ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 16, No. 4 2009

Małgorzata RAFAŁOWSKA[1] and Andrzej SKWIERAWSKI[1]

INFLUENCE OF AN AGRICULTURAL FARM ON THE EFFLUENT OF PHOSPHORUS BY A DRAINAGE NETWORK

WPŁYW GOSPODARSTWA ROLNEGO NA ODPŁYW FOSFORU SIECIĄ DRENARSKĄ

Abstract: The aim of the research was to determine the influence of intensive farming on seasonal changes in drainage waters flowing out of catchment areas classified as lands particularly exposed to water pollution from agricultural sources.

The research of the influence of farming on the outflow of phosphorus by a drainage network was conducted in 2005 and 2006 in the catchment area of Dobskie Lake. The research object is situated in the area of the Mazurian Lakeland, in the village of Doba. Agricultural areas surrounding the village are used by an agricultural farm named Dobrol, which specialises in pig husbandry.

During the 2-year research period, it was noted that the amount of phosphorus flowing by the drainage network depended most of all on atmospheric conditions, season and intensity of agricultural exploitation of the area.

Keywords: catchment area, drainage area, phosphorus

Waters flowing from agriculturally utilized areas are enriched with substances, whose type and amount depends on the geological structure of the subsoil, terrain relief, types of soils and their buffer and sorption capabilities. The quality of water also depends on the method of land management, intensity of agrotechnology, drainage systems and climate conditions influencing the availability of the water for plants [1–4]. Draining agriculturally utilised areas speeds up the outflow of water and intensifies the washing out of components from the soil, which is particularly visible on the example of light soil leaching [3, 4]. The main source of biogenic components in the agriculturally utilised catchment is mostly mineral and organic fertilization which, when misused, can contribute to a substantial overload of drainage waters. Mineral com-

[1] Department of Land Reclamation and Environmental Management, University of Warmia and Mazury in Olsztyn, pl. Łódzki 2, 10–957 Olsztyn, Poland, tel. 089 523 39 92, email: malgorzata.rafalowska@uwm.edu.pl

ponents, mostly nitrogen and phosphorus, not utilised in the process of agricultural production, lead to the pollution of ground and surface waters (eutrophication).

The aim of the research was to determine the influence of intensive farming on seasonal changes in phosphorus concentrations in drainage waters flowing from catchments classified as areas particularly exposed to water pollution from agricultural sources.

Research material and methods

The research on the influence of farming on the phosphorus effluence through a drainage network was conducted in 2005–2006 in the catchment of Dobskie lake. The research object is situated in the area of the Mazurian Lakeland, in the village of Doba. The agricultural lands surrounding the village are used by a farm which specialises in pig husbandry.

The research covered three drainage areas marked with numbers 520, 521, 523, situated in the vicinity of the Doba village in the catchment of Dobskie lake (Fig. 1). According to the guidelines of the Nitrate Directive [5], those catchments are part of an area particularly exposed to pollution, in which the nitrogen effluence from agricultural sources should be limited. The area was marked on the basis of the nitrate concentration in ground waters, which reaches 95 mg · dm^{-3} [6].

The catchment of the drainage area no. 520 is 9.7 ha. On the agricultural lands, in 2005 winter wheat was grown, and in 2006 – spring barley. In the research period,

