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Monitoring of selected fertilizer nutrients in surface waters and soils of agricultural land in the river valley in Central Poland

Irena BURZYŃSKA ABCDEF ✉

Institute of Technology and Life Sciences, Falenty, al. Hrabska 3, 05-090 Raszyn, Poland; e-mail: i.burzynska@itp.edu.pl

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Abstract

The aim of the study was to assess the content of soluble forms of fertilizer nutrients (N, P, K) in the cultivated soil layer up to 20 cm deep from agricultural land in the river valley, and the concentration of these nutrients in the surface waters of the Raszynka River.

In the years 2016–2017, the surface water samples from the Raszynka Rriver (17 points) and soil (19 points) were collected from agricultural areas near the Raszynka River.

The surface water samples were collected once a month during the March–October 2016–2017. The contents of nitrogen (N_{tot}, NO_3-N and NH_4-N), phosphorus (P_{tot}, PO_4-P), total organic carbon (TOC and K and Ca) in soils and in waters were determined in the sample solutions.

It was shown that river water was of low quality due to the high concentration of nitrogen and phosphorus and electrical conductivity (*EC*). The most polluted were the waters of the lower section of the river located in the vicinity of arable land and agricultural built-up areas. The soluble forms of nutrients content in the cultivated soil layer was varied depending on the kind of nutrient, way of agricultural land use, and the term of soil sampling. The content of dissolved P forms in the soil was the highest in autumn on arable lands after harvesting of vegetables (GO-W: 10.24 mg $P_{tot}·kg^{-1}$ in D.M.) and this component may migrate with surface runoff and increase the risk of surface water eutrophication.

Key words: *agricultural catchment, cultivated soil layer, nutrients, surface waters, the river valley*

INTRODUCTION

Agricultural pollution is mainly of an area nature and concerns the loss of nutrients from mineral and organic fertilizers used on arable land and erosion processes affecting the migration of nutrients in the environment [ZAK *et al.* 2018; ZBIERSKA (ed.) 2002]. The way of using agricultural land may affect on rate of erosion, the soil moisture, the availability nutrients, return of biomass to the soil and the soil structure [PRIJONO *et al*. 2015; SURYOPUTRO *et al.* 2018]. According to studies by SAVCI [2012] from a dose of nitrogen fertilizer introduced into the soil only about 50% take plants, 25% is immobilized in soil, 20% is gas loss and 5% is leaching.

Intensification of agricultural production against the background of increasing climate changes may increase the migration of nutrients to the surface waters [DODDS 2007; JEPPESEN *et al*. 2010; WOLF *et al.* 2005]. The problem of eutrophication of surface waters concern about 40% of the world's waters and it is closely related to the nutrients concentration, especially nitrogen and phosphorus [GAŁCZYŃSKA, BUŚKO 2016; GARG, GARG 2002; JEPPSEN *et al*. 1999; LIU *et al*. 2008; WWAP 2009]. Excessive enrichment of surface waters with nutrients degrades aquatic ecosystems and impedes the economic use of waters for agriculture and other purposes. Nutrients from agricultural sources (nitrogen and phosphorus) from the Poland territory are discharged into the Baltic Sea by the Vistula River (54% of waters) and the Odra River (34% of waters) [IGRAS, PASTUSZAK (ed.) 2009].

The aim of the study was to evaluate the content of selected mineral nutrients, i.e. N, P, K, Mg, Ca in the cultivated soil layer from soils agricultural used in the river valley in the aspect of the surface water quality of the river in the agricultural catchment.

MATERIALS AND METHODS

The studies carried out in the agricultural catchment of the Raszynka River (N 52’08’34.1 E 020’56’09.5), which is the right tributary of the Utrata River. The Raszynka River is a small lowland river in Center Poland with a length of 17.40 km and flowing through two districts i.e. Piaseczno and Pruszków in the Masovia Province. The source of the river is taking its origin in the commune of Lesznowola, and in the final section of the Raszynka River it flows into the Utrata River.

The river catchment covers an area of 75.9 km^2 and is situated on the border between the mesoregions of the Łowicko-Błońska Plain (the lower part of the basin) and the Warsaw Plain (middle and upper part) [CZARNECKA (ed.) 2003]. In the river valley there are mostly black cumulative soils and brown soils according to the classification PTG 2011 [MARCINEK, KOMISAREK (ed.) 2011].

