in their structure of dominance, and the differences occurred only between the research seasons.

PCA analysis distinguished three groups of sampling sites. The first and the most distinctive one comprised the sites at which the material was collected only in the summer season, the second one – the sites at which the material was collected during the winter season, and the third group included sites at which the material was collected in spring and autumn. Site 2 was different from the others in

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Table 3

Values of diatom indices at the studied sites in the Wisłoka River in 2010-2011

Site	Season	SPI	GDI	TDI	% PT
1	October 2010	12.4	13.2	72.5	17.4
2		12.1	11.7	77.7	22.4
3		11.7	12.2	78.5	20.3
4		11.2	12.1	79.7	22.2
1	January 2011	12.7	8.8	88.6	30.8
2		12.2	11.7	80.3	11.8
3		10.6	12.2	76.8	19
4		11.6	12.2	80.1	21.1
1	May 2011	12.5	14.2	64.8	13.4
2		10.7	11.6	69.8	24.2
3		12.4	12.6	72.3	18.1
4		9.9	13.8	56.4	10.4
1	August 2011	11.8	12.2	78.5	15.8
2		11.3	10.9	76.5	19.3
3		12.1	12.1	78.9	16.8
4		12.5	12.7	72.9	12.5

Ecological status SPI, GDI, TDI	high	good	moderate	poor	bad

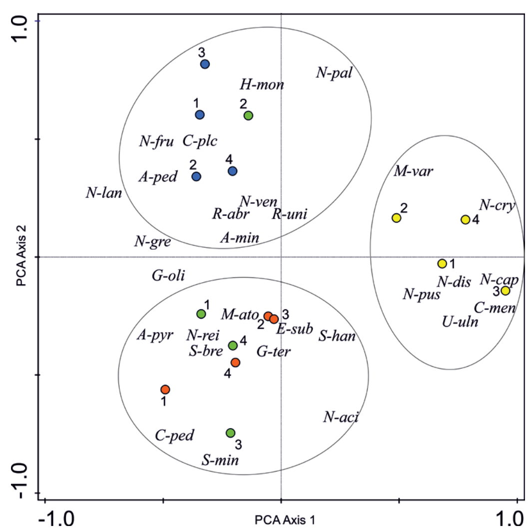

Figure 3

PCA ordination of sampling sites determined by relative community composition. Circled clusters represent sites of similarity based on the sampling season. Three distinct zones were identified (green points – spring season, yellow points – summer season, orange points – autumn season, blue points – winter season). The main species codes are as follows: A-pyr – *Achnanthidium pyrenaicum*, A-min – *Achnanthidium minutissimum* var. *minutissimum*, A-ped – *Amphora pediculus*, C-ped – *Cocconeis pediculus*, C-plc – *Cocconeis placentula* var. *euglypta*, C-men – *Cyclotella meneghiniana*, E-sub – *Eolimna subminuscula*, U-uln – *Ulnaria ulna*, G-ter – *Gomphonema tergestinum*, G-oli – *Gomphonema olivaceum* var. *olivaceum*, H-mon – *Halamphora montana*, M-ato – *Mayamaea atomus* var. *atomus*, M-var – *Melosira varians*, N-cap – *Navicula capitatoradiata*, N-cry – *Navicula cryptotenella*, N-gre – *Navicula gregaria*, N-lan – *Navicula lanceolata*, N-rei – *Navicula reichardtiana*, N-ven – *Navicula veneta*, N-aci – *Nitzschia acicularis*, N-dis – *Nitzschia dissipata* ssp. *dissipata*, N-fru – *Nitzschia frustulum* var. *inconspicua*, N-pal – *Nitzschia palea*, N-pus – *Nitzschia pusilla*, R-uni – *Reimeria uniseriata*, R-abr – *Rhoicosphenia abbreviata*, S-han – *Stephanodiscus hantzschi*, S-min – *Surirella minuta*, S-bre – *Surirella brebissonii* var. *brebissonii*

the spring season and belonged to the second group (Fig. 3).

Based on the RDA analysis, statistically significant correlations between environmental factors and the structure of diatom assemblages were determined (F = 1.9, p = 0.03). RDA analysis indicated that the first axis explained 32.4% of the variation, the second axis – 50.6%, the third axis – 68.2%, while the fourth axis – 78.2%. Among the environmental factors, only sulfate ions had a statistically significant impact on the differentiation of diatom assemblages (p = 0.042) and explained 16.4% of the variance. The concentration of nitrate ions explained 27.6% of the variance, conductivity and chlorides – 13.2%, while pH – 12.5%, however, they did not show a statistical significance ($p > 0.05$). Sulfate ions showed a very strong correlation with the chloride content (r = 0.99), which correlated with the presence of such taxa as *Nitzschia dissipata* ssp. *dissipata* ($r > 0.9$), *Cyclotella meneghiniana* ($r > 0.7$), *Navicula capitatoradiata*, *N. cryptotenella* and *N. reichardtiana* (r ~0.6) (Fig. 4).

