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Contents of Biogenic Components in Surface Waters of Small Catchments in the Zielonka Forest

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Introduction

Quality of surface waters is at present one of the most essential issues in studies on environmental protection. Increasing water demand, observed in recent years, leads to the necessity to protect its resources, not only in terms of quantity, but also quality (Szafrański 2007). Dynamics of translocation of different mineral and organic compounds and their different chemical forms is dependent on many factors, the major ones being catchment management, soil type, mineral fertilization and precipitation (Ilnicki 2002, Szpakowska and Karlik 2002). In recent years considerable changes have been implemented in farming methods applied in agriculture, characterized by reduced application of mineral fertilizers and chemical plant protection agents. However, it needs to be stressed that water transport of chemical compounds depends on many factors (soil properties, topography, weather conditions and cultivation measures) and may be a very long process, lasting from several to over a dozen years (Ryszkowski 1992). Thus the basic action aiming at the improvement of water quality is to reduce the inflow of biogenic elements, such as: nitrogen, phosphorus and potassium (Błażejewska et al. 2003). The aim of the study was to assess contents of biogenic components in surface waters of small catchments located in the Zielonka Forest.

Method

The object of the study consisted of two lowland watercourses: the Hutka watercourse to the Huta Pusta section line, and the Potaszka watercourse

to the Potasze section line (Fig 1). The catchment of the Hutka watercourse is forested in 89% while in case of the catchment of the Potaszka watercourse it is only 15%.

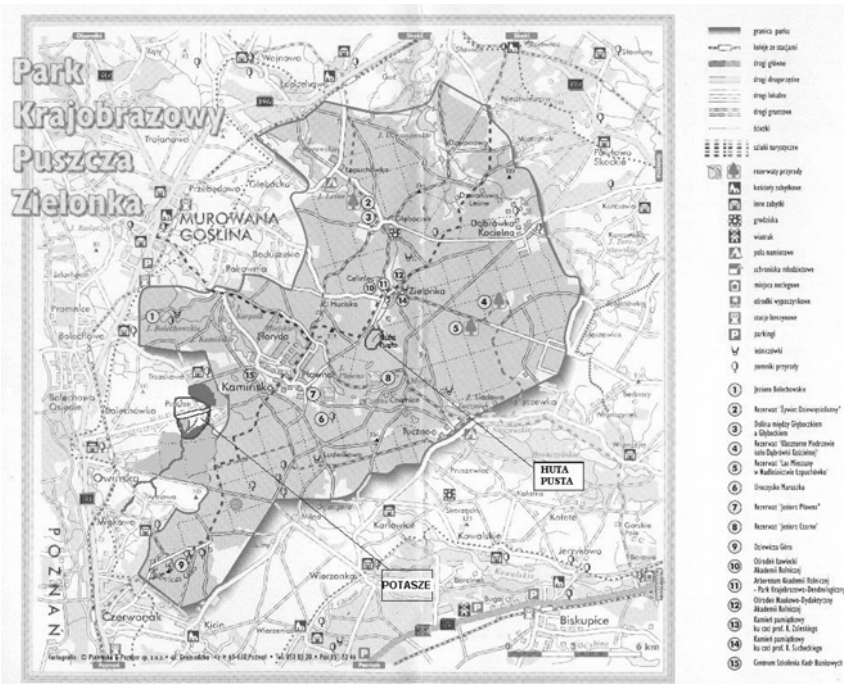

Fig. 1. The forest eco-system of the "Zielonka Forest"
Rys. 1. Ekosystem leśny „Puszcza Zielonka"