The research area is located in the third climate zone of Poland and is characterised by a vegetation period of 210–220 days and low annual precipitation of 450–500 mm.

The catchment had agricultural specifics, and arable lands constitute 65.5%, built-up areas 24.0%, forests 11.5%, and soils 2.5% of the land development structure. The direct vicinity of the city of Warsaw boosts high demand for agricultural products, fostering production of vegetables in the municipalities neighbouring the Warsaw metropolitan area.

In 2016–2017 the surface water samples were taken from the Raszynka River (17 points) and the soil (19 points) samples were taken from the land situated near this river. Surface water samples were collected once a month during March–October 2016–2017 period in accordance with PN-EN 25667-2: 1999. Soil samples from the cultivated soil layer up to 20 cm deep were collected twice a year, i.e. early spring (March) and autumn (October) 2016–2017. Soil samples were taken from agricultural land located in the vicinity of the river, i.e. arable land (GO-W and GO-K), grassland (UZ-P and UZ-N), and wooded areas with alder (NU-L). pH value was measured in the solution from the soil (in 0.01 M $CaCl_2$) and in surface waters – potentiometry using a pH meter, according to PN-EN ISO 10390:1997 and PN-EN ISO 10523:2012. Determination of electrical conductivity (*EC*) of the surface waters tested was measured by the conductomer method according to PN-EN 27888: 1999.

Soil samples were mineralized in concentrated mineral acids (perchloric and nitric) according to the procedure PB/31/02/2014 – for K_{tot}, Ca_{tot}, P_{tot} and in sulfuric acid according to PB/31/03/2014 for N_{tot}. The total organic carbon (TOC) content in the soil samples was made using the Tiurn’s method [SAPEK, SAPEK 1997]. Labile forms of nutrient such as: N, P, K, Ca were determined after soil extraction with water solution (1:5) in accordance with PN-EN 13652: 2002.

Physicochemical measurements were made in surface water samples.

The content of nitrogen (N_{tot}, NO_3-N and NH_4-N), phosphorus (P_{tot}, PO_4-P) and TOC in solutions were determined using the automated method with segmented flux flow (SFA) in accordance with the Skalar methods and PN-EN ISO 13395:2001; PN-EN ISO 6878:2006; PN-EN 1484:1999. The content of K and Ca in solutions measured by atomic flame spectrophotometry [PN-ISO 9964-2:/Ak: 1997]. Total organic carbon (TOC) content in the soil was determined by the manual colorimetric method [SAPEK, SAPEK 1997].

All chemical analyses were performed at the Research Laboratory of Environmental Chemistry in the Institute of Technology and Life Sciences at Falenty.

Table 1. Description of the surface waters and soils sampling from the agricultural land in the vicinity of the Raszynka River

Part of the river	Km of the river	Water sampling point	Soil sampling point	Locality	Community	Land use
Lower	0.0–4.50	R-1	G-1 and G-2	Podolszyn Nowy	Lesznowola	NU-L
		R-2	G-3	Łady	Raszyn	NU-L
		R-3	G-4	Dawidy B	Raszyn	GO-W
		R-4	G-5	Dawidy	Raszyn	UZ-P
		R-5	G-6	Dawidy	Raszyn	GO-W
		R-6	–	–		–
Middle	4.60–11.0	R-7	G-7	Jaworowa	Raszyn	UZ-P
		R-8	G-8	Jaworowa	Raszyn	UZ-P
		R-9	G-9	Falenty, al. Hrabska	Raszyn	NU-N
		R-10	G-10	Falenty, GOŚ	Raszyn	GO-W
		R-11	G-11	Falenty, before GOŚ Raszyn	Raszyn	UZ-P
		R-12	G-12	Raszyn ditch Opaczewski	Raszyn	GO-W
		R-13	G-13	Raszyn	Raszyn	NU-N
			G-14	Raszyn	Raszyn	NU-N
			G-15	Raszyn	Raszyn	NU-N
Upper	11.5–17.0	R-14	G-16	Michałowie Wieś	Michałowice	NU-L
		R-15	G-17	Michałowie Wieś	Michałowice	GO-K
		R-16	G-18	Pęcice	Michałowice	UZ-N
		R-17	G-19	Pęcice	Michałowice	UZ-N

Explanations: GOŚ = Communal Sewage Treatment Plant, GO-W = arable land, vegetable grown; GO-K = arable land, maize; UZ-P = production meadow; UZ-N = natural meadow; NU-L = alder forest.
Source: own elaboration.

