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SOME WATER QUALITY INDICES IN SMALL WATERCOURSES IN URBANIZED AREAS

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NIEKTÓRE WSKAŹNIKI JAKOŚCI WODY MAŁYCH CIEKÓW NA TERENIE ZURBANIZOWANYM

W pracy przedstawiono wyniki hydrochemicznych badań wody w dwu ciekach: o zlewni położonej w całości na terenie dużego miasta oraz o zlewni użytkowanej rolniczo w źródłowej części a przy ujściu zurbanizowanej. W próbkach wody pobranych z obu cieków w przekrojach kontrolnych zlokalizowanych u źródeł i w dolnym biegu oznaczono stężenia jonów NH_4^+, NO_2^-, NO_3^- i PO_4^{3-}, SO_4^{2-}, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+}, Mn^{2+}, $Fe^{2+/3+}$ oraz przewodność elektrolityczną właściwą (konduktywność), suchą pozostałość i pH. Stwierdzono, że w przekrojach na terenach zurbanizowanych wody charakteryzowały się znaczną zmiennością stężeń większości rozpuszczonych składników. W przekrojach tych wody obu cieków wykazywały wyraźne cechy degradacji na skutek wysokich stężeń fosforanów, amonowej i azotynowej formy azotu oraz żelaza i manganu. W niektórych przekrojach stężenia te kwalifikowały wodę do klasy V, potwierdzając silne oddziaływanie czynników antropogenicznych. W obecnym stanie badane wody nie mogą być wykorzystywane do zaspokajania lokalnych potrzeb, a gromadzenie ich zagrażałoby eutrofizacją zbiorników.

Summary

The paper presents the results of hydrochemical tests of water in two watercourses: one with a catchment situated wholly in the large city area and the other with the agricultural catchment situated in the source section but at the mouth of the urbanized one. In water samples collected from both watercourses at the measurement-control sections localized by the sources and in the lower course, the concentrations of the following ions were assessed: NH_4^+, NO_2^-, NO_3^-, and PO_4^{3-}, SO_4^{2-}, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+}, Mn^{2+} and $Fe^{2+/3+}$ also electroconductivity, dry residue and pH were evaluated. It was found that in the sections in the urbanized areas waters were characterized by considerably variable concentrations of most dissolved solids. In these sections waters of both watercourses revealed apparent signs of degradation in result of high concentrations of phosphates, ammonium and nitrite form of nitrogen and iron and manganese. In some sections these concentrations placed water in V water purity class, which confirmed strong effect of anthropogenic factors. At their present state the tested waters cannot be used for local needs and their storing would pose a hazard of the reservoir eutrophication.

INTRODUCTION

Urbanized areas are characterized by a considerable accumulation of anthropogenic pollutants. These negatively affect surface waters quality and may even lead to their total degradation. Therefore, in large agglomerations with considerable population density and active industries, ecological and usable functions of surface waters are limited to various extent, whereas both sources and kinds of pollution are usually diversified [1, 9].

In order to improve widely understood living standard quality of city and rural dwellers it would be advisable for the watercourses in these areas to be important landscape elements and factors of biodiversity of urban environment. Presented work is a contribution to identification of some chemical component concentrations in waters of the Sudół and Drwinka streams flowing in the city of Krakow area which is one of the main pollutant emitting centers in the Małopolska region. The practical objective of the paper was to determine the usability of the Drwinka water for filling and maintaining the water level in small ornamental ponds whose reconstruction was planned in the A. and E. Jerzmanowski Park, whereas water from the Sudół stream is supposed to feed the flood control retention reservoir whose construction has been planned in the frame of so called Małopolska Program of Small Retention. Identification of individual indices may contribute to undertaking possible prevention measures aimed at elimination of pollution sources and restoring good water quality in these watercourses.

