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Original Research

The Use of Various Biotic Indices for Evaluation of Water Quality in the Lowland Rivers of Poland (Exemplified by the Liwiec River)

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Abstract

Water quality of the Liwiec River (the longest tributary of the Bug River, the South Podlasie Lowland, and the Central Mazovia Lowland) was evaluated in 1998-2000 and 2002 using selected physical and chemical parameters and macroinvertebrate analysis. Classification of water quality was done on the basis of physical and chemical parameters. Taxonomic composition of invertebrate macrofauna was used for calculation of the following biological indices: Belgian Biological Index (BBI), British BMWP/OQR Index, and modified for Polish rivers, Margaleff's index of biological diversity. The values of physical and chemical parameters showed that water of the Liwiec River belongs to the 2nd and 3rd class of quality (in the five degree scale). The values of BBI and BMWP/OQR indices revealed that the water was moderately polluted. According to the biodiversity index, the Liwiec River was classified as the 1st quality class. Correlation between chemical parameters and BBI and BMWP/OQR values shows that these indices may be used for evaluation of water quality in Polish lowland rivers (like Liwiec). However, in the case of the biodiversity index, the ranges for various water quality classes should be modified.

Keywords: macroinvertebrates, biotic indices, physical and chemical parameters, lowland river

Introduction and the Aim of Study

As a member of the EU Poland is obliged to evaluate environment status according to the criteria imposed by EU directives, including river quality [1]. In most European countries, evaluation of river water quality includes analysis of macroinvertebrate diversity.

Unification of river classification and the use of a common biotic index are impossible due to different geographic distribution of macroinvertebrate species, and biotypological differences among the rivers.

Various European countries use various indices with different levels of identification of organisms, and different assumptions of final interpretation of results. The values of biotic indices are calculated with the usage of special tables which include taxa of different sensitivity to pollution. The more sensitive to pollution taxa found in the sample are, the higher their score is, while taxa less sensitive to pollution receive a lower number of points [2-4].

In Poland, a new act of the Minister of Environmental Protection concerning classification of surface waters, adjusted to EU legislation, was established in March 2004 [5]. It includes eight groups of indices: physical, aerobic, biogenic, salinity, metals, industrial pollutants, microbiological, and biological. Among the biological indices, besides the saprobic index, phytoplankton and periphyton, also benthic macroinvertebrates, divided into two indices: diversity and biotic index, are included. On the basis of the extreme values of biodiversity and biotic index measured indices, waters may be

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classified to five quality classes. The act [5], however, does not specify the ways of calculating these indices. Researches aiming to prepare the method of the assessment of Polish river quality according to biodiversity index were held by Kownacki et al. [6]. The authors have suggested that this index should be calculated according to the formula: d=S/logN (d – biodiversity index, S – the number of families, N – the number of individuals). The formula is a modified version of Margaleff's biodiversity index: I = (S-1)/ln N (S – the number of species, N – the number of individuals) [6 after 7].

Therefore, application of EU criteria of river water quality evaluation requires the development of reference values, detailed analysis of taxonomic composition of Polish riverine macrofauna, and the development or adaptation of reliable biotic indices appropriate for evaluation of purity status of our rivers.

The present study was undertaken to:

- evaluate Liwiec River water quality using selected physical and chemical parameters, according to the criteria applied in Poland,
- evaluate biotic quality of the Liwiec River water using selected indices applied in the EU: Belgian BBI, and British BMWP/OQR,
- evaluate Liwiec River water quality using the biodiversity index.

Study Area, Materials and Methods

The study was done in the Liwiec River situated in the South Podlasie and Central Mazovia Lowlands [8], the largest left tributary of the Bug River (126,2 km long). The average flow of the Liwiec River is about 12m^3 s^{-1} [9]. The valley and the bed of the Liwiec River are almost natural, except for the upper and parts of the lower course. The river is not regulated, and it is winding across the lowland, showing numerous meanders, and in its lower course – also islets. The hydrographic network of the catchment area is rich. The Liwiec River has 10 tributaries, and the basin area is 2779 km^2. Grassland comprises about 75% of catchment area, 20% of forests and 5% of wastelands [10]. Areas directly adjacent to the river banks are used mainly as meadows and pastures [11]. The Liwiec River is contaminated mainly with the purified sewage (about 22000 m^3/day) discharged from the Siedlce sewage treatment plant.