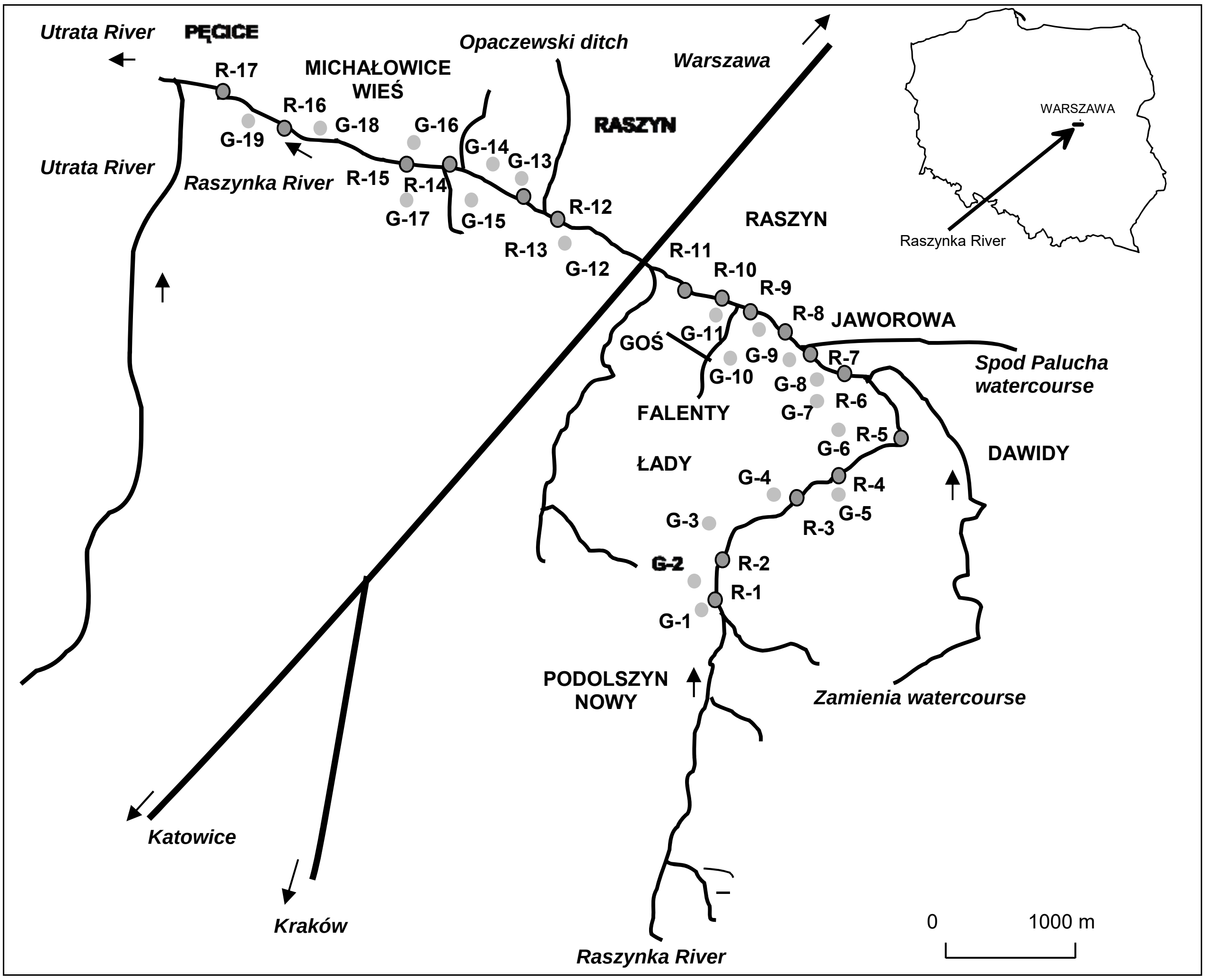

Fig. 1. Measuring points in the catchment of the Raszynka River; source: own elaboration

STATISTICAL ANALYSIS

The obtained results were processed statistically using Statistica 7.0. In order to evaluate the physico-chemical parameters in the Raszynka River, a one-way ANOVA variance analysis was performed for the mean values. The significance of the differences between the mean values was checked with the Tukey's HSD (honest significant difference test) level of $p = 0.05$.