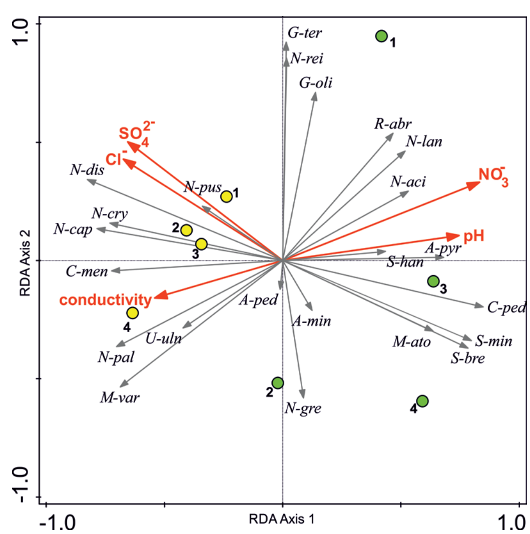

Figure 4

Diagram of the redundancy analysis (RDA) presenting the relationships between the analyzed diatom assemblages and water chemical parameters (green points – spring season, yellow points – summer season). Taxa abbreviations – see the Fig. 3.

Discussion

Benthic diatoms are the primary tool used in the assessment of water quality in most European countries, including Poland. For several years, the research on the water quality has also been conducted

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in rivers and streams of SE Poland. Diatoms are characterized by a great diversity of adaptations to ecological conditions. Many of the studied rivers and streams in the region of Podkarpacie are characterized by a large variety of diatom species (Noga et al. 2014a). Large rivers are characterized by the most abundant development of *Achnanthidium minutissimum* var. *minutissimum* and *A. pyrenaicum* in the upper reaches, while *Navicula lanceolata* and *N. gregaria* often dominate in the middle and lower reaches (Noga 2012; Pajączek et al. 2012; Noga et al. 2014a; 2015). All of these taxa also dominated in the Wisłoka River, but some occurred less frequently, for example *Achnanthidium pyrenaicum*.

Achnanthidium minutissimum var. *minutissimum* has a wide ecological amplitude and develops in oligo- to eutrophic conditions, while *A. pyrenaicum* is defined as an alkaline species (Van Dam et al. 1994; Lange-Bertalot & Steindorf 1996), although according to Hofmann (1994) is neutral in relation to pH. Both taxa have a wide range of tolerance to trophic conditions (Hofmann 1994) and are characterized by low bioindication potential (indicative value for SPI index = 1) (Coste in CEMAGREF 1982). These taxa occurred in large numbers also in the streams of the Tatra Mountains (Kawecka 2012).

Navicula lanceolata and *N. gregaria* developed in large numbers at all studied sites, from autumn 2010 to spring 2011. *Navicula lanceolata* grows best in more mesotrophic and eutrophic waters, *N. gregaria* is a halophile species. Both species are one of the most frequent diatoms in Central Europe, occurring in waters of a wide ecological range. They also grow well at low temperatures (Krammer & Lange-Bertalot 1986; Lange-Bertalot & Steindorf 1996; Hofmann et al. 2011). This was confirmed by PCA analysis that grouped both species between sampling sites from winter and autumn-spring seasons. These taxa were less frequent in the summer season. In the area of Podkarpacie, the largest populations were observed in small anthropogenically transformed streams (e.g. Matysówka and Baryczka), which flow in narrow valleys with intensive detached housing development (more than 60% of the diatom communities). Most localities in the valleys of the studied watercourses do not have a sewage system, and wastewater is discharged directly into streams (Noga et al. 2013b,d).

Amphora pediculus was the most dominant species in the studied part of the Wisłoka River throughout the studied seasons. It is one of the most widely dispersed and most abundant species in Central Europe. It occurs in oligo- and ß-mesosaprobic conditions, in a wide range of trophic conditions (Krammer & Lange-Bertalot 1986; Hofmann et al. 2011). According to Rakowska (2001), it is an alkaliphilous species, tolerant to pollution. In the region of Podkarpacie, the species frequently occurs in rivers and streams (Bernat & Noga 2012; Noga 2012; Pajączek et al. 2012; Noga et al. 2014a, 2015). According to other authors investigating the benthic diatoms, similar dominant species occur in heavily and slightly polluted rivers, including the most numerous *Planothidium lanceolatum*, *Cocconeis placentula*, *Navicula lanceolata*, *N. gregaria*, *N. tripunctata*, *Nitzschia palea*, *Ulnaria ulna* (Wasylik 1985; Kawecka 1986; Ligowski 1988; Rakowska 2001).

Chemical analysis of the water showed good or high water status for all sites in spring and autumn, at the time when the water chemistry was analyzed. Chemical parameters measured in the Wisłoka showed better water quality compared to the small streams in the area of Podkarpacie (Noga et al. 2013b,d), which probably results from better capacity for self-purification of the water in large rivers. Similar water chemistry, as in the Wisłoka, was determined along the entire length of the Biała River, whose sources are also in the Low Beskids (Noga et al. 2015), and in the upper section of the San, in the San Valley Landscape Park (Noga et al. 2014b). In contrast to the Wisłoka River, the water chemical status of the Wisłok River was below good, which was indicated by the following parameters: NH_4-N and NO_3-N, BOD_5 and COD (Noga et al. 2013c). The Wisłok River basin is a receiver of different types of pollution (municipal wastewater, surface runoff from fields, illegal landfills, etc.), and is distinguished from the others by a higher content of organic pollutants and biogenic compounds (WIOŚ 2009).