Studies and field observations were conducted in hydrological years 2003÷2005. They included both standard hydrometeorological measurements concerning recorded water levels in watercourses, daily recording of precipitation as well as monthly analyses of surface water quality in the Hutka and Potaszka watercourses, as well as the forest and field ponds. Laboratory analyses of collected water samples included assays of 20 indexes and components charactering physical, chemical and oxygen conditions, as well as contents of biogenic components. Water analysis was performed following the guidelines contained in the "List of standards in water and sewage analyses" (1993). This study was based only on results concerning assays of different nitrogen forms (nitrate nitrogen $N\text{-}NO_3$, nitrite nitrogen $N\text{-}NO_2$ and ammonia nitrogen $N\text{-}NH_4$), phosphates $P\text{-}PO_4$ and potassium K. Assessment of water quality was based on data contained in the Ordinance of the Minister of the

Environment of 11 February 2004 (the official Gazette "Dziennik Ustaw" of 2004, no. 32, item 284) on the classification used in the presentation of surface and underground water purity state, monitoring methods and methods to interpret results and present purity state of these waters.

Results

Analyzed catchments of investigated watercourses are located in the central part of the Wielkopolska region, approx. 20 km north-east of Poznań, in the Zielonka Forest, at a distance of approx. 7 km from each other. The catchment of the Hutka watercourse, with an area of 0.52 km^2, is forested in 89%, the other 11% being covered by swamps and wasteland (Fig. 2). The predominant sites are fresh mixed coniferous forest (BMśw), fresh coniferous forest (Bśw) and alder carr forest (Ol).

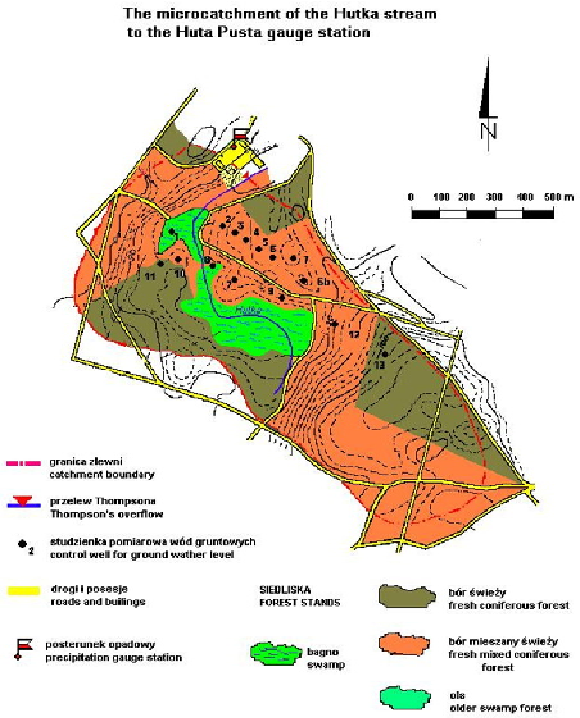

Fig. 2. The catchment of the Hutka watercourse
Rys. 2. Zlewnia cieku Hutka

The catchment of the Potaszka watercourse is over two times bigger, with an area of 1.33 km^2. Here forest cover only 14.7 % catchment area, arable land (GO) occupies approx. 75%, while grassland (UZ) constitutes 10.3% (Fig. 3). Landscape in both catchments is characterized by a large number of interior depressions, filled partly with rainwater or peatbogs, with poorly developed natural drainage. Discussed catchments are also characterized by a similar size of their watercourses. The watercourses do not exceed 1 km in length, the mean width is approx. 0.5 m, while mean depth ranges from 0.2 to 0.3 m. Podzol soils, formed from sands, predominate in the area of both analyzed catchments. In land depressions, where the ground water table is located immediately below the ground surface, mucky soils are found.