RESULTS AND DISCUSSION

SELECTED PHYSICOCHEMICAL PARAMETERS OF THE RASZYNKA RIVER WATERS

The pH of waters from the Raszynka River were in the range 6.89–9.04 pH at the average pH value of pH 8.00 in the years 2017–2018. The obtained value was on the border of the acceptable pH range for the lowland sandy and clay river [Rozporządzenie… 2016]. There were no significant differences between the average pH values between parts of the river (Tab. 2).

River waters were excessively contaminated with mineral nutrients, because the average value of electrical conductivity (*EC*) was 753 $\mu S \cdot cm^{-1}$ and exceeded the acceptable range for the 2nd quality class for the surface waters [Rozporządzenie… 2016]. A significant variation of the *EC* values of these surface waters (80–1149 $\mu S \cdot cm^{-1}$).

The range of nitrate nitrogen concentration in the Raszynka River water was varied from 0.09 to 7.55 mg $N\text{-}NO_3 \cdot dm^{-3}$. The average concentration of these nutrients in parts of the Raszynka River was even 1.5–2 times higher than the limit values for the 2nd quality class for the surface waters [Rozporządzenie… 2016]. The most polluted with this nutrient was water taken from the upper section of the Raszynka River (0.0–4.5 km) near that, there were arable lands under cultivation of vegetables (Tab. 2). The concentration of $N\text{-}NO_3$ in the surface waters from the lower section of the river (11.5–17.0 km), although it was outside the acceptable range, it was much smaller than in the upper part of this river. In the structure of land use in the lower part of the river, natural meadows dominated without economic use. The way land use was probably had an effect on the partial reduction of $N\text{-}NO_3$ concentration in river waters. A similar tendency of lower water pollution in the lower part of the Raszynka River was also observed by PAWŁAT-ZAWRZYKRAJ [2003] and DĄBKOWSKI, PAWŁAT-ZAWRZYKRAJ [2003].

Table 2. Selected physicochemical parameters in the waters of the Raszynka River in 2016–2017

Part of the river	Value	pH	*EC* μS·cm^{-1}	N-NO$_3$	N-NH$_4$	P-PO$_4$	K	Ca	OWO
				mg·dm^{-3}					
Lower (*n* = 40)	mean	8.02 a	792 a	5.17 a	4.66 a	0.49 a	13.68 a	65.32 a	7.75 a
	min–max	7.24–9.01	80–1053	0.29–11.23	0.02–28.18	0.09–0.83	6.65–33.75	19.50–108.30	4.18–30.92
	SD	0.34	179	3.24	8.74	0.21	6.62	24.85	4.85
Middle (*n* = 38)	mean	7.96 a	723 a	4.24 ab	1.08 b	0.38 a	15.25 a	53.50 a	7.27 a
	min–max	6.83–9.04	149–1149	0.09–7.55	0.05–13.72	0.07–0.78	6.62–38.79	10.66–99.81	3.35–16.00
	SD	0.60	179	2.76	2.76	0.20	7.62	23.66	2.28
Upper (*n* = 22)	mean	7.99 a	737 a	3.20 b	0.39 b	0.34 a	11.22 a	50.92 a	7.14 a
	min–max	7.14–8.96	498–974	1.38–5.58	0.07–2.11	0.14–0.66	8.34–18.91	17.94–80.81	5.86–9.74
	SD	0.50	136	1.02	0.49	0.15	3.18	16.00	1.16
All (*n* =100)	mean	8.00	753	4.38	2.36	0.41	13.74	57.66	7.43
	min–max	6.83–9.04	80–1149	0.09–7.55	0.02–28.18	0.07–0.83	6.62–38.79	10.66–108.30	3.35–30.92
	SD	0.54	172	2.54	6.05	0.20	6.59	23.48	3.40

Explanations: *EC* = electrical conductivity; *SD* = standard deviation; TOC = total organic carbon; *n* = numbers; a, b = homogenous groups.
Source: own study.

