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Research Article

**BENTHIC DIATOMS IN POLLUTED RIVER SECTIONS OF  
CENTRAL POLAND\***

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**Key words:** diatoms, river, benthic, Lange-Bertalot biological analysis, Pantle & Buck index, water quality

**Abstract**

Water quality was investigated in the most polluted sections of three rivers in Central Poland: the Rawka, Jeziorka and Bzura. The estimate was carried out using the Lange-Bertalot indicative method, which is based on various diatom tolerances to pollution, and by calculating the saprobity index of Pantle & Buck.

In the investigated rivers, *Cocconeis pediculus*, *C. placentula*, *Fragilaria construens*, *F. pinnata*, *Gomphonema olivaceum*, *Melosira varians*, *Meridion circulare*, *Navicula lanceolata* were the most frequent dominants of species sensitive to pollution.

The most frequent tolerant species were *Achnanthese lanceolata* ssp. *frequentissima*, *Cymbella silesiaca*, *Fragilaria capucina* var. *vaucheriae*, *F. ulna*, *Navicula capitata* var. *capitata*, *N. gregaria*, *N. pupula*, and *Nitzschia amphibia*.

The dominants of the resistant group were *Gomphonema parvulum*, *Navicula saprophila*, *N. veneta*, and *Nitzschia palea*.

On the basis of the methods mentioned above, the water of the Rawka River was assigned to water quality class II/II-III, that of the Jeziorka to class II-III/III and that of the Bzura (at both study sites) to class II-III.

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## INTRODUCTION

The aim of the present study was to present the diatom communities occurring in the most polluted sections of three lowland rivers located in Central Poland that differ in length and type and degree of pollution.

The Rawka, a right tributary of the Bzura, is 90 km in length and is among Poland's slightly polluted rivers (Rakowska 2000). The largest pollution load is input at the 56 km. It originates from communal sewage and the meat processing facility in the town of Rawa Mazowiecka and becomes manifest at the site of Nowy Dwór.

The Jeziorka, a left tributary of the Vistula, is 66.3 km in length and receives the greatest load of pollution at the 58.5 km from communal sewage produced by the paper processing facility in the town of Konstancin (Ochman 2003).

**Table 1**

### Water quality classes determined by the Lange-Bertalot method

Water quality class	Participation of species from differentiating groups
I and I-II (no or slight pollution)	occasional, frequently allochthonous
II (beta-mesosaprobic)	sensitive species dominate, i.e. >50%
II-III (beta-alpha-mesosaprobic)	sensitive species >10%, but below the threshold of domination; resistant species <50%
III (alpha-mesosaprobic)	sensitive species <10%; tolerant species dominate, i.e. >50%
III-IV (alpha-meso-polysaprobic)	resistant species >50%; tolerant species below the threshold of domination, but still over 10%
IV (polysaprobic)	resistant species >90%

The Bzura, a right tributary of the Vistula, is 166 km in length and is among the most polluted rivers in Poland. It receives the greatest discharge of pollution at the 47 km mostly from communal sewage and dye factory pollution from the town of Ozorków. This causes water degradation down to its mouth at the town of Wyszogród (Chud-Wiśniewska 2000, Sadkowska 1999, Szczepocka 2003).

The biological estimate of water quality was carried out using the Lange-Bertalot (1978, 1979a, 1979b, 1994) indicatory method, which is based on the various tolerance of diatoms to saprobic water pollution.

On the basis of percentages of sensitive, tolerant and resistant species in samples, water quality in the investigated sites was estimated. The estimate of water quality on the basis of the Pantle & Buck (Lange-Bertalot 1994) saprobity index was also carried out.

In addition to characterizing the sites' main chemical parameters, oxygen, BOD, nitrite nitrogen and phosphates (minimal and maximal values) are also presented.

## MATERIAL AND METHODS

The investigations were based on benthos samples collected in three rivers, the Rawka, Jeziorka, and Bzura, which flow across Central Poland in the Vistula River system, in 1995-2000. Results concerning only the most polluted sites are presented. On the basis of permanent slides in Pleurax that contained cauterized diatom frustules, the following characterization was carried out:

- qualitative diatom composition was determined;
- percentages of given taxa in all counted diatoms on the basis of 400 individuals (Cholnoky 1968) were established;
- dominants (taxa higher than 5%) and subdominants (between 2% and 5%) were identified (Descy 1980);
- the quality of water was assessed with the Lange-Bertalot (1994) method (Table 1);
- the Pantle & Buck saprobity index (modified by Lange-Bertalot 1994) was calculated (Table 2).