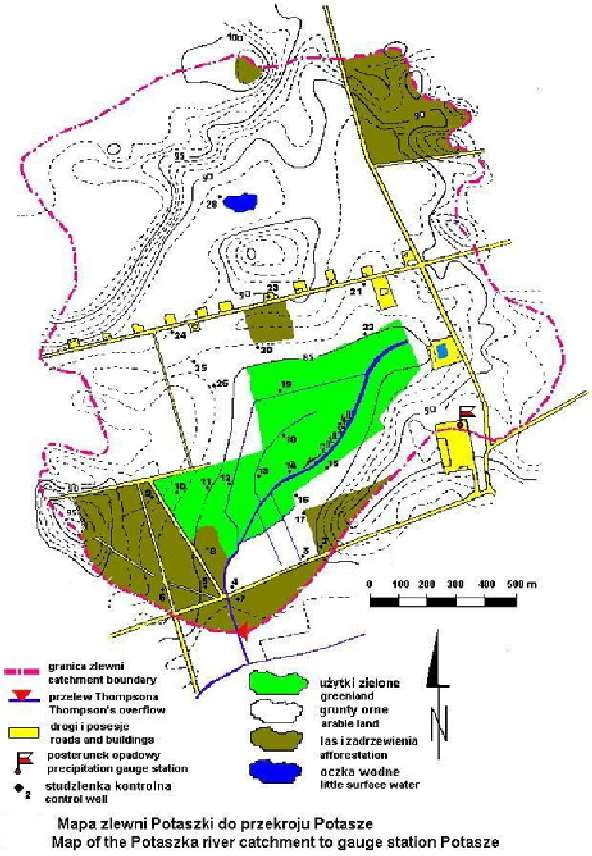

Fig. 3. The catchment of the Potaszka watercourse
Rys. 3. Zlewnia cieku Potaszka

The weather conditions in analyzed hydrological years 2003÷2005 were evaluated on the basis of annual and half-year total precipitation levels and mean annual air temperatures measured at the rain gauging stations in view of multiannual data for the period 1970÷2005, recorded at the Arboretum Zielonka station (Fig. 4.).

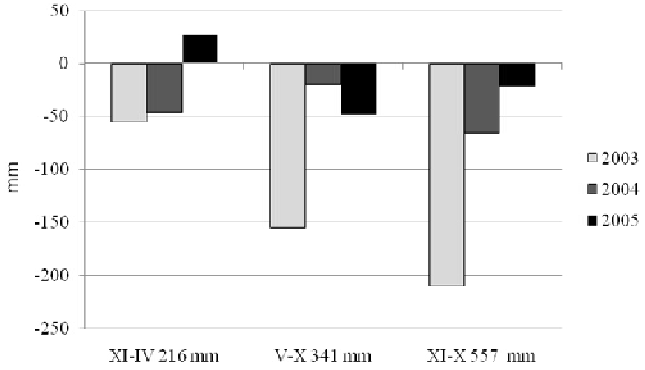

Fig. 4. Half-year and annual deviations of precipitation totals in hydrological years 2003÷2005 from mean half-year and annual precipitation totals in the multiannual period of 1970÷2005

Rys. 4. Półroczne i roczne odchylenia sum opadów atmosferycznych w latach hydrologicznych 2003-2005 od średnich półrocznych i rocznych sum opadów w wieloleciu 1970÷2005

The first year of the study, i.e. 2003, was very dry, with precipitation total of 347 mm, lower than the multiannual mean by as much as 210 mm. Mean air temperature in that year was 8.6°C. In both half-years of the analyzed year precipitation totals were by 55 mm and 155 mm, respectively. The next year of the study, 2004, was dry in terms of the precipitation level. Precipitation total was 492 mm and it was by 65 mm lower than the multiannual mean. Mean air temperature was 9.1°C and it was by 0.6°C higher than the mean. The winter half-year was characterized by precipitation total lower than the mean by 21%, while the summer half-year was similar to the multiannual mean. In turn, the hydrological year of 2005 was an average year. Precipitation total was lower than the multiannual mean by 22 mm, at a temperature higher than the mean by 0.3°C. In the winter half-year precipitation total was higher by 27 mm, while in the summer half-year it was lower by 49 mm than the mean value. In both half-years mean air temperatures were similar to the multiannual means.

When assessing the quality of surface waters in analyzed catchments, it is necessary to focus on content of biogenic components, which constitute the

main source of pollution for these waters. Water in the Hutka and Potaszka watercourses in the three analyzed years of the study, in terms of their contents of different nitrogen chemical forms, was classified as quality class I (very good quality) (Tab. 1.).

