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ANTHROPOGENIC INFLUENCE ON THE QUALITY OF WATER IN THE PRĄDNIK RIVER

The anthropogenic influence on water quality in a small surface stream – the Prądnik River, a left side tributary of the upper Vistula River, is assessed. Although a small area of the Prądnik River basin is protected as a part of Ojcowski National Park, it is typical of an area of agricultural and rural settlement. The collected data consists of concentrations of nitrites, nitrates, total nitrogen and phosphorus on the upper reaches and the lower reaches of the Prądnik River. The study lasted from 2004 to 2005 and was made possible by the Provincial Inspectorate of Environment Protection in Cracow. A statistical analysis was completed using the program STATISTICA 8.0. The anthropogenic influence on the deterioration of water quality in the Prądnik River is evident, being corroborated by an increase in total phosphorus concentration (on the level of 90%). In the section below Ojców and at the outlet to the Vistula, the phosphorus concentration reached 0.13 mg P·dm^{-3} and 0.32 mg P·dm^{-3}, respectively, corresponding to I and II quality classes.

1. INTRODUCTION

The physicochemical composition of surface water depends on natural and anthropogenic factors. The influence of the latter on river water quality is both intense and dynamic and can limit the scope of river water use. It occurs not only in urban catchments, but also in agricultural ones. Surface runoff from agricultural lands fertilized by mineral and organic fertilizers as well as crude domestic sewage discharged into rivers deliver organic nitrogen and phosphorus to surface water [1], [2], [5], [6].

In this paper, the anthropogenic influence on the quality of surface water in the Prądnik River is assessed. Although the part of the river basin is protected as a part of Ojcowski National Park, it is typical of a rural, agricultural area with some suburban development.

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2. OBJECT OF INVESTIGATIONS

The Prądnik River, in its lower reaches called the Białucha, is a left-side tributary of the Vistula River reaching Cracow in 81.9 km. The sources of the river are located in the village of Sułoszowa at an altitude of about 450 m a.s.l, and the river is 33.4 km long [4]. The basin of the Prądnik is located in the southeastern part of Jura Krakowsko-Częstochowska and covers an area of 195.8 km^2. About 10.9% of this area is situated within Ojcowski National Park, and 3.6% is within the administrative borders of Cracow. The basin is similar to typical agricultural basins with 46.4% of its area composed of arable lands and 21.5% of grasslands. The remainder is covered by forests (14.7%), waste land (11.4%), and buildings, roads and the like (6.0%). The agricultural lands produce cereals, potatoes, and fodder crops. Breeding is developed to small degree. There are 14 settlements in the area of the basin and all of them lack a proper wastewater management system [3].

3. MATERIAL AND METHOD

Concentrations of nitrites, nitrates, total nitrogen, and total phosphorus were analyzed in water from the Prądnik River. The study conducted in 2004–2005 was made possible by the Provincial Inspectorate of Environmental Protection in Cracow. The concentrations of the mentioned indicators were determined in water samples taken in two control sections:

- at km 21+600 of the river (below Ojców within Ojcowski National Park),
- at km 0+300 of the river (at the outlet to the Vistula).

The empirical data collected was subjected to statistical analysis using the program STATISTICA version 8.0. The basic descriptive statistics including mean, minimum, maximum, standard deviation and variability coefficient were calculated for each indicator. The quantile method was used to determine the concentration values amounting to 90% [9]. The results were compared with the permissible values for given water purity classes from the decree of the Polish Environment Ministry [7].

Anthropogenic influence on river water quality was assessed by testing significance differences and mean concentrations of chosen indicators using parametric tests (for normal distribution) and the non-parametric test of the Mann–Whitney series (for non-normal distribution). The distribution of empirical data was tested by means of the Shapiro–Wilk test at the significance level $\alpha = 0.05$. The verification of variance homogeneity is an important issue in the analysis of statistical hypotheses for parametric tests [8]. The F-test was used to verify the null hypothesis of variation homogeneity in both groups in relation to the alternative at the significance level $\alpha = 0.05$.