Furthermore, sampling sites selected for this study did not differ significantly in terms of diatom assemblages. Differences in the structure of dominance could only be observed between the seasons, while the sites throughout the seasons were very similar. This was confirmed by PCA analysis, i.e. the studied sites were clustered according to seasons, except for spring and autumn which formed one separate group. Also Rott et al. (1998) presented clustering of sampling sites in relation to sampling time and suggested that this could be accounted for by a seasonal gradient related to temperature.

Statistical analysis using the RDA method showed no significant differences between the environmental factors and the structure of diatom assemblages. The instability of weather conditions,

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resulting in often violent freshet waters, can contribute to the compensation for physical and chemical parameters of the Wisłoka waters. Only sulfate ions had a statistically significant effect on the differentiation of diatoms ($p = 0.042$), but explained only 16.4% of the variance. The SO_4^{2-} ions were correlated with the occurrence of *Nitzschia dissipata* ssp. *dissipata* ($r > 0.9$), *Cyclotella meneghiniana* ($r > 0.7$), *Navicula capitatoradiata*, *N. cryptotenella* and *N. reichardtiana*. These are cosmopolitan species, commonly occurring in eutrophic or oligo- to eutrophic waters, with the increased content of electrolytes, and sometimes in brackish water (Krammer & Lange-Bertalot 1986, 1988, 1991b, Hofmann et al. 2011). Some of them, for example *Navicula capitatoradiata*, are tolerant to organic pollution (Krammer & Lange-Bertalot 1986).

The conducted studies using diatom indices showed that the Wisłoka in the middle course in Dębica and the surrounding area are characterized mainly by moderate or low ecological status. Organic pollution indices, SPI (Coste in CEMAGREF 1982) and GDI (Coste & Ayphassorho 1991) demonstrate the improved water quality compared to the index TDI, which determines the trophic status of the studied waters (Kelly & Whitton 1995). The TDI index frequently indicated bad ecological status corresponding to hypertrophy. The index had lower values only in the spring season, which corresponded to eutrophic or mesotrophic conditions (the site located outside the town, in Brzeźnica). PT values at most sampling sites were low or moderate and did not exceed 30% and most often indicated minor organic pollutions. Over 20% contribution of pollutant tolerant taxa suggested the possibility of organic pollution and the risk of eutrophication (Kelly & Whitton 1995; Kelly et al. 2001).

In 2001-2003, the ecological status of selected rivers in Southern Poland, including the Wisłoka River at one site in the town of Dębica, was determined using the diatom indices (Dumnicka et al. 2006). The GDI index value slightly varied during nearly ten years and was characterized by moderate ecological status (both during the research in 2001-2003 and in 2010-2011), while the SPI and TDI indices had lower values in the classification compared to 2001-2003.

The analysis with diatom indices SPI, GDI and TDI was also performed on other rivers and streams in Podkarpacie: Biała, Baryczka, Matysówka, San, Wisłok and the Żołynianka (Noga et al. 2013b,c,d; 2014b; 2015; Peszek et al. 2015). The waters of these watercourses showed mostly moderate or poor ecological status (class III or IV), which is similar to the quality of waters in the Wisłoka. Only the Biała and the San in the upper section were characterized by good or moderate ecological status (class III or II). Also other watercourses in the area of Poland, where water quality was analyzed using these indices, had a similar ecological status (Dumnicka et al. 2006; Szczepocka & Szulc 2009; Rakowska & Szczepocka 2011). As evidenced by the analysis of diatom indices performed in Poland, the best indicators to determine the water quality are SPI and GDI indices and therefore, they are recommended for our country (Kawecka et al. 1999; Kelly et al. 2001; Żelazowski et al. 2004; Kelly et al. 2008; Szczepocka & Szulc 2009; Noga et al. 2013b,c,d; 2014b; 2015; Peszek et al. 2015). Also Blanco et al. (2007) claimed that SPI is the best index in the assessing the water quality in Central Europe.

Physicochemical analysis of the water in the Wisłoka River at the sampling sites located in the town of Dębica and the surrounding area showed good or very good water status. Whereas, the ecological preferences of most dominant diatom taxa are large amounts of nutrients and eutrophic water. This is also confirmed by diatom indices, which mostly showed moderate and poor ecological status corresponding to water-quality class III or IV. Statistical analysis showed no significant correlations between the environmental factors and the structure of diatom assemblages.

The study showed that in assessing the quality of waters in large rivers flowing through urban areas (e.g. the Wisłoka) characterized by high instability of hydrological conditions, there are significant differences between seasons during which the material was collected, rather than between sampling sites. In addition, the use of diatom indices, particularly SPI and GDI, gives more relevant information on the water quality in the studied watercourse. The assessment based solely on physicochemical parameters does not seem to provide a reliable assessment of the facts.

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