Diatoms were identified after Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b).

**Table 2**

Water quality classes distinguished on the basis of the Pantle & Buck saprobity index

Saprobity index - S	Pollution	Water quality class
1.0-<1.5	Unburdened to slightly burdened with pollutants	I
1.5-<1.8	Slightly burdened	I-II
1.8-<2.3	Moderately burdened	II
2.3-<2.7	Critically burdened	II-III
2.7-<3.2	Strongly burdened	III
3.2-<3.5	Very strongly burdened	III-IV
3.5-<4.0	Excessively burdened	IV

Table 3

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**Characteristics of the sampled site in the Rawka River and its benthic diatoms**


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Right tributary of the Bzura (86 km in length)

**Site: Nowy Dwór**

Dissolved oxygen	6.30 - 9.30 mg O <sub>2</sub> /l
BOD <sub>5</sub>	2.00 - 6.00 mg O <sub>2</sub> /l
Nitrite nitrogen	0.08 mg O <sub>2</sub> /l
Phosphates	0.13 - 0.40 mgO <sub>2</sub> /l

Number of identified taxa	162
- sensitive species (s)	50
- tolerant species (t)	23
- resistant species (r)	6

**Dominant species > 5%**

*Achnanthes lanceolata* ssp. *frequentissima* (t)  
*Achnanthes minutissima* (s)  
*Amphora pediculus* (s)  
*Cocconeis pediculus* (s)  
*Cocconeis placentula* (s)  
*Cymbella silesiaca* (t)  
*Diatoma vulgare* (s)  
*Fragilaria capucina* var. *vaucheriae* (t)  
*Fragilaria construens* (s)  
*Fragilaria pinnata* (s)  
*Fragilaria ulna* (t)  
*Frustulia vulgare* (s)  
*Gomphonema olivaceum* (s)  
*Gomphonema parvulum* (r)  
*Melosira varians* (s)  
*Navicula capitata* var. *capitata* (t)  
*Navicula capitoradiata* (s)  
*Navicula gregaria* (t)  
*Navicula lanceolata* (s)  
*Navicula pupula* (t)  
*Navicula reinhardtii* (s)  
*Navicula rhynchocephala* (s)  
*Navicula slesvicensis* (s)  
*Navicula tripunctata* (s)  
*Navicula trivialis* (t)  
*Navicula veneta* (r)  
*Nitzschia amphibia* (t)  
*Nitzschia linearis* (s)  
*Nitzschia palea* (r)  
*Nitzschia recta* (s)

**Subdominant species 2-5%**

*Cymbella silesiaca* (t)  
*Fragilaria capucina* var. *vaucheriae* (t)  
*Navicula pupula* (t)  
*Nitzschia acicularis* (t)

Percentage of sensitive species	44.2%
tolerant species	47.6%
resistant species	9.3%
Water quality class after Lange-Bertalot	II / II-III
Saprobity index after Pantle & Buck	2.37 - 2.50
Water quality class according to the index	II / II-III

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Table 4

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**Characteristics of the sampled site in the Jeziorka River and its benthic diatoms**


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Left tributary of the Vistula (66 km)