MATERIAL AND METHODS

The Sudół stream catchment, with a total area of about 18.7 km^2, in its north-west and west part is situated in the Wielka Wieś village district, in the agricultural area, whereas its other part is on a settled terrain and in the urbanized areas of the Krakow quarters of: Bronowice Wielkie, Krowodrza and Prądnik Biały.

The stream sources are at Giebułtów village; below it flows through suburban villages of Trojadyn, Pękowice and Tonie (Fig. 1). In its middle course, at Tonie village and below, the stream flows through extensive and partly water-logged suburban meadows. In this section the stream is fed by inflows from drainage ditches, its banks are overgrown with bushes and the bottom by soft vegetation. In its lower course the Sudół flows through strongly urbanized city areas covered by typical many-storey apartment buildings. In its end part it flows along Opolska Street and flows into the Białucha River which is a left bank tributary of the Vistula.

The Drwinka river catchment is situated on the opposite, south part of the city (Fig. 1). This stream is about 4.2 km long from its source to the measurement-control section No. 4 (Fig. 1) closing the catchment part of the area of 5.12 km^2. It flows out in the area of Piaski Nowe housing estate, below flows along the border of the Kozłówek housing estate, then through Prokocim estate and in its lower part; down from the control section No. 4 located in the north part of A. and E. Jerzmanowski Park – through the Bieżanów swamps. It flows into the Drwina, which is the right bank tributary of the Vistula. Strongly urbanized catchment of the Drwinka stream, with well developed street network is intersected to the east by E-4 road with heavy traffic.

The Krakow region is characterized by mean annual air temperature +8°C and means annual rainfall of 630 mm.

The water physico-chemical properties were assessed on the basis of results provided by analyses conducted on 15 indices, which were determined in four measurement-control sections distributed in pairs in the source (No. 1 and 3) and lower (No. 2 and 4) parts of the streams (Fig. 1). The tests were performed at seven dates from May to October 2003. pH and electroconductivity were measured during water sampling, while

