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Analysis of the Ecological Status of Surface Waters in the Region of the Lublin Conurbation

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1. Introduction

The chemistry of waters is a result of landscape geochemistry, chemical composition and distribution of precipitation, soil water management, land development and use, and plant cover (Ryszkowski 1992). The chemistry of waters can also differ depending on their terrain situation (Grzywna 2010). Therefore, it is of major importance to identify the processes causing the pollutants to move in water in the case of increasing small retention resources. A significant pressure factor is precipitation water or melt-water taken in sewerage systems, flowing from polluted areas, including city centres, industrial areas and roads with heavy traffic as well as car parks. The waters taken in sewerage systems require treatment, otherwise they become a source of pollution for surface waters and groundwaters. Leachate must also be treated both during and after the operation of the landfill (Mouri et al. 2012; Kowalik et al. 2014).

Eutrophication is a process in which the productivity of water increases because of improper agrarian activity and water and sewage management. This process causes mass growth of algae and cyanobacteria. Consequently, water becomes cloudy and biological life disappears (Balcerzak & Rybicki 2011). The issue of agricultural pollution of water was identified in the member states of the European Union (EU) a long time ago. The EU set the rules for handling such pollution (Directive 2000). Poland transposed the provisions of the EU directive into the Water Law act (Dz. U. 2001.115.1229).

The purpose of monitoring surface waters, according to the Water Framework Directive, is to obtain information about the status of waters in river basins for the needs of water management planning and evaluating the accomplishment of environmental goals. The ecological status of waters is determined by biological elements (phytoplankton, phytobenthos, macrophytes) and chemical elements (oxygen conditions, salt content, nutrients) (Pietruczuk & Szoszkiewicz 2012; Lai et al. 2013; Kowalik et al. 2014; Grzywna et al. 2015).

The changes in the quality of water were evaluated using the macrophyte and phytobenthos index and major physico-chemical parameters of waters in the rivers of the Lublin region. The aim of the work was to determine the ecological potential of watercourses using biological and chemical elements.

2. Material and methods

The Bystrzyca – a left-bank tributary of the River Wieprz, has its source in Sulów (at 227 m above sea level). The total length of the river is 70.3 km, and the area of the river basin 1315.5 km^2. Below Spiczyn (at 152 m above sea level) it flows into the River Wieprz. In Osmolice the River Kosarzewka flows into the Bystrzyca. Within the limits of Lublin three more tributaries flow into the river: Krężniczanka from the west, Czerniejówka from the south and Czechówka from the northwest. The last tributary outside the city limits is Ciemięga. The storage reservoir Zalew Zemborzycki is situated on the river in the southern part of Lublin – a place for leisure and recreation, with a base of tourist and sports services (Michalczyk & Wilgat 1998).

The paper presents the results of surveys into the ecological status of rivers in the Lublin region. Lublin is the largest city in Poland east of the Vistula, situated on the northern edge of the Lublin Highland, on the River Bystrzyca, at 163-238 m above sea level. It is ranked ninth in Poland in terms of population (300,000 inhabitants), and 16th in terms of area (147 km^2). The River Bystrzyca, and its tributaries Czerniejówka and Czechówka, flow through Lublin city from the south to the northeast. The Bystrzyca Valley divides the city into two parts with separate landscapes: the left-bank portion forming a part of the Nałęczów Plateau with a varied relief, deep valleys and old loess gorges and the right-bank portion forming a part of the Świdnica Plateau and the Giełczew Elevations, with flatter and less varied relief. Industry is mainly concentrated in the north-eastern and south-eastern parts of the city. Single-family housing estates are intermingled with blocks of flats. Recreation grounds are concentrated in the south-western part of the city around lake Zalew Zemborzycki. The Campus is a compact area (GUS 2015, Kozyra 2002).

