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Ecological status of the River Nysa Łużycka (Lausitzer Neisse) assessed by epilithic diatoms

Joanna Picińska-Fałtynowicz

Institute of Meteorology and Water Management, Wrocław Branch, Department of Ecology, Parkowa 30, 51-616 Wrocław, Poland; joannapf@wp.pl

INTRODUCTION

The River Nysa Łużycka (Lausitzer Neisse) is a left-side tributary of the River Odra with springs located in Iser Mountains (Czech Republic). Its sub-basin has been selected as one of 15 Pilot River Basins to test CIS Guidance Documents of the EU Water Framework Directive/60/2000 EC (the WFD). The total length of the river is 246.1 km; the first section of 49.6 km belongs to the Czech Republic, while the remaining stretch of 196.5 km constitutes the Polish–German boundary. The whole sub-basin covers 4426.6 km^2 (58 % Poland, 33 % Germany and 9 % Czech Republic). In the upper part, the sub-basin is composed of magma-metamorphic (Iser Mts.) and crystalline (Lausitzer Mts.) geological formations, in the middle part of Tertiary deposits with brown coal, and in the lower part of Quaternary deposits. The river is strongly impacted by various anthropogenic pressures. The main point sources of pollution are six municipal wastewater treatment plants (Liberec, Sieniawka–Zittau, Bogatynia, Zgorzelec–Goerlitz, Łęknica–Bad Muskau and Gubin–Guben) and one industrial wastewater treatment plant (Bogatynia). The main diffuse sources of pollution, particularly of nutrients are agricultural activities and atmospheric precipitation. The river is also affected by water abstraction for industrial purposes and for flooding brown coal mine workings. The river's morphology is significantly transformed due to bank regulation, numerous hydroelectric power plants and barriers (dams and weirs) (Błachuta et al. 2004).

The aim of the study was to assess an ecological status of the river during the four years period by diatom phytobenthos using the Polish diatom multimetric index IO (Indeks Okrzemkowy).

MATERIAL & METHODS

According to the Polish typology of running waters (Błachuta et al. 2005), the section under study is of lowland sandy-clayey river character with a catchment area between 1000 and 5000 km^2 (the Polish type 19). The river is ca. 30–40 m wide and maximally 2–3 metres deep here. Large stone material is present in steps and bank regulation, while bed with pebbles and gravel can be found along the whole investigated stretch. The river is of mixed siliceous-calcareous character, but the bed consists mainly of acid rock material. In the years 2004–2006, the waters were neutral or slightly alkaline, with medium conductivity, usually low content of total suspended solids and low alkalinity. Concentrations of nitrates and phosphates were high, but decreased along the river course and from year to year. BOD_5 was usually moderate except at the three-border point. Chlorophyll a values were low and proved that Nysa Łużycka could not be regarded as a phytoplankton-rich river (Table 1).

Therefore, diatom phytobenthos has been chosen as one of biological quality elements to assess the ecological status of the river. Samples were collected in May 2003 and 2004, in August 2005 and in September 2006 at six sites selected in accordance with the river course: Koźlice (above Zgorzelec-Goerlitz), Bielawa, Sanice, Siedlec and Olszyna (all below Zgorzelec-Goerlitz) (Fig. 1). At each locality, a place of typical water flow was chosen. Epilithon was scraped using a scalpel and fixed in the field with 4 % formalin. One sample from a particular site consisted of several sub-samples taken from different stones and pebbles. Material was cleaned by applying hot sulphur acid method, and empty diatom frustules were mounted in Naphrax (PN-EN 13946: 2006). Taxa were identified according to recent literature (Krammer & Lange-Bertalot 1986, 1991a, 1991b, 1997, Lange-Bertalot 2001). 300–500 valves per sample were counted on permanent slides. Taxa abundancies greater than

10 % were considered dominants, those sharing 5–10 % as co-dominants and those with 1–5 % abundance as accompanying. Basing on relative abundance of indicator species, the Polish diatom multimetric index IO (Picińska-Fałtynowicz et al. 2006) was calculated. The index is an average of three modules: the Trophic Index TI (Rott et al. 1999), the Saprobic Index SI (Rott et al. 1997) and the Abundance of Reference Species GR, and was patterned after the German multimetric DI_{FG} (Schaumburg et al. 2005). The TI and SI were transformed in order to equalise scales of all modules. In Poland, organic pollution of running waters is still considerable; therefore in the IO index the saprobic module is as important as the trophic one. The IO values vary from 1 (the best status) to 0 (the worst status). Preliminary class boundaries of ecological status for the Polish group of rivers including the above mentioned Type 19 have been proposed as follows: for ecological status high: IO > 0.65, good: 0.45, moderate: 0.25, poor: 0.10 and bad: < 0.10.