**Site: Konstancin**

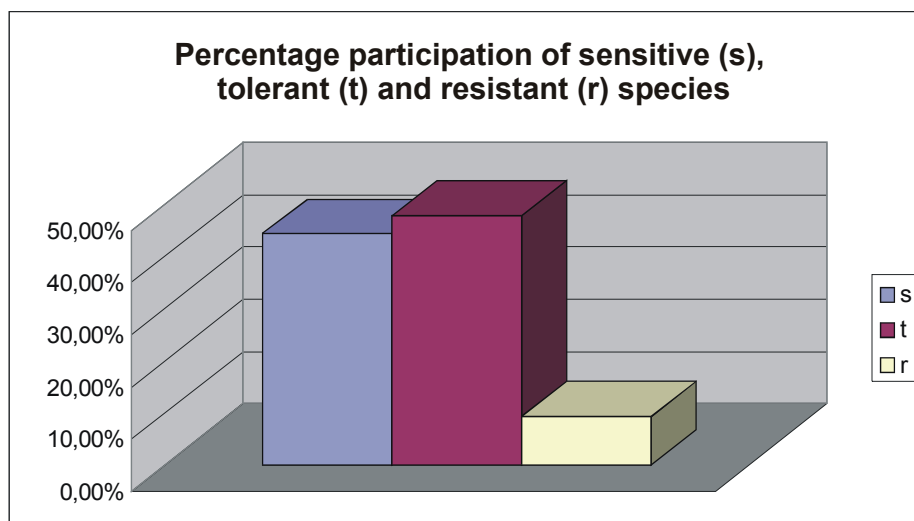
Dissolved oxygen	3.90 - 11.9 mg O <sub>2</sub> /l
BOD <sub>5</sub>	6.90 - 11.3 mg O <sub>2</sub> /l
Nitrite nitrogen	0.31 - 0.23 mg O <sub>2</sub> /l
Phosphates	0.12 - 5.69 mg O <sub>2</sub> /l
Number of identified taxa	151
- sensitive species (s)	41
- tolerant species (t)	25
- resistant species (r)	9
<b>Dominant species &gt; 5%</b>	
<i>Achnanthes lanceolata</i> ssp. <i>frequentissima</i> (t)	
<i>Achnanthes lanceolata</i> (s)	
<i>Cocconeis pediculus</i> (s)	
<i>Cocconeis placentula</i> var. <i>euglypta</i>	
<i>Cyclotella meneghiniana</i>	
<i>Fragilaria ulna</i> (t)	
<i>Gomphonema parvulum</i> (r)	
<i>Melosira varians</i> (s)	
<i>Navicula subminuscula</i> (r)	
<i>Nitzschia amphibia</i> (t)	
<i>Nitzschia palea</i> (r)	
<i>Stephanodiscus hantzschii</i>	
<b>Subdominant species 2-5%</b>	
<i>Achnanthes hungarica</i> (t)	
<i>Achnanthes lanceolata</i> ssp. <i>frequentissima</i> (t)	
<i>Achnanthes lanceolata</i> ssp. <i>lanceolata</i>	
<i>Amphora veneta</i> (r)	
<i>Cocconeis pediculus</i> (s)	
<i>Fragilaria capucina</i> var. <i>vaucheriae</i> (t)	
<i>Fragilaria pinnata</i> (s)	
<i>Fragilaria ulna</i> (t)	
<i>Gomphonema parvulum</i> (r)	
<i>Melosira varians</i> (s)	
<i>Meridion circulare</i> (s)	
<i>Navicula capitata</i> var. <i>capitata</i> (t)	
<i>Navicula gregaria</i> (t)	
<i>Navicula lanceolata</i> (s)	
<i>Navicula pupula</i> (t)	
<i>Navicula saprophila</i> (r)	
<i>Navicula slesvicensis</i> (s)	
<i>Navicula veneta</i> (r)	
<i>Nitzschia amphibia</i> (t)	
<i>Nitzschia palea</i> (r)	
<i>Stephanodiscus hantzschii</i>	
Percentage of sensitive species	39.6%
tolerant species	38.9%
resistant species	2.3%
Water quality class after Lange-Bertalot	II-III / III
Saprobity index after Pantle & Buck	2.36 - 3.00
Water quality class according to the index	II-III / III

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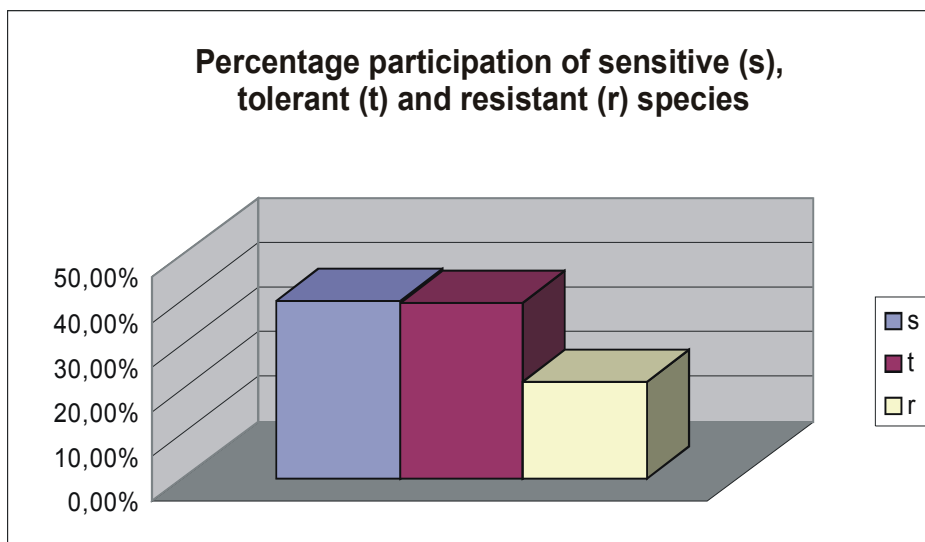
Table 5