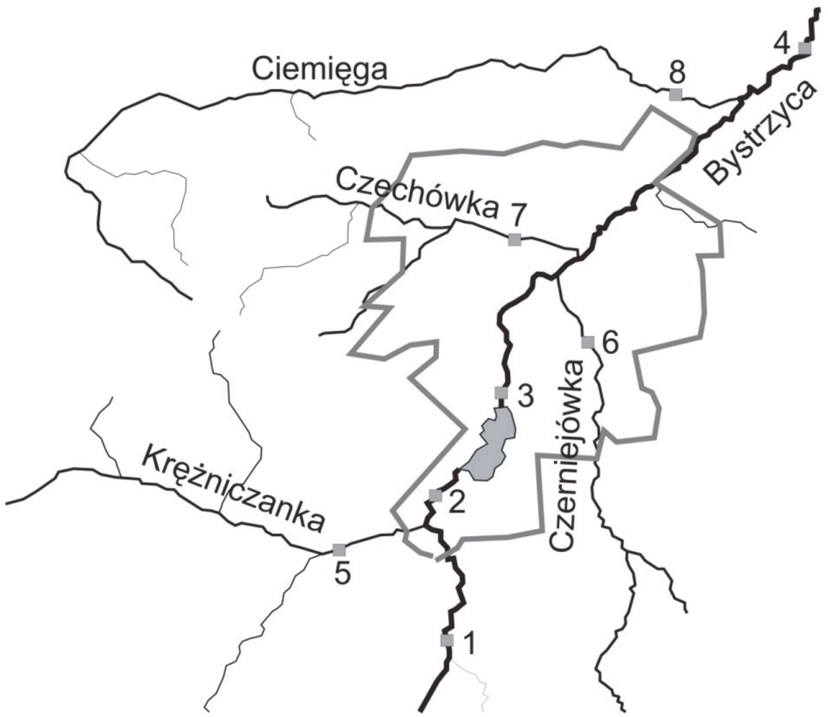

Fig. 1. The hydrographic network in the region of Lublin; 1-8 locations of checkpoints
Rys. 1. Sieć hydrograficzna w rejonie Lublina. 1-8 lokalizacja punktów badań

Biological and chemical elements were analysed between 2012-2014. Analyses were carried out at the following checkpoints on the rivers (Fig. 1): Bystrzyca (No. 1 – Osmolice, 48th km of the river, No. 2 m^3/s flow rate; No. 2 – Zemborzyce, 38th km; No. 3 – Dąbrowa, 34th km; No. 4 – Spiczyn, 5th km, 4.5 m^3/s flow rate, sub-catchment 838 km^2), Krężniczanka (No. 5 – Krężnica, tributary of the Bystrzyca on 40th km, 0.6 m^3/s flow rate, catchment 225 km^2); Czerniejówka (No. 6 – Fabryczna, tributary on 25th km, 0.5 m^3/s flow rate, catchment 172 km^2), Czechówka (No. 7 – Botanik, tributary on 24th km, 0.16 m^3/s flow rate, catchment 78 km^2), Ciemięga (No. 8 – Pliszczyn, tributary on 12th km, 0.5 m^3/s flow rate, catchment 158 km^2) (Czarnecka 2005).

The following chemical indicators were determined in water samples: conductivity at 20°C (Con), BOD_5, general hardness (Hard), total nitrogen (N), Kjeldahl nitrogen (N-K), ammonia nitrogen (N-NH_4) and nitrate nitrogen (N-NO_2), phosphates (PO_4), total phosphorus (P). In addition, biological indicators were determined: Polish Macrophyte Index for Rivers (MIR) according to macrophyte species, diatom index (IO) according to the species of diatoms (Picińska-Fałtynowicz & Błachuta 2008; Szoszkiewicz et al. 2010; Grzywna et al. 2015).

The planning of a surface waters monitoring network was based on the regulation concerning the forms and method of monitoring of uniform parts of surface waters and groundwaters. The quality of water was evaluated according to the regulation on the method of classification of uniform parts of surface waters and environmental quality standards for priority substances.