The study was carried out in 1998-2000 and 2002 at 12 sites (Fig. 1). The sites were chosen along the river, at similar distances from one another. The flow of purified sewage from the treatment plant was also taken into consideration while establishing study sites. Biological samples and water for physical and chemical analyses were taken simultaneously, three times per year (spring, summer, fall). A total of

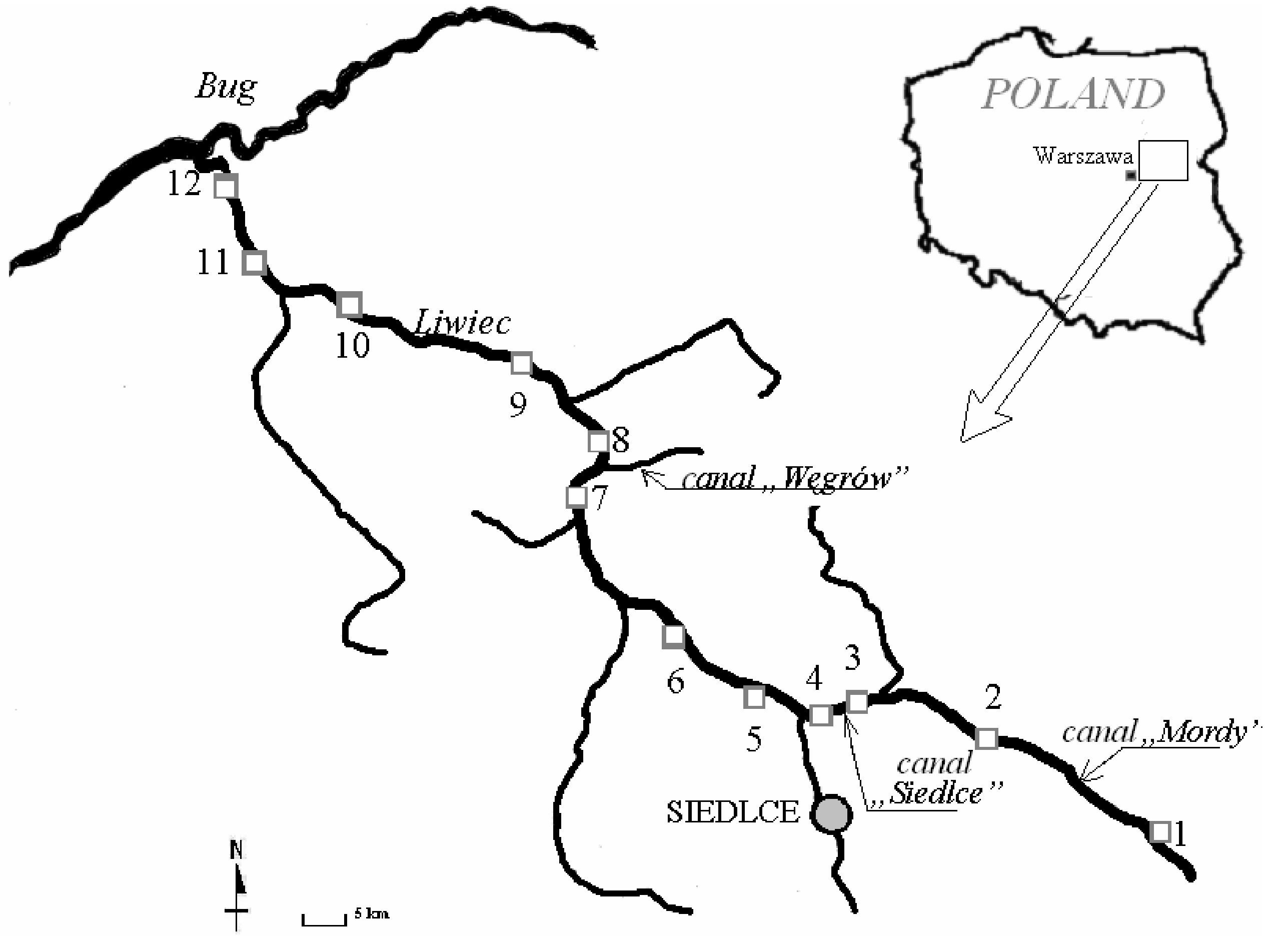

Fig. 1. Location of sampling sites along the Liwiec River. Sampling sites: 1 – Wyczółki, 2 – Golice, 3 – Chodów, 4 – downstream from the discharge of the Siedlce sewage treatment plant, 5 – Kisielany, 6 – Zaliwie,7 – Liw, 8 – Węgrów, 9 – Paplin, 10 – Łochów, 11 – Gwizdały, 12 – Kamieńczyk

Table 1. The admissible values of some physical and chemical parameters of surface waters, biodiversity index (d), biotic indices: BBI, and BMWP/OQR, and related water quality classes.