Table 1. Concentrations of biogenic compounds in water of Hutka and Potaszka watercourses
Tabela 1. Stężenia biogenów w wodach cieku Hutka i Potaszka

Parametry *Parameters*		Zlewnia Potaszka *Catchment Potaszka*			Zlewnia Hutka *Catchment Hutka*		
	rok	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Azot azotanowy Nitrate nitrogen **(mg N-NO_3/dm^3)**	**min**	0.1	0.2	0.1	0.2	0.2	0.2
	śr	0.5	0.6	0.4	0.45	0.48	0.4
	max	0.95	0.8	0.9	0.9	0.6	0.8
Azot azotynowy Nitrite nitrogen **(mg N-NO_2/dm^3)**	**min**	0	0	0	0.01	0	0
	śr	0.01	0.01	0.01	0.02	0.01	0.01
	max	0.02	0.02	0.02	0.02	0.02	0.02
Azot amonowy Ammoniacal nitrogen **(mg N-NH_4/dm^3)**	**min**	0.02	0.02	0.02	0.05	0.02	0.03
	śr	0.06	0.08	0.05	0.22	0.21	0.21
	max	0.08	0.12	0.07	0.37	0.27	0.35
Fosforany Phosphates **(mg PO_4/dm^3)**	**min**	0.05	0.1	0.1	0.3	0.4	0.2
	śr	0.11	0.12	0.18	0.78	0.7	0.5
	max	0.15	0.18	0.22	1.4	0.8	0.7
Potas Potassium **(mg K/dm^3)**	**min**	1.0	0.9	0.8	0.8	0.6	0.8
	śr	1.2	1.1	1.3	1.0	1.2	1.0
	max	1.6	1.3	1.6	1.2	1.4	1.4

Due to high mean concentrations of phosphates in the Hutka watercourse, ranging in the period of the study from 0.5 mg $PO_4 \cdot dm^{-3}$ (2005) to 0.78 mg $PO_4 \cdot dm^{-3}$ (2003), exceeding two times the standard for quality class III (0.4 mg $PO_4 \cdot dm^{-3}$), waters in that watercourse were found in class IV – unsatisfactory quality. An exception in this respect concerned phosphate concentration in the very dry summer half-year of 2003 (186 mm), where in May and June at a monthly precipitation totals of only 10 and 30 mm and very low means of monthly flow of 0.16 and 0.09 $dm^3 \cdot s^{-1}$, phosphate concentration reached the maximum value of 1.4 $PO_4 \cdot dm^{-3}$. Such a high phosphate concentration in those months qualifies waters of the Hutka watercourse in 2003 to the worst class V – water of poor quality. An increase in phosphate concentration in the watercourse, especially in summer and autumn months, at the simultaneous decrease in the content of soluble oxygen, could have resulted

from the release of soluble phosphorus compounds from bottom deposits under anaerobic conditions (Fig. 5).