The results obtained were processed by statistical methods including the determination of the differentiation of water quality ratios as regards the checkpoint (measuring site) and the year of measurement. To this end, methods of descriptive statistics were used, including box-plots. The data was analysed using Statistica 10 software.

3. Results

At the end of 2013, seven wastewater treatment plants were in operation in the conurbation of Lublin: two municipal and five industrial. Despite this fact, evaluation of the level of the risk of eutrophication caused by sewage effluents from municipal sources revealed that the phenomenon did occur. Agriculture is another source of pressure on the aquatic environment. The widespread use of mineral fertilizers and pesticides leads to an increased load of nitrogen and phosphorus compounds in waters (GUS 2015).

It is assumed that the life of the analysed biological, physico-chemical and hydromorphological elements in operating monitoring is 3 years. Every biological element has different sensitivity to specific pressure. For example, diatom phytobenthos (IO) is a sensitive indicator of eutrophication. However, this is a short-term indicator referring to a river habitat. Short life cycles of diatoms and fast production rate prevent conclusions on long-term changes in the environment. On the other hand, these organisms quickly respond to the deteriorating condition of the environment (Gołub 2010; Tarkowska-Kukuryk 2013).

The IO values were average and they mostly ranged from 0.3-0.5. However, for checkpoints 2, 7 and 8 the value was lower than 0.3 (tab. 1, fig. 2). In single cases for checkpoint 1 the value of the index exceeded 0.5. Depending on the checkpoint and year of study, the watercourses are classified as waters of II, III or IV quality class. Irrespective of the checkpoint, diatoms were predominantly species with a wide range of ecological tolerance, often found in waters subject to anthropogenic pollution from surface run-off.

Tabela 1. Wartości średnie analizowanych wskaźników jakości wody
Table 1. The mean values of the analyzed indicators of water quality

Point	1	2	3	4	5	6	7	8	Mean
IO	0.50	0.29	0.46	0.33	0.41	0.34	0.28	0.28	0.36
MIR	40.9	36.5	39.3	38.4	39.5	34.8	33.4	37.9	37.6
Con	491	518	358	552	546	529	641	576	526
Hard	301	316	288	237	347	356	384	363	324
BOD_5	2.4	2.7	7.4	3.2	3.7	5.5	4.7	3.4	3.5
$N\text{-}NH_4$	0.090	0.128	0.183	0.271	0.282	0.123	0.189	0.169	0.18
N-K	0.92	1.03	1.16	1.41	1.38	1.19	1.54	0.93	1.20
$N\text{-}NO_2$	2.15	2.55	1.23	1.97	3.68	3.39	2.18	1.41	2.32
N	3.15	3.77	2.52	3.46	4.92	4.40	3.81	2.33	3.54
PO_4	0.28	0.36	0.17	0.29	0.46	0.35	0.43	0.29	0.32
P	0.15	0.17	0.15	0.21	0.27	0.19	0.33	0.16	0.20

Depending on the year, MIR values enabled classifying the watercourses into class II and III of water quality. The overall number of macrophyte species was average and ranged from 5 to 15. In the structure of dominance, the largest share was that of emergent macrophytes and pleustonic species. The structure of macrophyte species was typical of anthropogenic reservoirs or was subject to continuing influx of nutrients from the catchment area. MIR values most often ranged from 37 to 41. However, for checkpoints 2, 6 and 7 they were lower than 37.

In terms of BOD_5 at checkpoint 3 the mean value exceeded the acceptable limit (6 mg $O_2 \cdot dm^{-3}$) for class II. At checkpoints 1 and 2 above Lublin BOD_5 was within the range acceptable for waters of very good quality. At other checkpoints, surface waters were classified as II class of purity in terms of BOD_5. Statistical analysis revealed that biochemical oxygen demand was higher below checkpoint 4. Electrolytic conductivity was low in comparison to values acceptable for waters with class I ecological status.