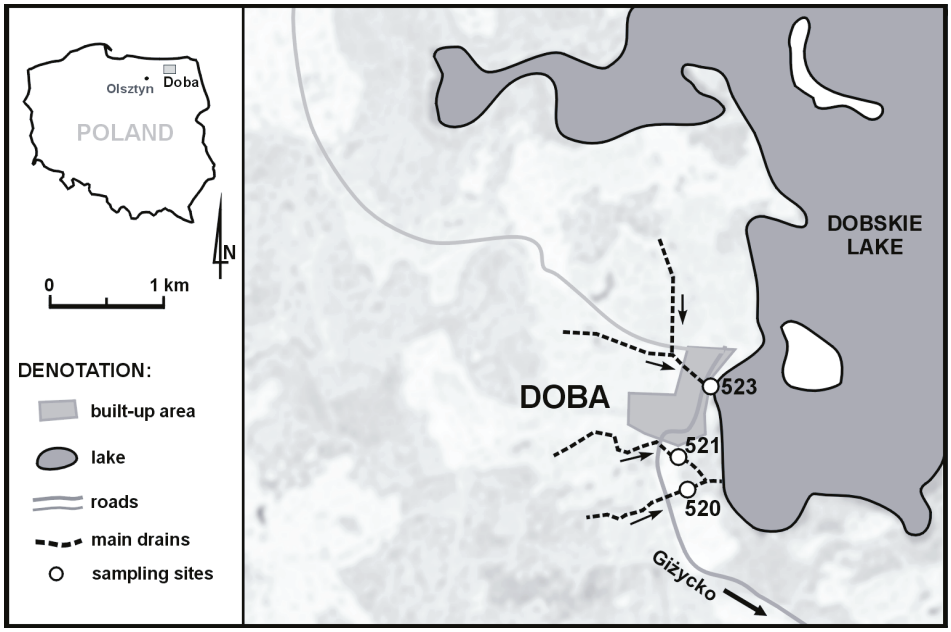

Fig. 1. Location of the research area and sampling sites

mineral fertilisation on similar levels was used – namely, in 2005 it was N-112 kg · ha^{-1}, P_2O_5-40 kg · ha^{-1}, K_2O-48 kg · ha^{-1}, and in 2006 N-98 kg · ha^{-1}, P_2O_5-46 kg · ha^{-1}, K_2O-60 kg · ha^{-1}.

The catchment of the drainage area no. 521 is 15.1 ha. In 2005, winter triticale was grown there. Mineral fertilisation was used in the amount of N-61 kg · ha^{-1} and organic fertilisation in the form of liquid manure at 20 m^3 · ha^{-1}. In 2006, spring barley was grown and the fertilization was the same as for the catchment of the area no. 520. In June 2006, liquid manure was poured out. There are some farm buildings in the area of the catchment. The arable lands of both catchments are located on moderately compact soils (strong clayey sands) classified as IVa and IIIb soil quality class.

The drain no. 523, located in the vicinity of the buildings of the village of Doba, drains water from fertilized agricultural lands (N-68 kg · ha^{-1}, P_2O_5-40 kg · ha^{-1}, K_2O-55 kg · ha^{-1} in 2005 for barley cultivation, and in 2006 it was fertilized with N-88 kg · ha^{-1}, P_2O_5-41 kg · ha^{-1}, K_2O-54 kg · ha^{-1} for rye cultivation) as well as from allotments and the village settlement. The soils are light, classified as quality class V. The catchment area is 41.7 ha. Considering particular drainage areas according to the intensity of utilisation measured by the amount of fertilizers and the level of anthropogenic impact (farms, housing buildings and gardens), they can be put in the following sequence: 521 > 520 > 523.

Water samples for physicochemical analyses were collected once a month from drainage outlets and determined for general phosphorus (after mineralisation) and P-PO_4 using colorimetry with ammonium molybdate and tin(II) chloride as a reductor. These tests were conducted according to generally accepted methods [7]. Seasonal variability of phosphorus concentrations was discussed on the basis of the following division of samples: winter (January–March), spring (April–June), summer (July––September), autumn (August–December).

Results and discussion

During the two-year research period, it was noted that the amount of phosphorus flowing by the drainage network depended mostly on atmospheric conditions, season and the intensity of farming in the area.

The highest average concentration (1.035 mg P · dm^{-3}) of phosphorus was noted in waters flowing by the drain no. 521 in 2005 and it was 2.5 times higher than in 2006 (0.393 mg P · $dm^{-3)}$, which was caused by increased fertilization with liquid manure. The lowest average concentration of 0.243 mg P · dm^{-3} was noted in the waters of the drain no. 520 in 2006 (Table 1).