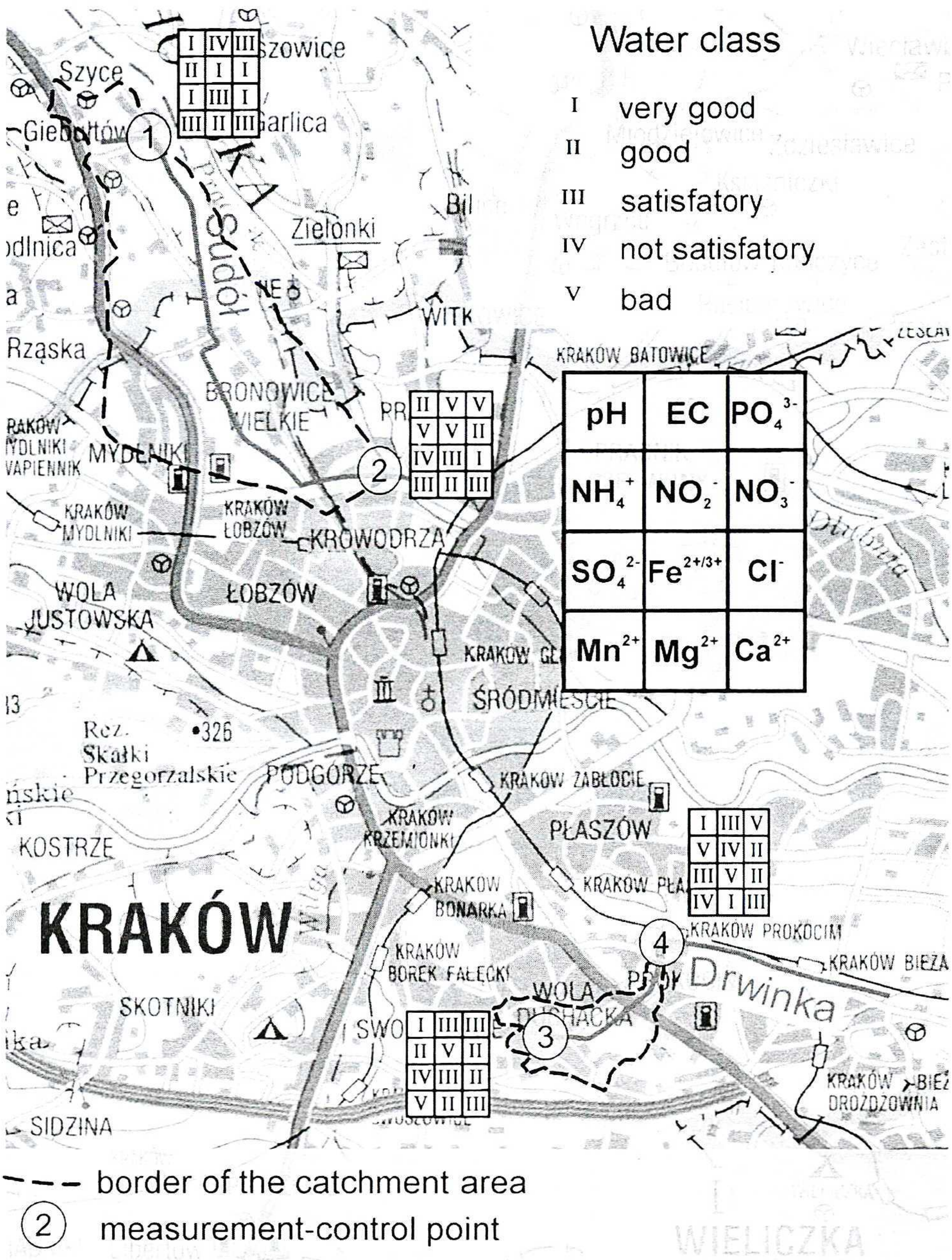

Fig. 1. Location of catchments and water quality in the Sudół and Drwinka streams

dry residue and concentrations of NH_4^+, NO_2^-, NO_3^- and PO_4^{3-} and also SO_4^{2-}, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+} and $Fe^{2+/3+}$ were assessed in the laboratory. The analyses were conducted by standard methods [2], including biogenic component assessment performed by the Swedish FIAstar 5000 flow analyzer. Minimum and maximum values were separated from the obtained results and mean values were computed. Water purity classes were determined on the basis of 5-degree scale, according to the regulations in the Decree of the Minister of Natural Environment Protection of 2004 [8].

RESULTS

Even on the basis of maps usability it is possible to assume that the waters of the Sudół stream are subject to diverse anthropopressure depending on the character of the adjoining catchment. No point pollution sources were identified in its agricultural upper part, a sewage treatment plant treating outflowing sewage from a school at Giebułtów is situated in the middle part, in a stream valley, while the other, a combined plant is located at Trojadyn village. The lower part of the catchment is strongly urbanized. Laboratory tests confirmed assumed diversification of water quality indices. Mean values of the measured indices were as a rule lower in the source part of the stream course – in the agricultural area (at measurement-control section No.1) than in measurement-control section No. 2 located in the built-up area and below the sewage treatment plant. In comparison with the section No. 1 over 21-fold increase in NO_2^-, 15-fold in NH_4^+, 13-fold in PO_4^{3-}, 10-fold in K^+ and over 2.5-fold increase in NO_3^- and SO_4^{2-} concentrations were assessed at this place (Tab. 1). The analysis of individual features shares in determining the Sudół stream water purity classes revealed that in the source section (measurement-control section No. 1) concentrations of five of them classified the water to class I, two to class II, four to class III and only electroconductivity pointed to class IV (Fig. 1). Mean EC and pH values, as well as concentrations of dry residue, nitrogen compounds, phosphates, sulphates, potassium and even chlorides, sodium and calcium more or less and on various levels were increasing along the stream course, whereas iron and manganese concentrations were decreasing. It evidences a greater environment pressure and no conditions for self-purification in consequence leading to a definite decrease in water purity in the section No, 2 situated closer to the stream inflow to the Białucha. In this measurement-control section, located in the urbanized area and below both sewage treatment plants only one index concentration (Cl^-) did not exceed the value obligatory for I class water purity; three indices (pH, NO_3^- and Mg^{2+}) placed it in II class and three ($Fe^{2+/3+}$, Mn^{2+} and Ca^{2+}) in III class and one (SO_4^{2-}) in IV class, whereas four indices (PO_4^{3-}, NH_4^+, NO_2^- and electroconductivity) in V class (Fig. 1).