4. RESULTS AND ANALYSIS

Basic descriptive statistics, guaranteed concentrations, and chemical parameters determined for the Prądnik River water in both control sections are presented in table 1. Compiled data shows that the composition of water varied both in terms of time and location. With the exception of nitrates, concentrations (mean, minimum, maximum, and guaranteed) of the remaining indicators were higher near the outlet to the

Table 1

Basic descriptive statistics and guaranteed concentrations of chemical parameters and the respective water purity classes

Statistics	Control section	
	km 21+600 (below Ojców)	km 0+300 (outlet to the Vistula)
	Nitrites	
Mean (mg NO_2·dm^{-3})	0.025 (I)*	0.066 (II)
Minimum (mg NO_2·dm^{-3})	0.008 (I)	0.020 (I)
Maximum (mg NO_2·dm^{-3})	0.102 (III)	0.193 (III)
Stand. deviation (mg NO_2·dm^{-3})	0.021	0.044
Variation coefficient (%)	83.7	66.7
Guaranteed conc. (mg NO_2·dm^{-3})	0.042 (II)	0.055 (II)
	Nitrates	
Mean (mg NO_3·dm^{-3})	3.65 (I)	3.62 (I)
Minimum (mg NO_3·dm^{-3})	3.05 (I)	2.32 (I)
Maximum (mg NO_3·dm^{-3})	4.42 (I)	4.20 (I)
Stand. deviation (mg NO_3·dm^{-3})	0.31	0.38
Variation coefficient (%)	8.5	10.4
Guaranteed conc. (mg NO_3·dm^{-3})	3.56 (I)	3.91 (I)
	Total nitrogen	
Mean (mg N·dm^{-3})	4.35 (II)	5.15 (III)
Minimum (mg N·dm^{-3})	3.53 (II)	4.28 (II)
Maximum (mg N·dm^{-3})	5.59 (III)	6.22 (III)
Stand. deviation (mg N·dm^{-3})	.50	0.53
Variation coefficient (%)	11.5	10.2
Guaranteed conc. (mg N·dm^{-3})	5.59 (III)	5.64 (III)
	Total phosphorus	
Mean (mg P·dm^{-3})	0.13 (I)	0.32 (II)
Minimum (mg P·dm^{-3})	0.06 (I)	0.19 (I)
Maximum (mg P·dm^{-3})	0.49 (III)	0.77 (IV)
Stand. Deviation (mg P·dm^{-3})	0.096	0.15
Variation coefficient (%)	76.3	47.3
Guaranteed conc. (mg P·dm^{-3})	0.13 (I)	0.32 (II)

(I)* water purity class.

Vistula than just below Ojców. For the example, on the upper reaches of the river the nitrate concentration fluctuated between 0.008 to 0.102 mg $NO_2 \cdot dm^{-3}$, that of total nitrogen between 3.53 and 5.59 mg $N \cdot dm^{-3}$, and that of total phosphorus between 0.06 and 0.49 mg $P \cdot dm^{-3}$, while at the outlet to the Vistula the concentration of nitrites ranged between 0.020 and 0.193 mg $NO_2 \cdot dm^{-3}$, that of total nitrogen between 4.28 and 6.22 mg $N \cdot dm^{-3}$, and that of total phosphorus between 0.19 and 0.77 mg $P \cdot dm^{-3}$. Mean concentrations of both nitrates (0.025 mg $NO_2 \cdot dm^{-3}$) and total phosphorus (0.13 mg $P \cdot dm^{-3}$) show that the water quality in the Prądnik River in the section below Ojców corresponds to I class purity, while total nitrogen (4.35 mg $N \cdot dm^{-3}$) applies to II class purity. On the other hand, in terms of maximum concentrations measured the river corresponds to III class purity in both sections, although at the river outlet total phosphorus corresponds to IV class purity. The time spans when the maximum concentrations were observed suggest that they should be treated as single incidents. The incidents occurred only once, in the second half of July 2005, for the entire two year monitoring period. The water at this particular time was characterized by high turbidity with concentrations of total suspended solids reaching 63 $mg \cdot dm^{-3}$ and 95 $mg \cdot dm^{-3}$ in the sections below Ojców and at the outlet to the Vistula, respectively. It is likely it occurred during or shortly after a heavy rain.