## Characteristics of the sampled sites in the River Bzura and its benthic diatoms

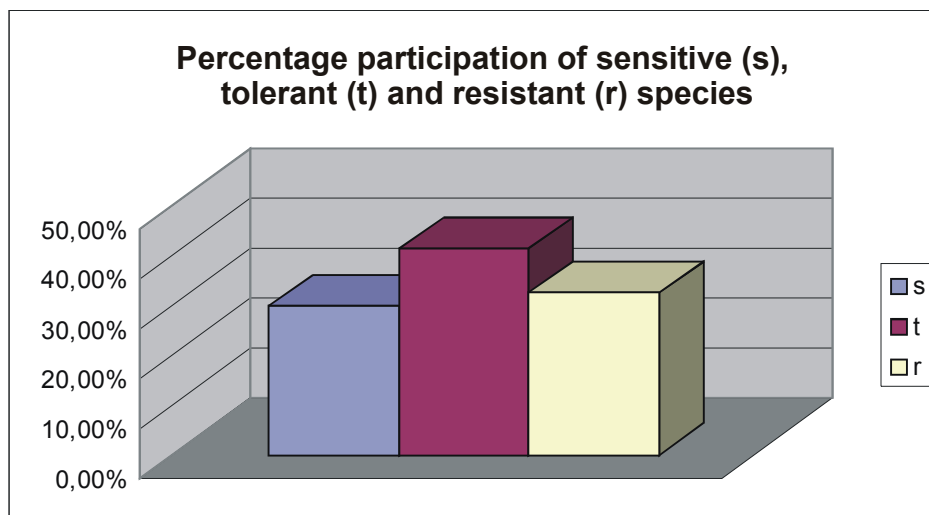
Left tributary of the Vistula (166 km)		
Sites:	Ozorków	Wyszogród
Dissolved oxygen	2.70 – 9.80 mg O <sub>2</sub> /l	6.60 - 12.5 mg O <sub>2</sub> /l
BOD <sub>5</sub>	6.10 - 26.9 mg O <sub>2</sub> /l	3.80 - 7.70 mg O <sub>2</sub> /l
Nitrite nitrogen	-----	0.03 - 0.18 mg O <sub>2</sub> /l
Phosphates	0.31 – 2.99 mgO <sub>2</sub> /l	3.70 - 10.0 mg O <sub>2</sub> /l
Number of identified taxa	80	174
- sensitive species (s)	44	59
- tolerant species (t)	24	29
- resistant species (r)	8	10
	<b>Dominant species &gt; 5%</b>	
	<i>Achnanthes lanceolata</i> ssp. <i>frequentissima</i> (t)	<i>Achnanthes lanceolata</i> ssp. <i>frequentissima</i> (t)
	<i>Achnanthes minutissima</i> (s)	<i>Aulacoseira granulata</i>
	<i>Aulacoseira granulata</i>	<i>Fragilaria ulna</i> (t)
	<i>Fragilaria capucina</i> var. <i>vaucheriae</i> (t)	<i>Gomphonema parvulum</i> (r)
	<i>Fragilaria pinnata</i> (s)	<i>Navicula capitata</i> var. <i>capitata</i> (t)
	<i>Fragilaria ulna</i> (t)	<i>Navicula gregaria</i> (t)
	<i>Gomphonema parvulum</i> (r)	<i>Navicula pupula</i> (r)
	<i>Meridion circulare</i> (s)	<i>Nitzschia palea</i> (r)
	<i>Navicula lanceolata</i> (s)	<i>Stephanodiscus hantzschii</i>
	<i>Navicula minima</i> (t)	
	<i>Navicula saprophila</i> (r)	
	<i>Navicula subminuscula</i> (r)	
	<i>Stephanodiscus hantzschii</i>	
	<i>Surirella brebissonii</i> var. <i>kuetzingii</i> (t)	
	<b>Subdominant species 2-5%</b>	
	<i>Cocconeis placentula</i> (s)	<i>Achnanthes lanceolata</i> ssp. <i>frequentissima</i> (t)
	<i>Cyclostephanos dubius</i>	<i>Achnanthes lanceolata</i> ssp. <i>rostrata</i> (s)
	<i>Cyclotella meneghiniana</i>	<i>Achnanthes minutissima</i> (s)
	<i>Cymbella silesiaca</i> (t)	<i>Amphora pediculus</i> (s)
	<i>Diatoma tenuis</i> (s)	<i>Aulacoseira granulata</i>
	<i>Fragilaria brevistriata</i> (s)	<i>Cocconeis placentula</i> (s)
	<i>Fragilaria capucina</i> var. <i>capucina</i> (s)	<i>Cyclotella meneghiniana</i>
	<i>Fragilaria capucina</i> var. <i>vaucheriae</i> (t)	<i>Fragilaria brevistriata</i> (s)
	<i>Fragilaria construens</i> (s)	<i>Fragilaria ulna</i> (t)
	<i>Fragilaria ulna</i> (t)	<i>Gomphonema parvulum</i> (r)
	<i>Gomphonema olivaceum</i> (s)	<i>Meridion circulare</i> (s)
	<i>Gomphonema parvulum</i> (r)	<i>Navicula capitata</i> var. <i>capitata</i> (t)
	<i>Melosira varians</i> (s)	<i>Navicula decussis</i> (s)
	<i>Navicula cryptocephala</i> (t)	<i>Navicula gregaria</i> (t)
	<i>Navicula cryptotenella</i> (s)	<i>Navicula lanceolata</i> (s)
	<i>Navicula lanceolata</i> (s)	<i>Navicula minima</i> (t)
	<i>Navicula menisculus</i> (t)	<i>Navicula subminuscula</i> (r)
	<i>Nitzschia palea</i> (r)	<i>Navicula pupula</i> (t)
	<i>Stephanodiscus hantzschii</i>	<i>Navicula slesvicensis</i> (s)
		<i>Navicula trivialis</i> (t)
		<i>Nitzschia linearis</i> (s)
		<i>Nitzschia palea</i> (r)
		<i>Stephanodiscus hantzschii</i>
		<i>Surirella brebissonii</i> var. <i>kuetzingii</i> (t)
Percentage of sensitive species	29.56%	40.67%
tolerant species	41.07%	39.25%
resistant species	32.28%	17.88%
Water quality class after Lange-Bertalot	II-III	II-III
Saprobity index after Pantle & Buck	2.50 - 3.10	2.45 – 2.67
Water quality class according to the index	II-III	II-III