The Raszynka River waters were also excessively contaminated with ammonium nitrogen (0.02–218.18 mg N-NH$_4$·dm^{-3}), and the average concentration of this nutrient depended on the river section. Surface waters from the upper part river were most polluted with ammonium nitrogen and average value of this nutrient was many times exceeded the acceptable range for surface waters [Rozporządzenie… 2016] (Tab. 2). Least of ammonium nitrate was in the lower part of river, and its average concentration was typical for 2nd class quality of the surface waters. Ammonium ions in surface waters usually come from the biochemical decomposition of organic nitrogen compounds of plant or animal origin, they also formed in the nitrate reduction process. The source of ammonium ions may also be uncontrolled discharge of sewage from human settlements and industry [HERMANOWICZ *et al.* 1999].

Surface waters taking from the Raszynka River were of poor quality due to the phosphate phosphorus high concentration. The concentration of this nutrient was range 0.07 to 0.83 mg of PO$_4$-P·dm^{-3} and no significant differences were found between the average values in parts of this river (Tab. 2). Studies conducted by DĄBKOWSKI and PAWŁAT-ZAWRZYKRAJ [2003], PAWŁAT-ZAWRZYKRAJ [2003] and BURZYŃSKA [2015; 2016], show that the waters taking agricultural origin from the Raszynka River were of poor quality due to nitrogen and phosphorus high concentration. The potassium and calcium concentrations in the surface waters were small (<16.0 mg K·dm^{-3} and <70.0 mg Ca·dm^{-3}) and did not change in parts of the river.

The average concentration of organic substances expressed in total organic carbon in the river waters were low (<8.00 mg TOC·dm^{-3}) and did not differ in individual parts of the river (Tab. 2).

PH VALUE AND SELECTED NUTRIENTS CONTENTS IN AGRICULTURAL SOILS FROM THE RIVER VALLEY

The total organic carbon (TOC) content in soils of agricultural land in the vicinity of the Raszynka River was varied in the range 11.4–145 g TOC·kg^{-1} in D.M. The highest average content of this nutrient was found in soils taking from the natural meadows and the alder forest (623 g TOC·kg^{-1} in D.M.). It's lowest content was obtained in arable land soils (GO-K: 20.5 and GO-W: 21.4 g TOC·kg^{-1} in D.M.) – Table 3. The obtained results are confirmed by the studies GŁODOWSKA and GAŁĄZKA [2018] and ZBYTEK

Table 3. pH value and N, P, K, total organic carbon – TOC (g·kg^{-1} in D.M.) content in the cultivated soil layer (to 20 cm depth) from agricultural land used in the vicinity of the Raszynka River in 2016–2017 (*n* = 40)

Land use category	Value	pH$_{CaCl2}$	TOC	N$_{tot}$	P$_{tot}$	K$_{tot}$	Ca$_{tot}$
			Parameters of the soil				
			g·kg^{-1}				
Arable land, vegetable grown (GO-W)	mean	6.37	21.4	1.82	0.79	1.69	3.50
	min–max	6.01–6.78	11.4–34.2	1.03–2.25	0.45–1.14	1.20–2.50	1.11–10.57
	SD	0.24	0.85	0.06	0.03	0.04	0.25
Arable land, maize (GO-K)	mean	6.41	20.7	1.80	0.84	0.98	2.86
	min–max	6.35–6.49	20.1–21.1	1.59–1.19	0.80–0.86	0.70–1.26	2.07–3.55
	SD	0.06	0.05	0.02	0.01	0.03	0.70
Meadows of productively use (UZ-P)	mean	6.77	57.2	2.95	0.68	1.19	3.62
	min–max	6.46–7.30	19.5–145.0	1.58–8.48	0.33–1.69	0.50–3.20	1.14–9.85
	SD	0.26	3.79	0.20	0.05	0.08	0.30
Natural meadows (UZ-N)	mean	6.36	62.3	3.61	2.40	1.00	3.18
	min–max	6.23–6.45	48.1–97.20	1.81–6.00	1.39–4.00	0.50–1.65	1.18–5.54
	SD	0.08	1.85	0.15	0.10	0.04	0.13
Alder forest (NU-L)	mean	6.25	62.3	5.45	1.18	1.40	3.21
	min–max	6.01–6.70	26.6–110.1	4.46–6.96	1.10–1.31	1.18–1.61	2.58–3.75
	SD	0.30	4.30	0.13	0.01	0.01	0.06

Explanations: *n*, *SD* as in Tab. 2.
Source: own study.

and TALARCZYK [2012]. These authors showed that intensification of cultivation and fertilization, crops on arable lands, contributes to reducing crop residue and the soil organic matter (SOM) reduce the formation. These factors contribute to the reduction of the soil potential production and may lead to of the agricultural soils degradation.