Water quality indices	Surface water quality classes				
	1 st	2 nd	3 rd	4 th	5 th
Conductivity [µS cm^{-1}] [5]	≤500	1000	1500	2000	>2000
Oxygen [mgO_2 dm^{-3}] [5]	≥7	6	5	4	<4
Nitrate [$mgNO_3^-$ dm^{-3}] [5]	≤5	15	25	50	>50
Phosphate [$mgPO_4^{3-}$ dm^{-3}[5]	≤0.2	0.4	0.7	1.0	>1.0
Biodiversity index (d) [5,6]	≥5.5	4.0	2.5	1.0	<1.0
BBI [2]	10-9	8-7	6-5	4-3	2-0
BMWP/OQR [3]	≥5	4	3	2	≤1

144 samples of water for physical and chemical analyses, and 144 samples of macroinvertebrates were taken.

According to the Polish standards, the following physical and chemical parameters were evaluated: dissolved oxygen, conductivity, dissolved phosphate, and nitrate concentration. On the basis of these parameters values, water was classified to quality classes according to the act of the Minister of Environmental Protection from Feb. 11, 2004 (Dz. U. No 32, poz. 283 and 284, 2004) [5] (Table 1).

Biological studies included collecting macroinvertebrates, and analysis of their qualitative and quantitative composition. They were sampled using the semi-quantitative method, using the bottom scraper (30 cm long, and 20 cm high). Three scrapes were done in different parts (for example river current, bank) of the same site. The total area of scrape from each site was about 1 m^2. Collected material was rinsed in the sieve of 0.5 mm mesh. Taxonomic identification of macroinvertebrates was done with the usage of the following sources [12-28] and after consultations with specialists.

The results of macroinvertebrate analysis were used for biological evaluation of Liwiec River water quality. The following indices were applied:

- Belgian Biotic Index (BBI) – standard method of evaluation of riverine water quality in Belgium [2],
- score system BMWP (Biological Monitoring Working Party score system) being a basis of the Overall Quality Rating [3] – developed in Great Britain,
- Margaleff's diversity index modified by Kownacki et al. [6], proposed by the Institute of Environmental Protection in Warsaw, and the Department of Freshwater Biology of the Polish Academy of Sciences in Cracow for biological evaluation of Polish freshwaters.

The ranges for all indices related to various water quality classes are shown in Table 1.

Relationships between the physical and chemical parameters (dissolved oxygen, conductivity, concentrations of nitrate and phosphate) and the values of biotic indices were tested using Spearman's correlation.

Results

The results of chemical analysis and the values of biotic indices and biodiversity index (d) modified by Kownacki et al. [6] revealed considerable discrepancy in classification of Liwiec River water quality.

The values of conductivity, dissolved oxygen, nitrate and phosphate ion concentrations, and final chemical classification of Liwiec waters are shown in Table 2. Due to the high number of measurements, mean values for each site are shown for particular years.

The values of physical and chemical parameters were within the following ranges: conductivity – 230-1642 µS cm^{-1}; dissolved oxygen concentration – 0.32-12.0 mgO_2 dm^{-3}, nitrate ions concentration – 0.5-19.0 $mgNO_3^-$ dm^{-3}, phosphate ions concentration – 0.1-3.4 $mgPO_4^{3-}$ dm^{-3}. Based on the mean values noted in 1998-2000 and 2002, the Liwiec River water at most study sites was qualified as the 2nd and 3rd classes of quality (Table 2). Mean concentration of dissolved oxygen in the upper (sites 1 and 2), and lower (sites 7-12) course of the river were characteristic of the 1st and 2nd classes of quality. At site 4, situated downstream from the discharge of the Siedlce sewage treatment plant, concentration of dissolved oxygen was typical for the 4th and 5th classes of quality.