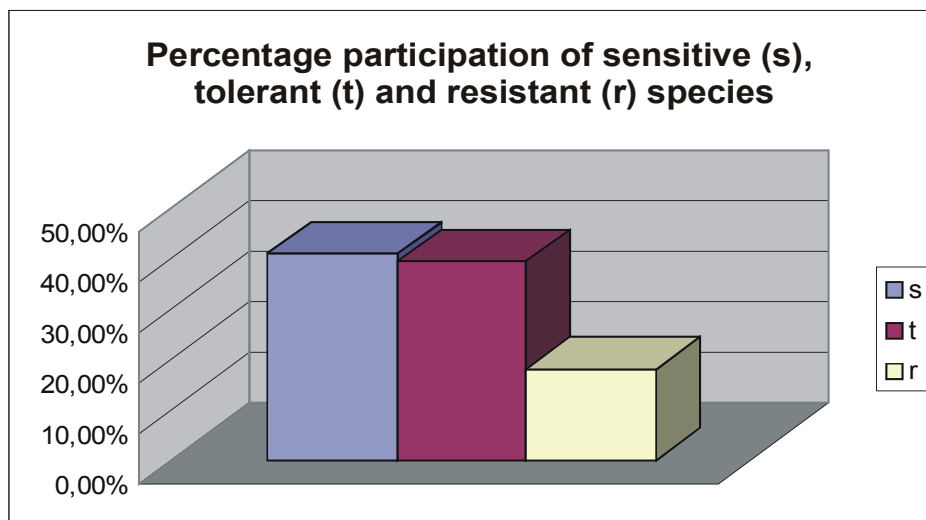
**Fig. 1.** Percentages of benthic diatoms in the site in the Rawka River (site at Nowy Dwór)