Total nitrogen content in the soil layer up to 20 cm deep similar to TOC was varied in the range: 103–848 mg $N_{tot}·kg^{-1}$ in D.M. on the agricultural land with diversified use. The smallest average content of this nutrient was found on the arable land (180 mg $N_{tot}·kg^{-1}$ in D.M.) and highest value was obtained under alder forest (5.45 mg $N_{tot}·kg^{-1}$ D.M.).

The content of soluble forms of nutrients in the cultivated soil layer was varied depending on the kind of nutrient, way of agricultural land use, and the term of soil sampling (Fig. 2). The soils of arable land had a much lower content of the easily soluble form of nitrogen than the grassland and alder forest (Fig. 2). The most fertile of nitrate nitrogen was the soil from the alder forest in (107.82 mg $N-NO_3·kg^{-1}$ D.M.) and meadows taking in the autumn (UZ-P; 89.95 and UZ-N; 80.53 mg $N-NO_3·kg^{-1}$ D.M.). However, ammonium nitrogen content in soils was significantly higher in the autumn than in the spring. The obtained tendency may indicate of the decomposition processes of crop residues from arable fields (Fig. 2).

The factor influencing to release of P and N from soil and migration of these nutrients to the soil-water environment is the mineralization process of soil organic matter. The process of soil mineralization of organic matter is the main cause of excessive release of these components to the soil solution, and the factors determining its pace is the change of redox conditions caused by the use of especially agrotechnical measures favouring oxygenation of soil [SAPEK 2010].

Losses of soil nitrogen after harvesting crops may pose a greater threat to the deterioration of water quality in the autumn and winter period, mainly during atmospheric precipitation, because the NO_3^- anion is not subject to exchangeable sorption in the soil and is easily leached by rainwaters [CIEĆKO *et al.* 1996; JADCZYSZYN *et al.* 2010; VOS, MACKERRON 2000].

The total phosphorus (P_{tot}) content in the assessed soils from the Raszynka River valley occurred in a wide range of 0.33–4.00 mg $P_{tot}·kg^{-1}$ D.M.). However, the most abundant in this nutrient was the soil taking from the natural meadow (2.40 mg $P_{tot}·kg^{-1}$ D.M.) and the alder forest (1.18 mg $P_{tot}·kg^{-1}$ D.M.) – Table 3.