The Drwinka river water quality looked different, since its whole catchment remains under strong pressure due to the fact that the area is covered densely with apartment blocks and no proper care is taken about the environment. The differences in comparison with the Sudół are perceptible particularly in the source measurement-control sections No.1 and 3 (Tab. 1). There are illegal dumping sites in the Drwinka catchment area on both sides of the watercourse; moreover wastes are burnt in the watercourse vicinity. Water pollution may also originate from liquid and gaseous fuels used by vehicles and households. The presence of foam and metallic color of water surface were found during a routine check in the lower part of the studied section, whereas an unpleasant odor could be smelled in the vicinity. Organoleptic observations were confirmed by the results of detailed field measurements and laboratory tests. Water in both researched measurement-control sections of this watercourse (No. 3 and 4) revealed quite similar mean values of indices. In measurement-control section No. 3, eight of them had slightly higher concen-

Table 1. Intervals and mean values of water quality properties

Property		Measurement-control section			
		Sudół		Drwinka	
		(1)	(2)	(3)	(4)
pH		7.27–7.53	7.60–8.56	7.28–8.44	7.17–7.60
		7.36	8.04	7.82	7.39
EC	[μS·cm⁻¹]	1590–1640	1740–2640	1136–1423	1210–1428
		1615	2358	1201	1308
SP	[mg·dm⁻³]	556–628	620–982	674–1092	746–1004
		581	794	798	831
NH_4^+		0.21–0.66	0.90–12.23	0.36–0.86	1.50–7.02
		0.41	6.18	0.60	3.66
NO_2^-		0.03–0.07	0.03–1.68	0.33–1.25	0.33–0.89
		0.04	0.86	0.69	0.61
NO_3^-		2.97–4.69	3.94–20.46	3.72–6.82	4.34–6.91
		3.59	9.58	5.31	6.12
PO_4^{3-}		0.07–0.49	0.49–5.72	0.11–0.49	0.56–3.76
		0.26	3.48	0.33	1.83
SO_4^{2-}		61–83	144–272	58–256	144–228
		75.2	214.6	138.0	181.5
$Fe^{2+/3+}$		0.23–0.42	0.06–0.48	0.32–0.91	0.16–2.09
		0.30	0.22	0.64	0.59
Cl^-		40–42.6	53.3–69.4	95–140	116–160
		40.9	62.2	115.3	132.6
K^+		0.61–1.44	7.35–14.98	22.5–32.4	10.9–12.4
		1.09	11.31	27.67	11.54
Mn^{2+}		0.09–0.42	0–0.36	0.40–1.13	0.19–0.64
		0.22	0.18	0.66	0.40
Na^+		24.5–26.7	34.6–60.7	65.6–93.6	57–78.2
		25.78	48.55	76.64	64.18
Mg^{2+}		18.8–25.3	16.3–25.7	22.4–47.4	16.1–22.5
		22.01	22.81	32.81	20.15
Ca^{2+}		87–111	102–141	90–182	102–131
		97.0	129.8	120.7	118.0