The average concentration of nitrate ions at all study sites was representative for the 1st and 2nd class.

Among all measured parameters, the highest variability was observed for phosphate ion concentrations. Their average yearly levels were representative for the 1st–5th classes of quality. The highest phosphate ions concentrations occurred at sites 4 and 5 situated downstream from the discharge of the Siedlce sewage treatment plant (Table 2).

In each year of research, the number of macroinvertebrate families found in the samples was from 6 (site 4) to 24 (sites in the upper and the lower part of the river). Throughout the total time of research (4 years), from 15 to 45 families were found at different sites of the Liwiec River (Fig. 2).

Table 2. Mean values of some physical and chemical parameters and classification of the Liwiec River water in 1998-2000 and 2002.

Site	Year	Values of parameters				Quality classes	Parameter determing quality class
		Conductivity µS cm^{-1}	mgO_2 dm^{-3}	mgNO_3^- dm^{-3}	mgPO_4^{3-} dm^{-3}		
1	1998	1100	8.2	4.4	0.4	3	Conductivity
	1999	850	6.7	1.9	0.5	3	PO_4^{3-}
	2000	829	7.7	3.9	0.3	2	PO_4^{3-}
	2002	802	6.5	1.8	0.2	2	O_2
2	1998	813	9.2	4.9	0.6	3	PO_4^{3-}
	1999	805	7.1	3.1	0.4	2	PO_4^{3-}
	2000	886	6.8	5.0	1.1	5	PO_4^{3-}
	2002	835	6.4	1.7	0.3	2	PO_4^{3-}, O_2
3	1998	821	8.5	3.5	0.3	2	PO_4^{3-}
	1999	634	5.5	5.3	0.3	3	O_2
	2000	844	5.7	10.0	0.2	3	O_2
	2002	845	6.1	3.0	0.4	2	PO_4^{3-}, O_2
4	1998	925	3.2	12.5	1.3	5	PO_4^{3-}, O_2
	1999	978	2.8	5.2	0.9	5	O_2
	2000	942	5.1	8.5	1.4	5	PO_4^{3-}
	2002	1011	4.0	7.2	0.8	4	PO_4^{3-}, O_2
5	1998	849	8.4	9.9	0.8	4	PO_4^{3-}
	1999	859	5.9	4.4	0.6	3	PO_4^{3-}, O_2
	2000	878	5.7	8.3	1.4	5	PO_4^{3-}
	2002	833	6.5	6.1	0.6	3	PO_4^{3-}
6	1998	837	8.6	10.0	0.7	3	PO_4^{3-}
	1999	829	6.4	5.4	0.6	3	PO_4^{3-}
	2000	882	4.5	9.1	0.9	4	PO_4^{3-}
	2002	858	6.9	5.3	0.7	3	PO_4^{3-}
7	1998	769	8.4	6.8	0.6	3	PO_4^{3-}
	1999	728	6.0	4.2	0.4	2	PO_4^{3-}, $O_{2,}$ Conductivity
	2000	738	7.1	4.6	0.5	3	PO_4^{3-}
	2002	779	8.1	3.5	0.3	2	PO_4^{3-}, Conductivity
8	1998	782	7.8	6.7	0.5	3	PO_4^{3-}
	1999	753	7.4	4.1	0.5	3	PO_4^{3-}
	2000	765	6.5	5.8	0.6	3	PO_4^{3-}
	2002	811	7.3	3.7	0.4	2	PO_4^{3-}, Conductivity
9	1998	784	8.5	6.3	0.5	3	PO_4^{3-}
	1999	746	8.1	4.1	0.4	2	PO_4^{3-}, Conductivity
	2000	758	8.7	4.7	0.5	3	PO_4^{3-}
	2002	796	7.8	3.5	0.3	2	PO_4^{3-}, Conductivity

Table 2. continued

10	1998	770	8.9	6.5	0.4	2	PO_4^{3-}, Conductivity
	1999	745	6.9	4.0	0.4	2	PO_4^{3-}, O_2, Conductivity
	2000	744	8.0	4.0	0.4	2	PO_4^{3-}, Conductivity
	2002	787	7.0	2.4	0.2	2	Conductivity
11	1998	751	8.8	6.7	0.4	2	PO_4^{3-}, Conductivity
	1999	724	8.9	3.5	0.4	2	PO_4^{3-}, Conductivity
	2000	736	8.9	4.6	0.3	2	PO_4^{3-}, Conductivity
	2002	765	7.2	3.3	0.2	2	Conductivity
12	1998	736	9.0	6.9	0.4	2	PO_4^{3-}, Conductivity
	1999	723	8.9	4.1	0.4	2	PO_4^{3-}, Conductivity
	2000	734	7.4	4.7	0.4	2	PO_4^{3-}, Conductivity
	2002	749	7.6	2.9	0.2	2	Conductivity