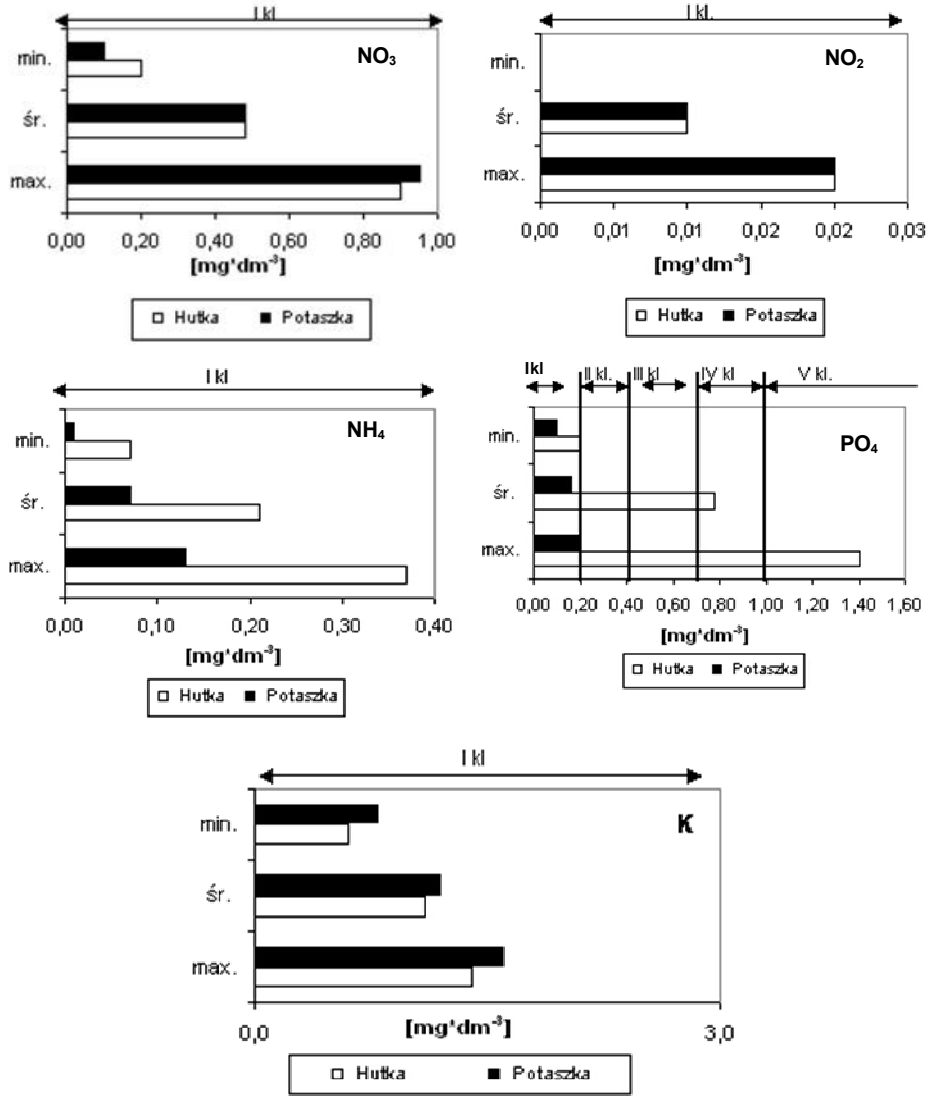

Fig. 5. Minimum, mean and maximum recorded concentrations of biogenic compounds in waters of Hutka and Potaszka watercourses in the years 2003÷2005

Rys. 5. Minimalne, średnie i maksymalne wartości zmierzonych stężeń substancji biogennych w wodach cieków Hutka i Potaszka w latach 2003÷2005

Conducted investigations showed that water in the field and forest ponds had similar quality parameters to waters in the analyzed watercourses. In the field pond found in the Potaszka catchment mean concentrations of nitrate, nitrite and ammonia nitrogen in the analyzed years classified water in the pond to water quality class I (Tab. 2, Fig. 6.).

Table 2. Concentrations of biogenic compounds in water of the field pond (Potaszka) and the forest pond (Hutka)
Tabela 2. Stężenia biogenów w wodach śródpolnego (Potaszka) i śródleśnego (Hutka) oczka wodnego