EC – electroconductivity, SP – dry residue

trations (but on quite low level) in comparison with the section No. 4, including almost 2.5-fold higher K^+ and about 1.6-fold higher Mn^{2+} and Mg^{2+} concentrations (Tab. 1). Two indices (NO_2^- and Mn^{2+}) in the section No. 3 qualified the water to V class, one to IV class, eight to III and II class and one to I purity class (Fig. 1). On the other hand, in measurement-control section No. 4 the values of seven indices were definitely higher than in the section No. 3, but only the values of NH_4^+ and PO_4^{3-} were between 6 and 5.5-fold, i.e. definitely higher. Three indices NH_4^+, PO_4^{3-} and $Fe^{2+/3+}$ placed the water in V purity class (Tab. 1), two and three respectively in classes IV and II, while two in I purity class (Fig. 1). It shows a slightly higher degree of water degradation in the lower section of the watercourse.

In both catchments together a total of six properties (EC, PO_4^{3-}, NH_4^+, NO_2^-, $Fe^{2+/3+}$ and Mn^{2+}) out of the investigated twelve compiled in the classification table [8], determined the water disqualification (V purity class). These included three indices (PO_4^{3-}, NH_4^+ and NO_2^-) noted in the two out of the four analyzed measurement-control sections (Fig. 1). It denotes complete unsuitability for use of the Drwinka water in both sections and the Sudół water in measurement-control section No. 2 in the city area. In the latter measurement-control section the most, i.e. four indices determined the water disqualification. In the sections No. 3 and 4 on the Drwinka stream the water was disqualified by respectively two and three properties, whereas in the least anthropogenized part of the Sudół catchment (measurement-control point No. 1) only one property classified water in IV purity class (Fig. 1). The Sudół stream carries waters of more diverse quality – heavily polluted in the lower course and of definitely better quality in the source section.

The data show also (Tab. 1) that in the sections with great anthropopressure characterized by relatively high concentrations of NH_4^+, NO_2^-, NO_3^- and PO_4^{3-}, K^+, SO_4^{2-}, Mn^{2+} and $Fe^{2+/3+}$in relation to the obligatory standard values considered in the classification [8], also their greater fluctuations were observed in comparison with dry residue and higher concentrations of Cl^-, Mg^{2+} and Ca^{2+}, which at the same time revealed a lower concentration level.

DISCUSSION AND CONCLUSIONS

Many-year research conducted in the sub-mountain and mountain terrain, in several catchments with different levels of anthropogenic factors, such as agriculture, rural settlements or small town [3–7] revealed considerably diversified concentrations of chemical substances in surface waters. Water samples were collected in these catchments on average twice a month. The investigations were conducted for two years in the Wieprzówka river catchment [5], for 3 years in Barnczak [3], Górka [3], Rzyki "G" [7] and Gaj "D" [7] catchments, for 5 years in Rzyki "B" catchment [4] and for 6 years in the Trybska River catchment [6]. In comparison with the studies conducted in the above-mentioned catchments, results presented in this paper usually differ unfavorably from almost all assessed indices, however it did not depend on the fact that the differences occur within the range over or below limit values disqualifying the water (Tab. 2).

Only in the Sudół stream catchment in No.1 cross section situated in the agricultural area, values of some indices, particularly NO_2^-, NH_4^+ and K^+ were approximate to those obtained in the analyzed agricultural catchments [3, 4, 7] but lower than in settlement catchments [6, 7] or on the Wieprzówka stream in the cross section localized below a big city [5] despite a sewage treatment plant operating in the city (Tab. 2). The concentrations of NO_3^- looked different. They were higher in the waters of watercourses draining agricultural and agricultural-settlement type catchments and in the stream flowing through a small town, than in the Sudół and Drwinka urbanized watercourses in the area of a large

Table 2. Some physico-chemical properties of small watercourse waters depending on the dominant form of anthropopressure in the catchment