Variations in the quality of water from the Prądnik River could not be distinguished by calculated guaranteed concentrations of nitrites, nitrates and total nitrogen. These values remain the same at their specific locations with respect to time. Guaranteed concentration of total phosphorus was the exception to this. On the upper reaches of the river, total phosphorus corresponded to I class purity, while on the lower reaches to II class purity. The data shows that nitrate concentrations in all the samples investigated were relatively low, in both sections below 5.0 mg $NO_3 \cdot dm^{-3}$. This corresponds to the highest quality, I class purity.

Table 2

Results of statistically significant differences between mean concentrations of chemical parameters in the Prądnik River

Parameter	Statistical test	Value of test statistics	Test probability	Value of the *F*-test	Test probability*	Conclusion
Nitrites	Mann–Whitney	–4.402	0.000011	–	–	significant difference
Nitrates	*t*-Student	0.341	0.734	1.407	0.427	insignificant difference
Total nitrogen	Mann–Whitney	–4.619	0.000004	–	–	significant difference
Total phosphorus	Cochran–Cox	22.042	0.00000	3.015	0.017	significant difference

* Concerns the *F*-test for the homogeneity of variance.

Table 2 presents the statistically significant differences between mean concentrations for both sections of the Prądnik River. It also contains the results of testing the hypothesis on the homogeneity of variance. Since the distributions of nitrite and total nitrogen concentrations were characterized by an indistinct right-hand asymmetry, the Mann–Whitney test was used for verifying the significant difference. Moreover, it was possible to distinguish homogeneous variance for the nitrate concentrations from heterogeneous variance in the case of total phosphorus concentration. That is why the significant difference in mean concentrations of nitrates was verified by the *t*-Student test, while that in total phosphorus was verified using the Cochran–Cox test. The tests clearly showed statistically significant differences between the mean concentrations of nitrites, total nitrogen, and total phosphorus, but no statistically significant difference between mean concentrations of nitrates. These results suggest deterioration in water quality if we go downstream, being connected with anthropogenic factors.

5. CONCLUSIONS

1. The differences in mean concentrations of nitrites, total nitrogen, and total phosphorus proved to be statistically significant between the control sections investigated. This points to a deterioration of water quality for the lower reaches of the river likely due to anthropogenic factors.

2. The concentration of nitrates in the Prądnik River was low in both control sections and within the values for I class purity, i.e. 5.0 mg $NO_3 \cdot dm^{-3}$. This low concentration of nitrates may be a result of their assimilation by biomass such as phytoplankton present in water.

3. Anthropogenic influence on the deterioration of water quality in the Prądnik River was indicated by the increase in total phosphorus. This was confirmed by calculating guaranteed concentration of this nutrient. In the section below Ojców, the phosphorous concentration amounted to 0.13 mg $P \cdot dm^{-3}$, while at the outlet to the Vistula River it reached 0.32 mg $P \cdot dm^{-3}$, corresponding to the I class and II class purity, respectively.

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WPŁYW ANTROPOPRESJI NA JAKOŚĆ WODY RZEKI PRĄDNIK

Oceniono wpływ antropopresji na jakość wody w niewielkim powierzchniowym cieku, jakim jest rzeka Prądnik, lewostronny dopływ górnej Wisły. Zlewnia rzeki w niewielkiej części podlega szczególnej ochronie (Ojcowski Park Narodowy), ale przede wszystkim jest typowym obszarem, na którym rozwinęło się osadnictwo wiejskie oraz na którym prowadzi się działalność rolniczą. Oznaczono stężenia azotynów, azotanów, azotu ogólnego i fosforu ogólnego w wodach Prądnika, w jego górnym i dolnym biegu. Oznaczenia te obejmują okres dwóch lat (2004–2005) i zostały udostępnione przez Wojewódzki Inspektorat Ochrony Środowiska w Krakowie. Poddano je komputerowej analizie statystycznej, korzystając z programu STATISTICA 8.0. Wpływ antropopresji na pogorszenie jakości wód Prądnika najwyraźniej
i najmocniej zaznaczył się jako wzrost zawartego w nich fosforu ogólnego. Potwierdziły to także uzyskane wyniki obliczeń stężeń gwarantowanych tego biogenu (na poziomie 90%). W przekroju poniżej Ojcowa ich wartość wynosiła 0,13 mg $P \cdot dm^{-3}$, a przy ujściu do Wisły 0,32 mg $P \cdot dm^{-3}$, co odpowiadało I i II klasie czystości.