Parametry Parameters		Zlewnia Potaszka Catchment Potaszka			Zlewnia Hutka Catchment Hutka		
	rok	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Azot azotanowy Nitrate nitrogen **(mg N-NO_3/dm^3)**	**min**	0.3	0.2	0.2	0.2	0.4	0.3
	śr	0.6	0.8	0.5	0.5	0.3	0.5
	max	0.7	1.0	0.9	0.73	0.6	1.2
Azot azotynowy Nitrite nitrogen **(mg N-NO_2/dm^3)**	**min**	0	0	0	0.01	0.01	0.01
	śr	0.01	0.01	0.01	0.02	0.02	0.01
	max	0.04	0.02	0.02	0.08	0.03	0.02
Azot amonowy Ammoniacal nitrogen **(mg N-NH_4/dm^3)**	**min**	0.1	0.04	0.15	0.1	0.08	0.05
	śr	0.25	0.2	0.2	0.8	0.5	0.7
	max	0.3	0.22	0.24	1.12	1.0	0.85
Fosforany Phosphates **(mg PO_4/dm^3)**	**min**	0.1	0.1	0.1	0.2	0.2	0.3
	śr	0.25	0.2	0.18	0.6	0.4	0.5
	max	0.5	0.4	0.35	0.85	0.56	0.7
Potas Potassium **(mg K/dm^3)**	**min**	15.3	9.8	12	1.4	1.2	0.6
	śr	19.6	16.3	15	2.1	1.4	0.8
	max	29.2	23	18.4	2.5	1.6	1.2

Slightly higher mean phosphate concentrations of 0.2÷0.25 mg $PO_4 \cdot dm^{-3}$ resulted in a deterioration of water quality, classifying those waters to class II. However, maximum phosphate concentrations, ranging from 0.35 mg $PO_4 \cdot dm^{-3}$ (2005) to 0.5 mg $PO_4 \cdot dm^{-3}$ (2003), result in the water of the analyzed pond being classified to quality class III. In the water of that pond very high mean potassium concentrations were also recorded, amounting in the years of the study to as much as 18.71 mg $K \cdot dm^{-3}$ (quality class IV). Their maximum values were recorded also in 2003, reaching 29.2 mg $K \cdot dm^{-3}$, which classified water in the pond to the worst class V – poor water quality.