Average phosphatic phosphorus concentrations were distributed similarly to the general phosphorus concentrations. The highest concentration was noted in the waters of the drain no. 521, both in 2005 and in 2006 – respectively 0.336 and 0.208 mg P-PO_4 · dm^{-3}, and the highest on the site no. 520 – 0.066 mg P-PO_4 · dm^{-3}.

During the two research years, the greatest variability of general phosphorus concentrations was noted in the water of the drain no. 521, ranging from 0.210 to 3.729 mg P · dm^{-3} in 2005. The maximum concentration was noted in March, as a result of the

flow from the melting snow and because of the presence of farm buildings. In 2006, general phosphorus concentrations ranged from 0.151 to 1.144 mg P · dm^{-3}. The maximum concentration was noted in June because of the liquid manure poured out in that time. The smallest variability of general phosphorus concentrations characterised the water from the drainage area no. 523 – from 0.198 to 0.468 mg P · dm^{-3} in 2005 (Table 1).

Table 1

Average values and ranges of general phosphorus (P) and phosphatic phosphorus ($P\text{-}PO_4$) in the drainage waters in the years 2005–2006 [mg · dm^{-3}]

No. of drainage area	2005		2006	
	P	$P\text{-}PO_4$	P	$P\text{-}PO_4$
520	0.237* (0.045–0.507)**	0.098 (0.015–0.252)	0.243 (0.053–0.617)	0.066 (0.026–0.202)
521	1.035 (0.210–3.729)	0.336 (0.049–1.220)	0.393 (0.151–1.440)	0.208 (0.093–0.545)
523	0.304 (0.198–0.468)	0.171 (0.084–0.382)	0.279 (0.143–0.822)	0.145 (0.093–0.196)

* average concentration; ** range of concentrations

The variations in the concentration of phosphatic phosphorus were distributed similarly to the variations in the concentration of general phosphorus. Also in this case a much greater variation of concentrations was noted in the water of the drainage area no. 521, ranging from 0.049 to 1.220 mg $P\text{-}PO_4$ · dm^{-3}, and the smallest in the drainage area no. 523, with values ranging from 0.093 to 0.196 mg $P\text{-}PO_4$ · dm^{-3}.

As far as the seasonal distribution is concerned, the highest concentrations of general phosphorus and $P\text{-}PO_4$ in the drainage waters in 2005–2006 were noted in winter and spring. It is a result of the fact that very little of it was used by plants – in the conditions of excessive humidity and low temperatures leading to periodic oxygen deficits limiting the growth and development of plants. Phosphorus is a component which is easily released, particularly during oxygen deficits [8]. The maximum concentration was noted in the waters of the drain no. 521 – 1.62 mg P · dm^{-3} in 2005 and 0.80 mg P · dm^{-3} in 2006, which was influenced by the lack of vegetation and increased rainfall (Fig. 2). High concentrations of general phosphorus in 2005 in the water of the drainage area persisted practically for the whole year except for autumn, which confirms the role of the intensity of agricultural utilisation. As it was said before, this catchment area was fertilised with liquid manure. On the basis of the obtained results it can be stated that the largest amount of phosphorus can be found in the water coming from the area which was intensely fertilized with liquid organic fertilizers. The existence of such dependencies is also confirmed by high concentrations of phosphatic phosphorus, the highest in spring in the water of the drain no. 521 – 0.71 mg $P\text{-}PO_4$ · dm^{-3} in 2005, 0.35 mg $P\text{-}PO_4$ · dm^{-3} in 2006 (Fig. 3). The increased values of phosphorus concentrations should be attributed to the presence of areas with farm buildings. In 2006 (June) liquid manure was poured out near a drainage outlet, which increased the concentration of phosphorus forms, which additionally proves the negative influence of farming on the