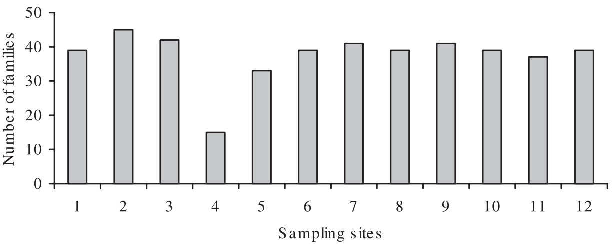

Fig. 2. Total number of macroinvertebrate families at the 12 sampling sites of the Liwiec River in 1998-2000 and 2002

Crustacea, represented by *Asellidae,* prevailed at most sites. The largest number of them was found in the upper part of the river. *Diptera* were the most numerous among insect larvae. Ten families of *Diptera* were found, and the most common were *Chironomidae. Trichoptera,* 13 families altogether, occurred at all study sites. The most popular of them were *Hydropsychidae, Limnephilidae, Polycentropodidae,* and *Phryganeidae.* Also *Odonata* appeared at all sites (except for site 4). They were represented by 6 families and the predominating ones were: *Calopterigidae, Gomphidae* and *Platycnemididae. Ephemeroptera* were represented by 8 families; the most frequently occurring were: *Baetidae, Caenidae, Ephemeridae* and *Heptageniidae. Plecoptera* larvae (3 families) were found at 7 sites. Among *Coleoptera* (8 families altogether) the dominant family was *Ditiscidae*, and among *Heteroptera* (7 families in total) *Corixidae* and *Gerridae* occurred at all sites. *Mollusca* were also at all study sites; *Lymnaeidae* and *Bithyniidae* were the most popular of them. The smallest number of macroinvertebrates families was found at site 4. *Oligochaeta* and *Hirudinea*, represented by *Erpobdellidae*, prevailed there.

The data concerning qualitative and quantitative analysis of macroinvertebrate communities were used for calculation of the biotic indices. The median values of the BBI, BMWP/OQR and diversity (d) indices are shown in Table 3.

The values of BBI varied within the 2-10 range, and in about 50% of samples they were equal to 5 or 6, which was representative for the 3rd class of quality (moderately polluted water). Over the entire study period, the lowest values were observed at site 4, situated downstream from the discharge of the Siedlce sewage treatment plant. The average BBI values at this site were typical for the 4th class of quality. At the sites situated downstream from site 4 (5, 6, 7), a gradual improvement of water quality was observed (Table 4).

The values of British BMWP/OQR ranged from 1.0 to 6.5. The average values (Table 3 and 4) were representative for excellent (the 1st class), and good (the 2nd class) water. Poor (the 4th class) quality of water occurred at site 4, downstream from the discharge of the Siedlce sewage treatment plant.

Variability in the BMWP/OQR and BBI values resulted from the presence of taxa of different sensitivity to water pollution. It should be stressed that very sensitive taxa were found in the Liwiec River: *Plecoptera* (sites: 1, 2, 8, 9, 10, 12), *Ephemeroptera*: *Ephemeridae* (sites: 1, 2, 3, 7, 8, 9), and *Heptageniidae* families (sites: 6, 8-12), and *Trichoptera*: *Phryganeidae* (sites: 2, 3, 5-8, 10), and *Molannidae* families (sites: 1, 3, 6-8).

The values of the Margaleff's diversity index d (modified by Kownacki et al. [6]) depended on the number of macroinvertebrate families present at each study site, and on their density. Over one entire study period the d index values ranged from 0.56 to 10.58. Similarly as in case of the BBI and BMWP/OQR indices, the lowest values were observed at site 4, representative for the 3rd and 4th water quality classes. At the other sites its values were typical for the 1st class.

The results of statistical analysis revealed a significant correlation between the chemical parameters, and the biotic water quality indices (Table 5).