Table 1. Selected physical and chemical variables (annual mean values) of the River Nysa Łużycka waters (data according to the WIOŚ Wrocław and WIOŚ Zielona Góra, 2004-2006). Cond. – Conductivity, TSS – Total Suspended Solids, BOD_5 – Biological Oxygen Demand, $N\text{-}NO_3$ – Nitrates, $P\text{-}PO_4$ – Orthophosphates, Alkal. – Alkalinity. Sites: Above Zgorzelec – near Koźlice, Sobolice – above Sanice, Żarki Wielkie – above Siedlec.

Site	Three-border point			Above Zgorzelec			Sobolice			Above Żarki Wielkie.		
Variable Year	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006
Cond. [μScm^{-1}]	391	325	360	427	347	448	422	402	378	384	385	367
TSS [mgL^{-1}]	22.2	24.1	14.6	36.7	157.0	20.8	20.6	6.4	10.4	14.8	6.9	22.2
pH	7.0	7.0	7.0	8.0	7.0	7.0	7.3	7.1	7.2	7.4	6.9	7.2
BOD_5 [mgO_2L^{-1}]	5.6	6.5	6.8	4.1	3.7	7.0	4.3	3.3	4.5	3.7	3.3	4.4
$N\text{-}NO_3$ [mgL^{-1}]	19.6	14.2	14.0	15.7	14.5	14.4	16.5	14.3	12.5	12.6	11.3	10.3
$P\text{-}PO_4$ [mgL^{-1}]	0.59	0.38	0.32	0.29	0.21	0.10	0.30	0.20	0.26	0.17	0.13	0.13
Alkal. [$mgCaCO_3L^{-1}$]	44	44	46	62	54	62	85	-	57	76	-	53
Chlorophyll a [μgL^{-1}]	3.8	5.0	1.7	7.2	4.1	2.1	18.4	15.3	8.2	23.5	15.5	15.9

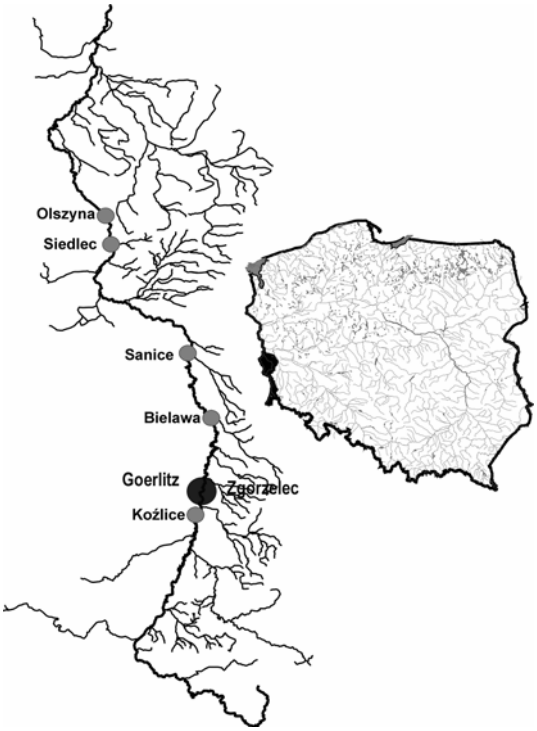

Fig. 1. Location of the sampling sites along the River Nysa Łużycka.