Below the city of Lublin, at checkpoint 4, the mean concentrations of all nutrient indicators were higher than recorded above the city at checkpoint 1 (Tab. 1). However, in the case of nitrate nitrogen the values were identical, while for other indicators the concentrations were significantly higher than those recorded at checkpoint 1 – from 1.3 (total nitrogen) to 3 times (ammonia nitrogen). Despite large differences between checkpoints, the ecological status of water was very good since the average values of total nitrogen and ammonia nitrogen did not exceed standard limits for class I. The watercourses were most varied in terms of nitrate nitrogen content (limit value 2.2 mg $N\text{-}NO_3 \cdot dm^{-3}$) and total phosphorus (limit value 0.2 mg $P \cdot dm^{-3}$), and depending on the checkpoint, waters were classified as purity class I or II (Fig. 2). In the case of Kjeldahl nitrogen (1-2 mg $N \cdot dm^{-3}$) and phosphates (0.2-0.4 mg $PO_4 \cdot dm^{-3}$) the analysed waters are classified as quality class II. However, the limit value for class II was exceeded for checkpoints 5 and 7 (no limit values given for other classes). The River Czechówka, flowing along the streets of Lublin, featured the worst parameters.

Water in the rivers can be considered hard as its general hardness at most study periods ranged from 300 to 400 mg $CaCO_3 \cdot dm^{-3}$ (Tab. 1). The mean values of salt content from many years at the checkpoint below and above the city were 301 and 238 mg $Ca\text{-}CO_3 \cdot dm^{-3}$ respectively, which made the water eligible for class I.