Property		Kind of anthropopressure, name of watercourse, measurement-control section												
		Agricultural – point (1), urbanized – point (2)		Urbanized – points (3) and (4)		Agricultural [3, 4, 7]*			Agricultural – settlement [3, 7]*		Agricultural – settlement „Trybska Rzeka" at Trybsz [6]*		Urban „Wieprzówka" at Andrychow [5]*	
		„Sudół"		„Drwinka"		„Rzyki" B	„Rzyki" G	„Barnczak"	„Gaj" D	„Górka"	above settlement	below settlement	above town	below town
		(1)	(2)	(3)	(4)									
pH		7.36	8.04	7.82	7.39	7.33	7.5	7.89	7.6	7.72	8.05	8.05	7.60	7.54
EC	[$\mu S \cdot cm^{-1}$]	1615	2358	1201	1308	–	–	771	–	711	–	–	182	288
SP	[$mg \cdot dm^{-3}$]	581	794	798	831	70	188	371	291	356	214	251	124	181
NH_4^+		0.41	6.18	0.60	3.66	0.82	0.80	0.53	0.87	2.18	0.58	0.95	0.59	1.05
NO_2^-		0.04	0.86	0.69	0.61	–	–	–	–	–	–	–	0.01	0.16
NO_3^-		3.59	9.58	5.31	6.12	41.76	21.70	19.7	11.96	21.39	13.9	18.3	12.09	18.95
PO_4^{3-}		0.26	3.48	0.33	1.83	0.08	0.05	0.18	0.06	0.82	0.06	0.27	0.07	1.17
SO_4^{2-}		75.2	214.6	138.0	181.5	34	42	52.2	58	51	29.3	34.1	24.6	32.3
$Fe^{2+/3+}$		0.30	0.22	0.64	0.59	0.15	0.18	0.11	0.21	0.28	0.07	0.13	0.04	0.10
Cl^-		40.9	62.2	115.3	132.6	8.4	11.0	24.2	26.0	25.1	0.8	3.0	7.0	16.1
K^+		1.09	11.31	27.67	11.54	1.45	2.59	–	1.28	–	0.76	1.51	–	–
Mn^{2+}		0.22	0.18	0.66	0.40	–	–	0.13	–	0.26	–	–	0.09	0.12
Na^+		25.78	48.55	76.64	64.18	8.18	10.8	–	18.4	–	5.76	8.14	–	–
Mg^{2+}		22.01	22.81	32.81	20.15	–	5.9	–	8.3	–	8.65	9.45	–	–
Ca^{2+}		97.0	129.8	120.7	118.0	–	33	–	58	–	47.7	56.8	–	–

EC – electroconductivity; SP – dry residue, * – references city (Tab. 2). The effect of settlement with uncontrolled sewage discharge (see the Gaj D and Górka streams and the Trybska river below and above the settlement), as well as the effect of urban areas (the Wieprzówka stream above and below Andrychów or the Sudół stream) became mainly evident as an increase in concentrations of ammonium and nitrite forms of nitrogen, phosphates and potassium (Tab. 2).

On the basis of the obtained results it may be concluded that:

1. The Sudół stream catchment is characterized by a more diversified level of anthropopressure than the Drwinka catchment, whose waters are degraded both in its source section and over 4 kilometers below the sources.
2. In the sections located in the urbanized area the waters of both watercourses are unsuitable for use; in their present state they cannot be used for feeding small ornamental ponds or water network in the area of the A. and E. Jerzmanowski Park planned for the reconstruction, whereas small retention flood control reservoir planned for construction on the Sudół stream may be threatened with eutrophication.
3. The poor water quality in the large city area was most affected by high concentration of phosphates, ammonium and nitrite forms of nitrogen, iron and manganese; the poor water quality was also evident as higher electroconductivity.
4. In the catchment of increasing environmental pressure (the Sudół) concentrations of ammonium, nitrites, phosphates and even sulphates and potassium were growing considerably along the watercourse.
5. Waters threatened with strong anthropopressure are characterized by a considerable variability of pollutant concentrations. This is especially true for biogens, potassium and sulphates.

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