**Fig. 2.** Percentages of benthic diatoms in the site in the Jeziorka River (site at Konstancin)



**Fig. 3.** Percentages of benthic diatoms in a site in the Bzura River (site at Ozorków)



**Fig. 4.** Percentages of benthic diatoms in a site in the Bzura River (site at Wyszogród)

## RESULTS

A characterization of the studied rivers, with the specification of their main chemical parameters, and numbers of taxa, including the impact of sensitive, tolerant and resistant species on water quality estimated by the Lange-Bertalot and Pantle & Buck methods, are presented in Tables 3, 4 and 5 and in Figures 1, 2, 3 and 4.

It can be concluded from the analysis of the relations among sensitive, tolerant and resistant species occurring along the course of the studied rivers that the effect of pollution is manifest in all the rivers.

In the Rawka, the effect of pollution was expressed in the decrease in the number of sensitive species from about 60% in the source section to 44.2% at the polluted site, while the number of tolerant ones increased from 30.0% to 38.9% and resistant ones from 2.8% to 9.3% at the two sites, respectively (Table 3).

In the Jeziorka, the number of sensitive species was 39.6%, tolerant ones - 39.0%, and resistant ones - 21.2% (Table 4).

In the Bzura, the number of sensitive species decreased from 69.64% in the source section to 29.56% at the polluted site, while tolerant species increased from 20.18% to 41.07%, and resistant ones - from 7.22% to 32.28%, respectively (Table 5).

The most abundant sensitive species were the dominants *Cocconeis pediculus* Ehrenberg, *C. placentula* Ehrenberg, *Fragilaria construens* (Ehrenberg) Grunow, *F. pinnata* Ehrenberg, *Gomphonema olivaceum* (Hornemann) Brébisson, *Melosira varians* Agardh, *Meridion circulare* (Greville) Agardh, *Navicula lanceolata* Agardh (Ehrenberg).

The most frequently occurring tolerant species were *Achnanthes lanceolata* ssp. *frequentissima* Lange-Bertalot, *Cymbella silesiaca* Bleisch, *Fragilaria capucina* var. *vaucheriae* (Kützing) Lange-Bertalot, *F. ulna* (Nitzsch) Lange-Bertalot, *Navicula capitata* Ehrenberg var. *capitata*, *N. gregaria* Donkin, *N. pupula* Kützing, *Nitzschia amphibia* Grunow.

Dominants of the resistant group were *Gomphonema parvulum* (Kützing) Kützing, *Navicula saprophila* Lange-Bertalot, *N. veneta* Kützing, *Nitzschia palea* (Kützing) W. Smith.

As the water quality improved, a change in diatom communities occurred: resistant species were substituted by tolerant ones, but mostly by sensitive species.

Classes of water purity distinguished by the Lange-Bertalot method on the basis of various diatom tolerances to pollution correlated with chemical water parameters and with the categories of the Pantle & Buck saprobity index.

On the basis of the methods mentioned above, the water of the Rawka River was assigned to water quality class II/II-III, that of the Jeziorka to class II-III/III, and that of the Bzura (at both study sites) to class II-III (Tables 3, 4, 5).