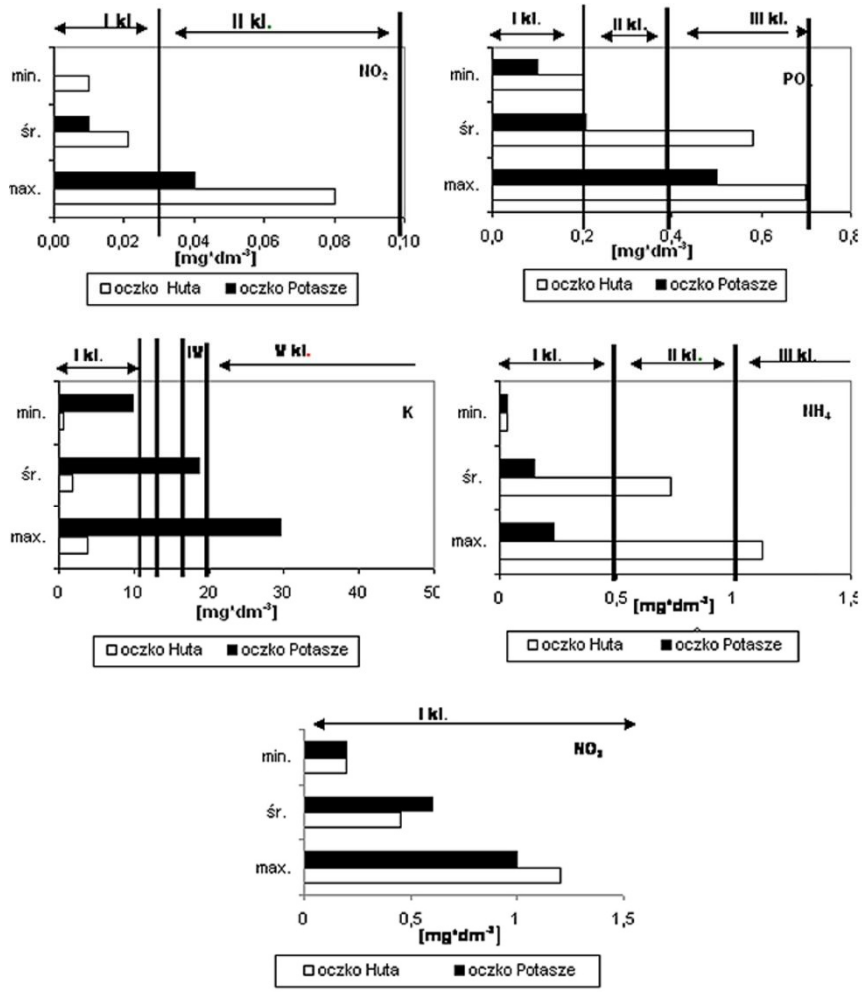

Fig. 6. Minimum, mean and maximum recorded concentrations of biogenic compounds in ponds

Rys. 6. Minimalne, średnie i maksymalne wartości zmierzonych stężeń substancji biogennych w oczkach wodnych

When analyzing quality of water in the forest pond located in the Hutka catchment, it needs to be stressed that mean concentrations of nitrate and nitrite nitrogen classify water in the pond to quality class I. In turn, mean values of ammonia nitrogen of 0.73 mg $NH_4 \cdot dm^{-3}$ result in a situation when analyzed water in terms of its quality was found to be of class II; however, the maximum

value of 1.12 mg $NH_4 \cdot dm^{-3}$ recorded in 2003 reduced quality class of these waters to class III. The situation is even worse when phosphate concentrations are evaluated. High values of their mean concentrations in the period of the study, ranging from 0.4 to 0.6 mg $PO_4 \cdot dm^{-3}$, classified analyzed water to class III – water of satisfactory quality.

The year of 2003 was an exception in this respect, as maximum values of phosphate concentrations exceeded the boundary of water quality class III (0.7 mg $PO_4 \cdot dm^{-3}$) and amounted to 1.12 mg $PO_4 \cdot dm^{-3}$, which classified water in the forest pond to class IV.

When comparing mean concentrations of biogenic substances in waters of the watercourses and in the ponds it may be observed that there are significant differences between concentrations of ammonia nitrogen and phosphates. In the Potaszka watercourse and in the field pond concentrations of different nitrogen forms corresponded to quality class I. In turn, phosphate concentration in the pond was two times higher than in the watercourse and corresponded to quality class III. A especially large difference was found for potassium concentration. Here an almost 18-fold difference was recorded between concentrations of this compound in the watercourse and in the pond, which resulted in the water of the latter belonging to class V – water of poor quality. In the Hutka watercourse and in the forest pond the concentrations of nitrate and nitrite nitrogen as well as that of potassium corresponded to class I. In turn, maximum ammonia nitrogen concentration was 3 times higher in the pond than in the watercourse and classified its water to quality class III. The evaluation of surface waters in terms of phosphate content gave the worst results. Water both in the Hutka watercourse and in the pond contained large amounts of phosphates, classifying water in the watercourse to class IV – water of unsatisfactory quality, while water in the pond – to the worst class V – water of poor quality.

Conclusions

1. Water quality at both catchments: Potaszka catchment of forestation 15% and intense agricultural use as well as at the Hutka catchment of forestation 89% was mainly dependent on biogenic components content (N, P, K). These components were the main pollutants of water in these watercourses as well as in the mid-forest pond.
2. Analyses showed that contents of biogenic components in surface waters of investigated catchments significantly affected the evaluation of quality of these waters. Water quality in the Hutka and Potaszka watercourses in the tree years of the study (2003÷2005), in terms of their contents of different chemical nitrogen forms, corresponded to class I of very good quality.