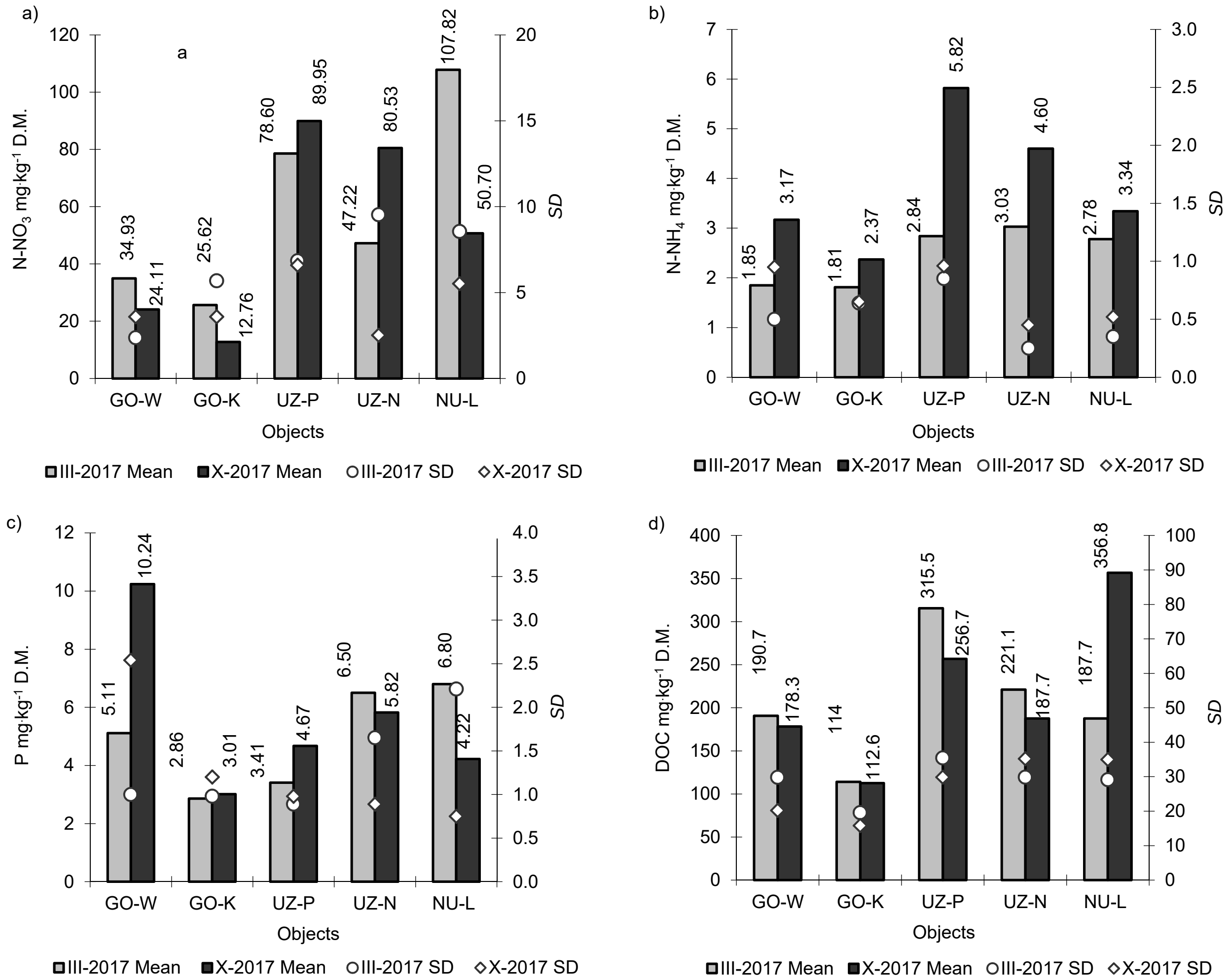

Fig. 2. The content of selected fertilizer nutrients in a soil layer up to 20 cm deep on the agricultural lands located in the vicinity of the Raszynka River: a) $N-NO_3$, b) $N-NH_4$, c) P, d) DOC; source: own study

The content of dissolved P forms was the highest in autumn after harvesting of ground vegetables from the arable land located in the river valley (GO-W: 10.24 mg $P_{tot}·kg^{-1}$ D.M.). The smallest of this nutrient content in soil, regardless of the time of sampling, was recorded in tons soils under long-term of the maize cultivation (GO-K: 2.86 mg $P_{tot}·kg^{-1}$ D.M.) – Figure 2. Small contents of some nutrients in the soil under maize cultivation may indicate a significant of the soil depletion, because the maize is a plant with high nutritional needs.

The dissolved P content in soil from natural meadows and from alder forest were slightly larger in spring (<7.00 mg $P·kg^{-1}$ in D.M.) than in autumn (<5.00 mg $P·kg^{-1}$ in D.M.) – Figure 2.

Phosphates are compounds which are strongly connected by soil colloids because insoluble salts are formed during the reaction between phosphorus soluble from phosphate fertilizers and aluminum, iron and calcium ions. These salts considerably limit the availability of phosphorus for plants (phosphorus backflow) [FOTYMA *et al.* 1987; GŁODOWSKA, GAŁĄZKA 2018].

Dissolved phosphorus in the soil solution is accumulated in the largest amount in the top soil and may to migrate with the surface runoff and increase the risk of the surface water eutrophication. Even a small concentration of this component in the waters is considered dangerous for water quality [GORLACH, GAMBUŚ 1997; HOODA *et al.* 1999].

Similar studies on the land use methods of N_{tot}, P_{tot}, BZT_5 concentrations in the surface waters, in Asia (Korea) were run by LEE *et al.* [2009]. These authors showed that the relationship between the studied parameters is influenced by crop types, irrigation and drainage systems and environmental conditions, i.e. precipitation, soil type and temperature.

In addition, it has been shown that the probability of deterioration of surface water quality is higher when there is a large diversity of land use in the catchment.

Most of the risks of surface water pollution in Poland are related to the structure of agricultural land use, and in particular the significant predominance of arable land (60%) over grassland. The trend obtained is the largest indicator in the EU [JANKOWSKA-HUFLEJT 2006; ZBIERSKA (ed.) 2002].