Particularly interesting are:
- negative correlation between the level of phosphate ions concentration, and BBI, BMWP/OQR and d values,
- significant correlation between the values of biotic indices.

Table 3. Median values of biotic indices: BBI, BMWP/OQR and biodiversity index (d) at 12 sampling sites of the Liwiec River in 1998-2000 and 2002.

Site	Year	Values of indices		
		BBI	BMWP/OQR	d
1	1998	7	5.0	5.27
	1999	5	4.5	5.80
	2000	7	4.5	6.94
	2002	9	5.0	7.78
2	1998	6	5.5	6.28
	1999	5	4.5	4.49
	2000	5	4.5	6.66
	2002	7	5.0	8.12
3	1998	5	4.5	6.39
	1999	5	5.0	6.43
	2000	7	5.5	7.35
	2002	7	6.0	8.45
4	1998	3	2.0	2.30
	1999	3	1.0	2.02
	2000	3	2.5	3.33
	2002	3	2.0	3.16
5	1998	4	3.0	3.90
	1999	5	3.5	6.39
	2000	5	3.5	5.52
	2002	6	4.5	8.98
6	1998	5	5.5	5.54
	1999	6	4.0	5.00
	2000	5	4.0	7.78
	2002	6	5.0	9.32
7	1998	6	5.5	5.62
	1999	4	3.0	5.36
	2000	5	4.5	5.12
	2002	7	4.5	5.93
8	1998	7	5.5	6.60
	1999	6	5.0	7.00
	2000	8	5.5	8.00
	2002	8	5.5	8.91
9	1998	6	4.5	5.70
	1999	6	4.5	6.25
	2000	5	5.0	6.15
	2002	5	5.0	5.30
10	1998	7	5.5	6.88
	1999	4	4.5	3.18
	2000	7	4.5	6.48
	2002	5	4.0	6.38
11	1998	5	4.5	7.01
	1999	6	5.0	6.16
	2000	5	4.0	5.88
	2002	5	3.5	6.49
12	1998	6	5.5	6.18
	1999	6	5.0	5.73
	2000	5	4.5	5.85
	2002	5	5.5	7.00

Discussion

According to the classification of surface waters used in Poland [5] and based on physical and chemical parameters, the indicator determining the quality class is the one which shows waters of worse quality. For example, if oxygen concentration represents the 1st water quality class, and phosphate ion concentrations represent the 4th water quality class, the waters in final classification belong to the 4th class of quality. Values of chosen physical and chemical parameters of Liwiec indicated that the river waters belong to the 2nd or 3rd quality class. The final classification was determined mainly by phosphate ions (compare the data in Tables 1 and 2), which also was indicated in the assessment of Liwiec water quality done by the Voivodeship Inspectorate of Environmental Protection in Warsaw [29].

The results of studies of diversity of macroinvertebrate communities in the Liwiec River (four years, three samplings a year) were used for testing various biotic water quality indices used in the EU countries.

Evaluation of the Liwiec River water quality according to the Belgian Biotic Index BBI [2,30], taking into consideration the ratio between taxa most sensitive to water pollution to the number of all taxa present in the sample (in the 1-10 scale), revealed that the water was slightly (the 2nd class) or moderately (the 3rd class) contaminated (Table 1 and 3). The worst water quality was observed at site 4 (mean BBI value 3.0), classified as strongly contaminated (the 4th quality class).

The values of BMWP/OQR index calculated from the same data revealed very good and good quality of Liwiec water. Similarly as in case of BBI, site 4 got the lowest score (2.03), and its water was classified as poor quality (Tables 1 and 3).

Liwiec water classification was carried out on the basis of BBI index and at most sites it agreed with the classification prepared on the basis of chosen chemical param-

Table 4. Classification of the Liwiec River water at 12 sites, according to the median values of the indices: BBI, BMWP/OQR, and biodiversity index (d) in 1998-2000 and 2002.