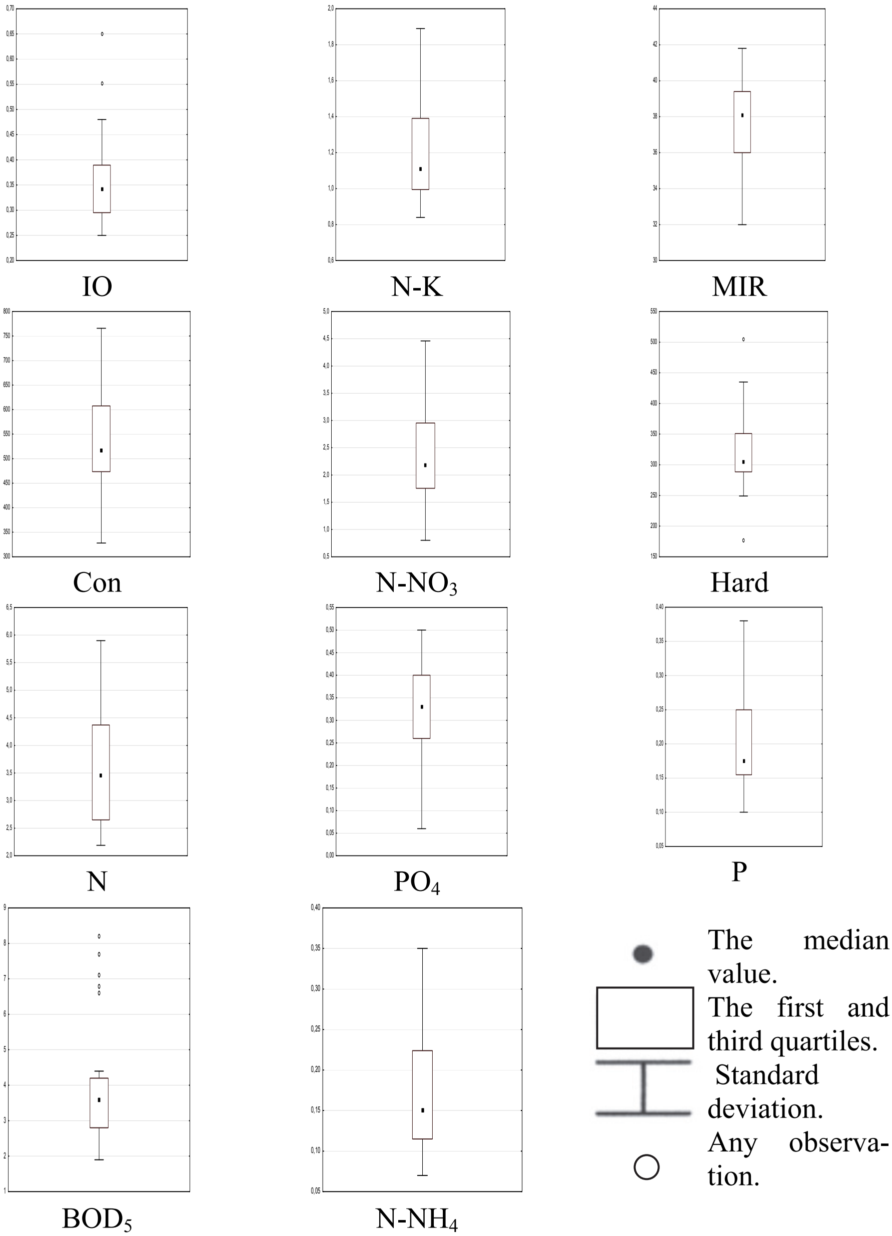

Fig. 2. Box-plot of water quality indicators in 2012-2014
Rys. 2. Zmienność wskaźników jakości wody w latach 2012-2014.

4. Summary

The analysed river waters were characterised by very low content of ammonia nitrogen below 0.4 mg $N\text{-}NH_4$/l, total nitrogen below 5 mg $N \cdot dm^{-3}$ and conductivity below 600 uS/cm. These values are characteristic of class I water purity. The content of Kjeldahl nitrogen within the range of 1-2 mg $N \cdot dm^{-3}$, phosphates within the range 0.2-0.4 mg $PO_4 \cdot dm^{-3}$, nitrate nitrogen 2-5 mg $N\text{-}NO_3 \cdot dm^{-3}$ and phosphorus 0.2-0.4 mg $P \cdot dm^{-3}$ makes the analysed waters eligible for purity class II. Sometimes the content of phosphates in the region of Lublin exceeds the limit value for class II – 0.4 mg $PO_4 \cdot dm^{-3}$. BOD_5 in lake Zalew Zemborzycki continuously exceeded the limit value for class II – 6 mg $O_2 \cdot dm^{-3}$.

The results were considerably worse for biological indicators. For MIR the index was 37-41, which made the waters eligible for purity class II. At some checkpoints within the limits of Lublin city the value of the index lower than 37 made the water eligible for purity class III. For IO the index most often ranged from 0.3 to 0.4, which corresponds to class III water purity. A decrease in the index below 0.3 in Ciemięga and Czechówka rivers made the water eligible for purity class IV.

The main reason for the poor ecological status of water was a high content of phosphates and a low diatom index. The largest variability in the value of the index was characteristic of the analysed watercourses for nitrate nitrogen and ammonia nitrogen and oxygen level. The watercourses are not very wide (1-3 m) and not very deep (0.2-1.0 m), they have a low flow and their beds are modified (profiled bed, concrete slabs). Watercourses located outside the city are characterised by moderate ecological potential (quality class III), whereas watercourses in Lublin are characterised by insufficient ecological potential (class IV).

Anova analysis showed a significant variability in values between the analysed checkpoints, which is not applicable to MIR only. In most cases no significant variability in the values of indicators was recorded between years at respective checkpoints, which is not applicable to phosphates and total phosphorus.