RESULTS

Altogether 117 diatom species, mainly benthic forms were determined during the counting procedure. The most diverse community was found in Sanice in August 2005 (58 taxa), the poorest in Bielawa in May 2003 (11 taxa) (Table 2). The most frequent were 14 taxa occurring in at least 65 % of all communities investigated. Simultaneously, they were usually dominants or co-dominants, e.g. *Navicula gregaria* Donkin, *N. lanceolata* Ehrenb., *Melosira varians* C.Agardh, *Nitzschia fonticola* (Grunow) Grunow, *N. amphibia* Grunow,

N. inconspicua Grunow, *Eolimna subminuscula* (Manguin) Gerd Moser, Lange-Bert. & Metzeltin, *Achnanthidium minutissimum* (Kütz.) Czarn., *Encyonema minutum* (Hilse) D.G.Mann and *Diatoma vulgaris* Bory, except *Gomphonema pumilum* (Grunow) E.Reichardt & Lange-Bert. which was always an accompanying species only. The next 12 taxa were less frequent but reached at least the relative abundance of 5 % (Table 2). Additional 26 accompanying taxa, abundant in 1–5 % were found sporadically. The TI varied from 2.07 to 3.51 in the study period round. The lowest value corresponded to a medium trophic level (meso-eutrophy), while the remaining, usually greater than 3.00, with high or very high trophic levels, up to polytrophy. The SI values changed from 1.93 to 2.59. Those between 1.93 and 2.12 indicated β-mesosaprobic level, from 2.16 to 2.50 – β -meso – α-mesosaprobic state, while 2.59 corresponded to α-mesosaprobic. The module Abundance of Reference Species GR varied considerably from 0.02 to 0.84, but the majority of the results ranged from 0.11 to 0.30. The multimetric diatom index IO changed from 0.24 to 0.67 and indicated twice a poor ecological status (Bielawa and Sanice in 2003), once a high status (Olszyna 2004), twice a good status (Siedlec 2003 and Olszyna 2006) and in the remaining cases – a moderate ecological status (Table 2).

DISCUSSION

In the studied communities, among 106 species with determined trophic preferences (Rott et al. 1999), diatoms indicating waters rich in nutrients (eu- to hypertrophic) prevailed considerably (72.6 %). In turn, among 97 taxa with determined organic pollution tolerance (Rott et al. 1997), the most numerous were diatoms moderately tolerant (30.9 %) indicating β-mesosaprobic level and resistant (to organic pollution: saprophiles and saprobionts) (36.0 %) indicating β-meso- α-mesosaprobic to α-meso -polysaprobic levels. Sensitive species shared 17.5 % and weakly tolerant 15.5 %. Majority of the dominants and co-dominants, e.g. *Navicula gregaria*, *N. lanceolata*, *Eolimna subminuscula*, *Melosira varians*, *Nitzschia amphibia*, *N. inconspicua* or *Surirella minuta* Bréb. ex Kütz. are poly-hypertrophilous and saprophilous species. As a result, the IO values were low and the ecological status assessed moderate or even poor in the upper and middle section of the river (Koźlice, Bielawa and Sanice). Three times, in epilithon in Siedlec and Olszyna, the most abundant were species preferring oligo-mesotrophic waters and weakly or moderately tolerant to organic pollution: *Achnanthidium minutissimum*, *Encyonema minutum* and *Diatoma vulgaris*. As a result, the IO values were high and the ecological status assessed good or high. In general, the ecological status based on diatom phytobenthos improved along the river course and corresponded to nutrients' concentrations (compare Table 1 and 2). The obtained results have also shown, how important species structure of a community and abundance of reference species in particular is. Among 117 taxa identified, only 20 represented basic reference species for both siliceous and calcareous running waters, and just *Achnanthidium minutissimum* and *Encyonema minutum* were significantly abundant. The next 28 taxa were of type-specific reference character (Picińska-Fałtynowicz et al. 2006, after Schaumburg et al. 2005). Only *Nitzschia fonticola* was a stable dominant or co-dominant in the researched epilithon. The others, e.g. *Diatoma vulgaris*, *Reimeria sinuate* (W.Greg.) Kociolek & Stoermer, *Amphora pediculus* (Kütz.) Grunow or *Fragilaria rumpens* (Kütz.) G.W.F.Carlson were more abundant just in a few cases. When analysing the GR module values (compare Table 2), one could observe that the worst to poor communities comprised hardly any reference species and those of moderate status only small numbers (not greater than 30 %). In communities of good or high status, abundance of reference taxa exceeded 50 %. To conclude, in the period of 2003–2006, diatom phytobenthos of the River Nysa Łużycka indicated usually moderate ecological status along the upper and middle part of the section investigated (Koźlice, Bielawa and Sanice) and good or high status along the lower part (Siedlec and Olszyna). The assessment was compliant to some extent with nitrates' and orthophosphates' concentrations along that stretch of the river.