Is estimated that permanent grassland in Poland accounts for only 21% of agricultural lands and 13% of the entire country [JANKOWSKA-HUFLEJT 2006]. According to RYSZKOWSKI *et al.* [2003], a strip of meadows with a width of 8 to 10 m can remove 64 to 97% (on average 90%) of nitrates permeating the root system into waters. The excess of nitrates probably accumulates in the form of organic nitrogen in the root zone and is therefore not leached out constituting a geochemical barrier. In order to limit the risk of contamination of surface water with fertilizer components in agricultural catchments, and especially in river valleys, monitoring of the contamination of the cultivated soil and water layer should be carried out.

CONCLUSIONS

1. The Raszynka River waters were of low quality due to the high concentration of nitrogen, phosphorus and electrical conductivity (*EC*). The most polluted of surface waters of the lower section of the river located in the vicinity of arable land and agricultural built-up areas, and the least water from the upper part of the river in the vicinity of the natural meadows.
2. The soluble forms of nutrients content in the cultivated soil layer were varied and depending on the kind of nutrient, way of agricultural land use, and the term of soil sampling.
3. The total organic carbon content in the soils of agricultural land in the vicinity of the Raszynka River varied (11.4–145 g $TOC·kg^{-1}$). Much more abundant of TOC and total dissolved forms of N and P were the meadow soil, especially of natural meadows (UZ-N) and from the alder forest than from the arable land, especially under growing maize (GO-K).
4. The organic matter content in the meadow soils stabilized of dissolved N and P forms release and constituted a geochemical barrier limiting the pollution of the lower part of the river.
5. The nitrogen and phosphorus content in the soils from the arable land was small, except for fields after autumn harvest of the ground vegetables. However, the concentration of these nutrients in the river's waters frequently exceeded the acceptable concentration range for the surface waters.
6. Dissolved P forms content in the soil was the highest in autumn on arable lands after harvesting of vegetables (GO-W: 10.24 mg $P_{tot}·kg^{-1}$ in D.M.). This nutrient may migrate with the surface runoff and to increase the risk of surface water eutrophication.
7. In order to limit the effects of uncontrolled spreading of nutrients to the environment, periodic monitoring of the cultivated soil layer and surface water in river valleys in agricultural areas should be carried out.

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Irena BURZYŃSKA

Monitoring składników nawozowych w wodach powierzchniowych i glebach użytkowanych rolniczo w dolinie rzecznej

STRESZCZENIE

Celem pracy była ocena zawartości rozpuszczalnych form składników nawozowych (N, P, K) w uprawnej warstwie gleby do 20 cm głębokości na gruntach rolniczych w dolinie rzecznej oraz stężenia tych składników w wodach powierzchniowych rzeki Raszynki.

W latach 2016–2017 do badań pobierano próbki wód powierzchniowych z rzeki (17 punktów) i gleby (19 punktów) z terenów rolniczych sąsiadujących z rzeką Raszynką. Próbki wód powierzchniowych pobierano raz w miesiącu w okresie III–X 2016–2017. W roztworach wodnym i po ekstrakcji gleby oznaczono zawartość związków azotu (N_{og}, $N\text{-}NO_3$ i $N\text{-}NH_4$), fosforu ($P_{og,}$ $P\text{-}PO_4$), ogólnego węgla organicznego – OWO (ang. total organic carbon – TOC) oraz K i Ca. Wykazano, że wody rzeki były niskiej jakości ze względu na znaczne stężenie azotu i fosforu oraz wartości przewodności elektrycznej właściwej (*EC*). Najbardziej zanieczyszczone były wody dolnego odcinka rzeki położone w sąsiedztwie gruntów ornych oraz rolniczych terenów zabudowanych. Zawartość rozpuszczalnych form składników w uprawnej warstwie gleby była zróżnicowana w zależności od rodzaju składnika mineralnego, sposobu użytkowania gruntów rolnych oraz terminu pobrania próbek gleby.

Zawartość rozpuszczonych form P w glebie była największa jesienią na gruntach ornych po zbiorze warzyw (GO-W: 10.24 mg $P_{og}\cdot kg^{-1}$ s.m.), a składnik ten może migrować ze spływem powierzchniowym i zwiększać ryzyko eutrofizacji wód powierzchniowych.

Słowa kluczowe: *dolina rzeczna, składniki biogenne, uprawna warstwa gleby, wody powierzchniowe, zlewnia rolnicza*