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## REFERENCES

- Cholnoky B. J., 1968, *Die Ökologie der Diatomeen in Binnengewässer* [Ecology of Diatoms in Inland Waters], J. Cramer Verl., 699 pp. [in German].
- Chud-Wiśniewska W., 2000, *Ocena jakości wody rzek Bzury na podstawie okrzemek bentosowych na stanowisku w Wyszogrodzie* [Estimate of the Bzura River water on the basis of benthic diatoms at a site in the town of Wyszogród]. MSc thesis, University of Łódź, Łódź, 75 pp. [in Polish].
- Descy J. P., 1980, *Utilisation des algues benthiques comme indicateurs biologiques de la qualité des eaux courantes* [Utilization of benthic algae as biological indicators of the quality of running waters], [in:] *La pollution des eaux continentales* [The pollution of continental waters], Pesson P. (ed.), Gauthier-Villars, Paris, 169-194. [in French].
- Krammer K., Lange-Bertalot H., 1986. *Bacillariophyceae 1. Naviculaceae*, [in:] *Süßwasserflora von Mitteleuropa*, Ettl H., Gerloff, J., Heyning H., Mollenhauer D. (eds.), 2/1, G. Fischer Verlag, Jena, 876 pp. [in German].
- Krammer K., Lange-Bertalot H., 1988. *Bacillariophyceae 2. Bacillariaceae, Epithemiaceae, Surirellaceae*, [in:] *Süßwasserflora von Mitteleuropa*, Ettl H., Gerloff, J., Heyning H., Mollenhauer D. (eds.), 2/3, G. Fischer Verlag, Jena, 600 pp. [in German].
- Krammer K., Lange-Bertalot H., 1991a. *Bacillariophyceae 3. Centrales, Fragilariaceae, Eunotiaceae*, [in:] *Süßwasserflora von Mitteleuropa*, Ettl H., Gerloff, J., Heyning H., Mollenhauer D. (eds.), 2/3, G. Fischer Verlag, Jena, 600 pp. [in German].
- Krammer K., Lange-Bertalot H., 1991b. *Bacillariophyceae 4. Achnantheaceae. Kritische Ergänzungen zu Navicula (Lineolatae) und Gomphonema*, [in:] *Süßwasserflora von Mitteleuropa*, Ettl H., Gerloff, J., Heyning H., Mollenhauer D. (eds.), 2/4, G. Fischer Verlag, Jena, 437 pp. [in German].
- Lange-Bertalot H., 1978, *Diatomeen – Differentialarten anstelle von Leitformen: ein geeigneteres Kriterium der Gewässerbelastung*, Arch. Hydrobiol., Suppl., 51, Algol. Stud. 21, 393-427. [in German].
- Lange-Bertalot H., 1979a, *Pollution tolerance of diatoms as a criterion for water quality estimation*, Nova Hedwigia 64, 285-304.

- Lange-Bertalot H., 1979b. *Toleranzgrenzen und Populationsdynamik benthischer Diatomeen bei unterschiedlich starker Abwassebelastung* [Tolerance limits and population dynamics of benthic diatoms at various strengths of sewage pollution], Arch. Hydrobiol., Suppl., 56, Algol. Stud. 23, 184-219.
- Lange-Bertalot H., 1994, *Benthische Diatomeen – Gesellschaften in Zuge veränderter Wasserqualitäten im Rhein zwischen Ludwigshafen und Lorch von 1974 bis 1993* [Benthic diatoms – accompanying various quality waters in the Rhein River between Ludwigshafen and Lorch from 1974 to 1993], MSc thesis in biology [Diplomarbeit im Fachbereich Biologie der J. W. Goethe - Universität Frankfurt am Main], Frankfurt am Main, 157 pp.
- Ochman P., 2003, *Ocena biologiczna i fizykochemiczna wody rzeki Jeziorki* [Biological and physico-chemical estimate of water quality in the Jeziorka River], MSc thesis, University of Łódź, Łódź, 110 pp.
- Rakowska B., 2000, *Qualitative assessment of water in the Rawka River (Central Poland) using communities of benthic diatoms*, Arch. Hydrobiol., Algol. Stud. Stuttgart, 99, 105-118.
- Sadkowska A., 1999, *Ocena jakości wody rzeki Bzury na podstawie okrzemek bentosowych na stanowiskach w Arturówku, Ozorkowie i Łęczycy* [Water quality assessment in the Bzura River on the basis of benthic diatoms at sites in the village of Arturówek and the towns of Ozorków and Łęczycza], MSc thesis, 80 pp.
- Szczepocka E., 2003, *Ocena jakości wody rzeki Bzury na podstawie okrzemek bentosowych* [Estimate of water quality in the Bzura River on the basis of benthic diatoms], [in:] Proceedings of the XXII International Symposium of the Phycological Section of the Polish Botanical Society, Wojewódzki Fundusz Ochrony Środowiska, Olsztyn, 75-76 pp.