Site	Indices	Quality classes			
		1998	1999	2000	2002
1	BBI	2	3	2	1
	BMWP/OQR	1	2	2	1
	d	2	1	1	1
2	BBI	3	3	3	2
	BMWP/OQR	1	2	2	1
	d	1	2	1	1
3	BBI	3	3	2	2
	BMWP/OQR	2	1	1	1
	d	1	1	1	1
4	BBI	4	4	4	4
	BMWP/OQR	4	4	4	4
	d	4	4	3	3
5	BBI	4	3	3	3
	BMWP/OQR	3	3	3	2
	d	3	1	1	1
6	BBI	3	3	3	3
	BMWP/OQR	1	2	2	1
	d	1	2	1	1
7	BBI	3	4	3	2
	BMWP/OQR	1	3	2	2
	d	1	2	2	1
8	BBI	2	3	2	2
	BMWP	1	1	1	1
	d	1	1	1	1
9	BBI	3	3	3	3
	BMWP/OQR	2	2	1	1
	d	1	1	1	2
10	BBI	2	4	2	3
	BMWP	1	2	2	2
	d	1	3	1	1
11	BBI	3	3	3	3
	BMWP/OQR	2	1	2	3
	d	1	1	1	1
12	BBI	3	3	3	3
	BMWP/OQR	1	1	2	1
	d	1	1	1	1

1 – 1st quality class, 4 – 4th quality class,
2 – 2nd quality class, 5 – 5th quality class
3 – 3rd quality class,

Table 5. The values of correlation coefficient Spearman (R) between some physical and chemical parameters of water and biotic indices BBI, BMWP/OQR, and biodiversity index (d).

Variables	BBI	BMWP/OQR	d
O_2	NS	0.21*	NS
NO_3^-	NS	NS	NS
PO_4^{3-}	-0.22**	-0.23**	-0.17*
Conductivity	NS	-0.26**	NS
BBI	-	0.64***	0.60***
BMWP/OQR	-	-	0.59***

p<0.001*** p<0.01** p<0.05* NS – non significant

eters of water. BMWP/OQP index and biodiversity index indicated better quality waters than chemical assessment (Tables 2 and 4).

Statistically significant correlations between phosphate ion concentrations (parameter most frequently determining the chemical classification of waters) and the values of tested biotic indices and biodiversity index were found (Table 5).

It is noteworthy that the taxa typical of very pure waters (not included in BMWP/OQR criteria) were found in the Liwiec River, including the larvae of: mayflies *Ametropodidae* [27, 31], dragonflies *Calopterygidae* [32], flies *Athercidae* [14, 27, 33], and flies of lower ecological requirements such as *Tabanidae, Ephydridae* [27, 34]. In the British index, the larvae of *Lestidae, Gomphidae, Corduliidae, Aeshnidae, Libellulidae* dragonflies are highly scored (8 points out of 10) [3]. These families were found at the following sites: *Lestidae* – 7, *Gomphidae* 5-12, *Corduliidae* – 3, 6, 7, 8, *Aeshnidae* – 5, and *Libellulidae* – 5, 8. According to Takamura et al. [35], their larvae are sensitive to some pollutants (e.g. pesticides). Presented results of the four-year study allow for a preliminary evaluation of usefulness of the biotic water quality indices used in the EU countries for Polish lowland rivers. Presented calculations indicate that the BMWP/OQR and BBI indices may be used for evaluation of riverine water in Poland.

The possibility of use of BBI index for evaluation of water quality in Polish rivers was already reported by Czerniawska-Kusza [36, 37]. According to Kudelska and Soszka [38], the BMWP/OQR is a more reliable pollution indicator when compared to BBI. To increase its reliability, the taxa such as *Ametropodidae, Calopterygidae, Athercidae, Tabanidae, Ephydridae* found in the Liwiec River should be included. In fact, each index could be modified and adjusted to Polish conditions because an index developed in one region cannot be directly used in another one.

The indices of taxonomic diversity may also be useful for evaluation of water quality [39-43]. Kownacki et al. [6], based on the data from 49 Polish rivers, proposed the modified Margaleff's biodiversity index. The statically significant correlation between the values of d and BBI (R = 0.60, p < 0.001), and the BMWP/OQR (R = 0.59,

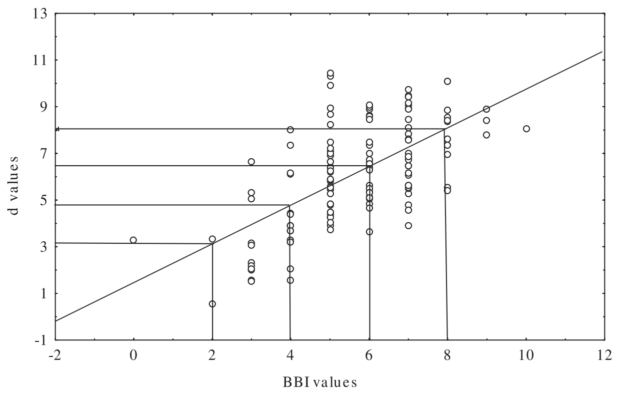

Fig. 3. Relationship between the biotic index BBI and the biodiversity index (d).