Table 2. Ecological status of studied sites according to taxa and their abundances at specific dates (see text).

SITE	KOŹLICE	BIELAWA	SANICE	SIEDLEC	OLSZYNA	KOŹLICE	BIELAWA	SANICE	OLSZYNA
TAXON / DATE	May 2003	May 2003	May 2003	May 2003	May 2003	May 2004	May 2004	May 2004	May 2004
Navicula gregaria Donkin	**31.2**	**9.9**	**12.9**	**11.7**	**22.2**	**21.1**	**25.0**	**20.1**	3.8
Navicula lanceolata Ehrenb.	**6.5**	**53.1**	**26.7**	**9.0**	**19.7**	**35.1**	**9.6**	**11.5**	1.4
Nitzschia fonticola (Grunow) Grunow	**9.8**	0.4	1.0	**13.8**	**10.1**	3.9	**6.3**	**6.2**	**5.5**
Fragilaria vaucheriae (Kütz.) J.B.Petersen	2.1	3.2	0.4	**7.7**		2.5	0.5	0.5	
Surirella brebissonii var. *kuetzingii* Krammer & Lange-Bert.	1.0	**11.3**	2.7	0.2	0.2	0.4		1.2	
Achnanthidium minutissimum (Kütz.) Czarn.	1.0		0.8	**8.6**	4.2	2.1	3.8	1.4	**62.4**
Encyonema minutum (Hilse) D.G.Mann	**5.0**	1.8	0.6	**25.9**	**5.5**	1.8	0.5	1.0	1.4
Reimeria sinuata (W.Greg.) Kociolek & Stoermer	0.3		2.5	4.0	1.7	3.0	1.4	1.7	**7.8**
Gomphonema pumilum (Grunow) E.Reichardt			0.4	0.7	1.7	0.4	0.5		1.7
Melosira varians C.Agardh	0.2			0.9	0.2	**5.3**		**12.4**	
Nitzschia amphibia Grunow					0.4	1.6	1.0	3.3	0.3
Nitzschia inconspiqua Grunow	**6.2**		**17.2**	**5.0**	**7.0**	1.1	**37.0**	2.1	**6.7**
Diatoma vulgaris Bory				0.2		1.8		0.3	
Eolimna subminuscula (Manguin) Gerd Moser, Lange-Bert. & Metzeltin	**31.2**		**26.7**	1.8	**16.9**			0.7	
Gomphonema parvulum (Kütz.) Van Heurck									
Navicula cryptotenella Lange-Bert.								1.0	
Rhoicosphenia abbreviata (C.Agardh) Lange-Bert.			0.8			1.1		1.7	0.3
Navicula rostellata Kütz.								0.3	
Nitzschia frustulum (Kütz.) Grunow						0.4			3.4
Nitzschia tubicola Grunow	0.3	**10.3**	2.3	0.7	0.4	1.8		3.8	
Planothidium frequentissimum (Lange-Bert.) Lange-Bert.									
Planothidium delicatulum (Kütz.) Round & Bukht.					0.2			**6.0**	
Amphora pediculus (Kütz.) Grunow				0.4				**5.5**	
Eolimna minima (Grunow) Lange-Bert.									
Fragilaria rumpens (Kütz.) G.W.F.Carlson						**6.3**		3.8	1.7
Luticola goeppertiana (Bleisch) D.G.Mann					0.4				
Mayamaea atomus var. *permitis* (Hust.) Lange-Bert.							**12.5**		
Nitzschia sociabilis Hust.		0.4							
Surirella minuta Bréb.		**9.2**	2.7			0.4			
NUMBER OF TAXA	16	11	19	26	31	31	14	40	16
TI	3.42	3.51	3.45	2.84	3.35	3.21	3.29	3.15	2.07
SI	2.59	2.30	2.50	2.05	2.38	2.20	2.35	2.19	1.93
GR	0.16	0.02	0.07	0.58	0.25	0.29	0.13	0.30	0.84
IO	**0.26**	**0.24**	**0.24**	**0.51**	**0.32**	**0.36**	**0.29**	**0.37**	**0.67**
ECOLOGICAL STATUS	**M**	**P**	**P**	**G**	**M**	**M**	**M**	**M**	**H**

Table 2. (continued).