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Analiza stanu ekologicznego wód powierzchniowych w rejonie aglomeracji lubelskiej

Streszczenie

W pracy przedstawiono wyniki prowadzonych badań stanu ekologicznego rzek w rejonie Lublina. Analizie poddano elementy biologiczne i chemiczne za lata 2012-14. Do analizy wytypowano 8 punktów kontrolnych na rzekach. W próbkach wody oznaczano wskaźniki chemiczne oraz elementy biologiczne. Na podstawie uzyskanych wyników badań przeprowadzono analizy statystyczne, które obejmowały określenie zróżnicowania wskaźników jakości wody ze względu na stanowisko oraz rok pomiarów. Wykorzystano w tym celu metody statystyki opisowej z wizualizacją w postaci wykresów pudełkowych. Analiza danych przeprowadzona została w programie Statisica.

Badane wody rzeczne charakteryzowały się bardzo niską zawartością azotu amonowego poniżej 0,4 mg $N\text{-}NH_4$/l, azotu ogólnego poniżej 5 mg $N\cdot dm^{-3}$ oraz przewodnością poniżej 600 uS/cm. Są to wartości charakterystyczne dla I klasy czystości wody. Zawartość azotu Kjeldahla w zakresie 1-2 mg $N\cdot dm^{-3}$, fosforanów w zakresie 0,2-0,4 mg $PO_4\cdot dm^{-3}$, azotu azotanowego 2-5 mg $N\text{-}NO_3\cdot dm^{-3}$ i fosforu 0,2-0,4 mg $P\cdot dm^{-3}$ klasyfikuje badane wody do II klasy czystości. W rejonie miasta Lublin niekiedy zawartość fosforanów przekracza wartość graniczną dla II klasy. W przypadku wielkości BZT_5 w Zalewie Zemborzyckim stale była przekroczona wartość graniczna dla II klasy. Znacznie gorsze wyniki otrzymano w przypadku wskaźników biologicznych. W przypadku MIR wartość indeksu wynosiła 37-41, co pozwalało na zaliczenie wód do II klasy czystości. W niektórych punktach położonych w granicach Lublina wartość indeksu wynosząca poniżej 37 powodowała zaliczenie wody do III klasy czystości. W przypadku IO wartość indeksu mieściła się najczęściej w zakresie

0,3-0,4 co odpowiada III klasie czystości wody. Spadek tego indeksu poniżej wartości 0,3 w rzekach Ciemięga i Czechówka powodował zaliczenie wody do IV klasy czystości.

Główną przyczyną złego stanu ekologicznego wody była wysoka zawartość fosforanów oraz niski indeks okrzemkowy. Największą zmiennością wartości wskaźnika charakteryzowały się badane cieki w przypadku azotu azotanowego i amonowego oraz natlenienia. Cieki charakteryzuje niewielka szerokość (1-3 m) oraz głębokość (0,2-1,0 m), mały przepływ wody, jak również modyfikacje koryta (koryto profilowane, płyty betonowe). Cieki zlokalizowane poza miastem charakteryzują się umiarkowanym potencjałem ekologicznym (III klasa jakości), zaś cieki na terenie Lublina charakteryzują się niedostatecznym potencjałem ekologicznym (IV klasa jakości).

Analiza Anova wykazała istotną zmienność wartości wskaźników między badanymi stanowiskami, co nie dotyczy tylko MIR. W większości przypadków nie stwierdzono istotnej zmienności wartości wskaźników między latami w poszczególnych stanowiskach, co nie dotyczy fosforanów i fosforu ogólnego.

Abstract

The paper presents the results of surveys into the ecological status of rivers in the region of Lublin. Biological and chemical elements were analysed between 2012-2014. Analyses were carried out at the following 8 checkpoints on the rivers. The following chemical and biological indicators were determined in water samples. The obtained results were processed by statistical methods including determining the differentiation of water quality indicators as regards the checkpoint (measuring site) and the year of measurement. To this end, methods of descriptive statistics were used, including box-plots. The data was analysed using Statistica software.

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Słowa kluczowe:
rejon Lublina, woda, stan ekologiczny, wskaźniki jakości

Keywords:
region of Lublin, water, ecological status, quality indicators