3. A high phosphate concentration in the Hutka watercourse, amounting to 0.78 mg $PO_4 \cdot dm^{-3}$, resulted in the classification of water in this watercourse to quality class IV, and in 2003 even to class V. An increase in phosphate concentration in the watercourse, especially in the summer and autumn months, at the simultaneous decrease in soluble oxygen content, could have resulted from the release of soluble phosphorus compounds from bottom deposits under anaerobic conditions.
4. When evaluating water quality in the field pond located in the catchment of the Potaszka watercourse it may be stated that mean concentrations of nitrate and nitrite nitrogen classify analyzed waters to class I – waters of very good quality. Due to the maximum phosphate concentration of 0.5 mg $PO_4 \cdot dm^{-3}$ water has to be classified to class III – water of satisfactory quality. In turn, very high potassium concentrations classified water in the analyzed pond to class IV and in 2003 even to class V – the worst quality class.
5. In the Hutka watercourse and in the forest pond located in this catchment concentrations of nitrate and nitrite nitrogen as well as potassium corresponded to class I. In turn, a high concentration of phosphorus compounds (1.4 mg $PO_4 \cdot dm^{-}$) resulted in a situation when water in the Hutka watercourse was classified to class V – water of poor quality, while in the forest pond (0.85 mg $PO_4 \cdot dm^{-3}$) to class IV – water of unsatisfactory quality.

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Zawartość składników biogennych w wodach powierzchniowych w małych zlewniach na terenie Puszczy Zielonka

Streszczenie

Jakość wód powierzchniowych jest obecnie jednym z najbardziej istotnych zagadnień w badaniach nad ochroną środowiska. Wzrastające zapotrzebowanie na wodę, obserwowane w ostatnich latach, zmusza do ochrony jej zasobów, nie tylko pod względem ilości, ale również jakości. Dynamika przemieszczenia różnych minerałów i związków organicznych oraz ich różnych form chemicznych jest uzależniona od wielu czynników, głównie od: zarządzania zlewnią, typem gleby, nawożenia mineralnego i opadów. W ostatnich latach znaczne zmiany zostały wprowadzone w metodach uprawy stosowanych w rolnictwie, polegające na redukcji stosowania nawozów mineralnych i chemicznych środków ochrony roślin. Jednakże należy podkreślić, że transport wodny związków chemicznych zależy od wielu czynników (własności gleby, topografii, warunków pogodowych i sposobu uprawy) i może być bardzo długim procesem, trwając od kilku do kilkunastu lat. Podstawową metodą mającą na celu poprawę jakości wody jest zmniejszenie wprowadzania pierwiastków biogennych, takich jak: azot, fosfor i potas.

Celem pracy jest ocena zawartości składników biogennych w wodach powierzchniowych w małych zlewniach zlokalizowanych na terenie Puszczy Zielonka. Przedmiotem badań były dwa cieki nizinne: ciek Hutka do przekroju Huta Pusta oraz ciek Potaszka do przekroju Potasze. Zlewnia cieku Hutka jest zalesiona w 89%, natomiast zalesienie zlewni cieku Potaszka wynosi zaledwie 15%.

Badania i obserwacje polowe były prowadzone w latach hydrologicznych 2003÷2005. Składały się one zarówno ze standardowych pomiarów hydrometeorologicznych dotyczących rejestracji poziomów wody w ciekach, codziennej rejestracji opadów, jak z miesięcznej analizy jakości wody w ciekach Hutka i Potaszka oraz w śródpolnym i śródleśnym oczku wodnym. Analizy laboratoryjne próbek wody obejmowały 20 wskaźników i składników charakteryzujących fizyczne, chemiczne i tlenowe warunki a także zawartość substancji biogennych. Analiza wody została wykonana zgodnie z wytycznymi zawartymi w „Wykazie norm z zakresu analityki wody i ścieków".

Badania i obserwacje terenowe prowadzone w latach hydrologicznych 2003÷2005 wykazały, że jakość wód w omawianych ciekach pod względem zawartości różnych form chemicznych azotu odpowiadała I - klasie bardzo dobrej jakości. Natomiast pod względem zawartości fosforanów oraz potasu wody powierzchniowe należy zakwalifikować do IV klasy – niezadowalającej jakości, a w roku 2003 do najgorszej V klasy – wód złej jakości.