SITE	KOŹLICE	BIELAWA	SANICE	KOŹLICE	BIELAWA	SANICE	SIEDLEC	OLSZYNA
TAXON / DATE	Aug. 2005	Aug. 2005	Aug. 2005	Sept. 2006	Sept. 2006	Sept. 2006	Sept. 2006	Sept. 2006
Navicula gregaria Donkin	**7.3**	0.9	**9.4**	**11.5**	**7.2**	2.1	**7.4**	1.1
Navicula lanceolata Ehrenb.	**27.4**	**22.4**	3.4	**46.3**	4.8	**5.2**	**5.9**	**5.9**
Nitzschia fonticola (Grunow) Grunow		0.5	0.2	0.6	**5.2**	**7.9**	**5.9**	**20.5**
Fragilaria vaucheriae (Kütz.) J.B.Petersen	1.9	**9.8**	2.9	2.0	2.2	1.3	**31.5**	1.4
Surirella brebissonii var. *kuetzingii* Krammer & Lange-Bert.	0.9	1.4	1.3	1.7	0.4		0.4	0.3
Achnanthidium minutissimum (Kütz.) Czarn.	0.3		2.1		0.8		4.3	2.7
Encyonema minutum (Hilse) D.G.Mann	0.3	0.3	0.4					4.3
Reimeria sinuata (W.Greg.) Kociolek & Stoermer	0.3		1.9		2.8	**7.3**	1.2	
Gomphonema pumilum (Grunow) E.Reichardt	1.4	0.2	0.4	1.4	2.2	0.6	1.2	
Melosira varians C.Agardh	**7.5**	**26.9**	2.5	**10.3**	**12.0**	**16.7**	**11.4**	**20.3**
Nitzschia amphibia Grunow	**7.5**	0.9	1.9	0.6	**11.4**	**19.6**	4.7	4.3
Nitzschia inconspiqua Grunow	4.5		1.1		2.2	2.7	0.2	
Diatoma vulgaris Bory	0.2	3.0	0.2	3.7	0.4	0.4	**5.5**	**28.9**
Eolimna subminuscula (Manguin) Gerd Moser, Lange-Bert. & Metzeltin	1.4		0.4	0.6	2.6	0.2	0.2	
Gomphonema parvulum (Kütz.) Van Heurck	**5.2**	0.5	0.6	**10.3**	**5.0**	3.5	4.1	1.1
Navicula cryptotenella Lange-Bert.	1.2	0.3	1.7		0.4	0.6	1.4	0.5
Rhoicosphenia abbreviata (C.Agardh) Lange-Bert.	0.9		0.2		0.2		0.4	
Navicula rostellata Kütz.		1.1	1.3	0.3	1.8	1.5	1.0	0.3
Nitzschia frustulum (Kütz.) Grunow	**12.1**	2.0	1.1	0.9				0.5
Nitzschia tubicola Grunow								
Planothidium frequentissimum (Lange-Bert.) Lange-Bert.	1.7	0.3	**9.0**		**16.4**	**16.5**	2.3	
Planothidium delicatulum (Kütz.) Round & Bukht.	0.2		0.8		3.6	1.0	0.2	
Amphora pediculus (Kütz.) Grunow	0.3			0.6	0.8			
Eolimna minima (Grunow) Lange-Bert.	2.6	0.6	1.5		**8.8**	1.3		
Fragilaria rumpens (Kütz.) G.W.F.Carlson	1.7	3.1	1.1					
Luticola goeppertiana (Bleisch) D.G.Mann		**15.0**					0.2	3.5
Mayamaea atomus var. *permitis* (Hust.) Lange-Bert.				0.3	1.4			
Nitzschia sociabilis Hust.			**31.5**		0.4			1.4
Surirella minuta Bréb.	0.2	0.2						
NUMBER OF TAXA	44	43	58	23	35	30	38	22
TI	3.29	3.19	3.01	3.36	3.18	3.24	2.97	3.15
SI	2.24	2.38	2.12	2.33	2.34	2.31	2.25	2.16
GR	0.16	0.12	0.20	0.11	0.15	0.20	0.24	0.58
IO	**0.31**	**0.29**	**0.36**	**0.28**	**0.30**	**0.32**	**0.36**	**0.47**
ECOLOGICAL STATUS	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**G**

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