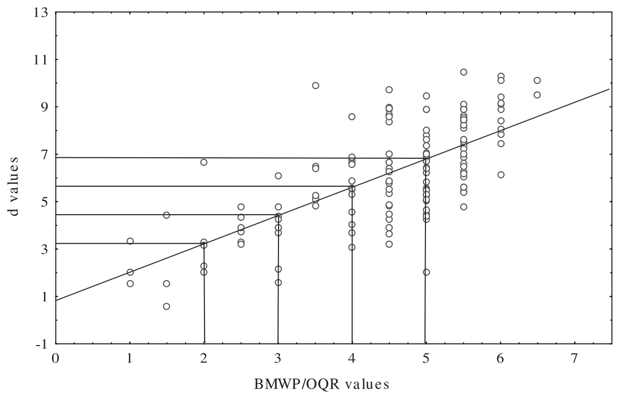

Fig. 4. Relationship between the biotic index BMWP/OQR and the biodiversity index (d).

$p < 0.001$) indices indicates the possibility of using the biodiversity index proposed by Kownacki et al. [6] for evaluation of Liwiec water quality. It is, however, striking, that the values of this index were representative mainly for the 1st quality class, the values of BBI were characteristic of the 2nd and 3rd classes, while BMWP/OQR values for the 1st and 2nd classes (Table 4). To obtain higher congruency between the values of d index and other biotic indices for the Liwiec River, the ranges of d for different quality classes should probably be changed.

The analysis of data presented in Fig. 3, showing a relationship between d and BBI indices for the 1st –5th quality classes, revealed that if BBI values indicate the 1st quality class (8-10 points) – d values are above 8, if BBI is 6-8 (2nd class) –d ranges from 6.5 to 8, if BBI is 4-6 (3rd class) – d ranges from 4.5 to 6.5, for the 4th class (BBI 2-4) – d is 3-4.5, while for strongly contaminated water (BBI < 2) d is <3.

Similar analysis of relationships between d and BMWP/OQR (Fig. 4) shows that for the 1st class water (BMWP/OQR >5), d value is above 7, for the 2nd class (OQR 4-5) – d ranges from 5.5 to 7, for the 3rd class (OQR 3-4) – d is 4.5-5.5, for the 4th class (OQR 2-3) – d ranges from 3 to 4.5, while for strongly contaminated water – d < 3.

Taking into consideration these relationships, statistically significant correlations between BMWP/OQR and BBI, and the values of phosphate ions, it seems that the values of biodiversity index for different water quality classes should be:

- very pure water (the 1st class) – d > 7.5
- slightly polluted water (the 2nd class) – d from 6.00 to 7.49
- moderately polluted water (the 3rd class) – d from 4.50 to 5.99
- polluted water (the 4th class) – d from 3.00 to 4.49
- strongly polluted water (the 5th class) – d < 2.99.

The above-mentioned relationships seem true for lowland moderately polluted rivers, such as Liwiec, but should be verified also for other types of rivers.

Conclusion

1. The results of our study allow for the preliminary evaluation of the usefulness of the biotic water quality indices used in EU countries for the assessment of Polish lowland rivers. Biotic evaluation of Liwiec River water quality revealed the usefulness of the Belgian Biotic Index BBI, and the British BMWP/OQR Index for assessment of water quality in Polish lowland rivers. The values of these indices correlated with the values of some chemical parameters of water.
2. Biological evaluation of Liwiec River water quality done over a four-year period showed that at most sites water of this river was slightly and moderately contaminated.
3. Evaluation of Liwiec River water quality on the basis of the biodiversity index, and the other biotic indices, and classification using some physical and chemical parameters revealed considerable discrepancies in the final classification. Therefore, a verification of the biodiversity index values for various water quality classes should be done in case of application of this index for assessment of water quality of lowland moderately polluted rives such as Liwiec.

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