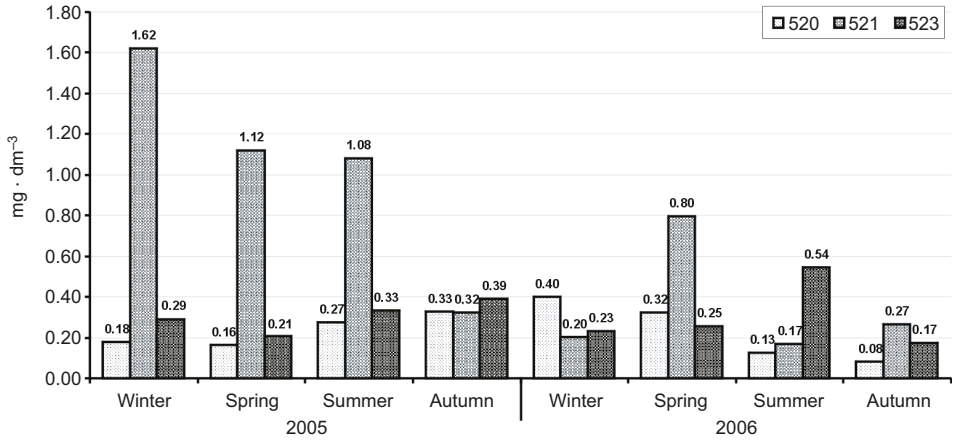

Fig. 2. Seasonal variability of general phosphorus concentrations in drainage waters flowing from the catchment of Doba in 2005–2006

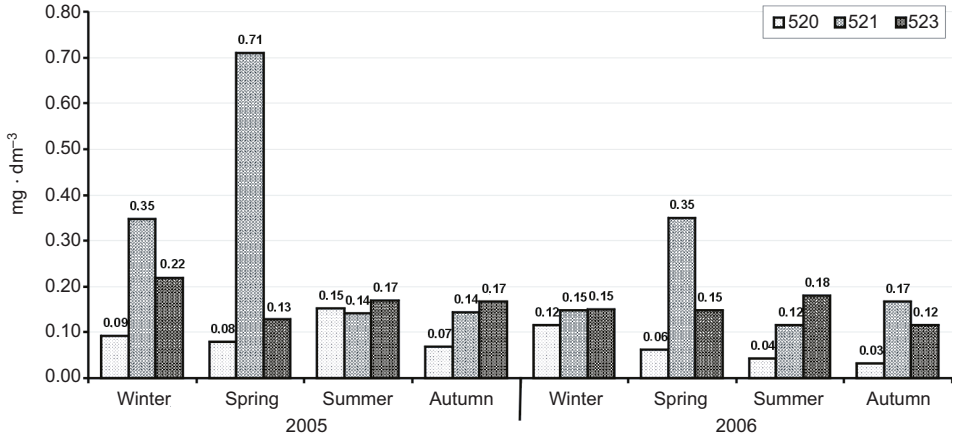

Fig. 3. Seasonal variability of phosphatic phosphorus ($P\text{-}PO_4$) concentrations in drainage waters flowing from the catchment of Doba in 2005–2006

quality of the catchment water. Of course, this action was not in accordance with the 'good farming practice' – actually, it was the contrary. The lowest concentration of general phosphorus and phosphatic phosphorus of all considered seasons was noted in the autumn.

The high concentration of general phosphorus contributed to the deterioration of the quality of the drainage waters to a larger extent than the concentration of phosphates. The average concentration of general phosphorus allows to classify the water from test sites no. 520 and 523 to the soil quality class II (good) and the water from the catchment of the liquid manure fertilized drainage area no. 521 to class V (poor). As far as the concentration of phosphates is concerned, the drainage waters represented mainly class II (good) [9].

Conclusions

1. During the 2-year test period it was noted that the amount of phosphorus flowing by a drainage network depended most of all on atmospheric conditions, season and intensity of agricultural utilisation of the area.

2. As far as seasonal distribution is concerned, the highest concentrations of general phosphorus and P-PO_4 for all drainage waters in 2005–2006 were noted in winter and spring. The maximum concentration was noted in drainage waters from the more intensely fertilized fields, where liquid manure was used – 1.62 mg P · dm^{-3} in 2005 and 0.80 mg P · dm^{-3} in 2006. These values were influenced by the lack of vegetation and increased rainfall.

3. The content of general phosphorus largely contributed to the lowering of the quality class of drainage waters. The average concentration of phosphorus allows to qualify the tested water from the areas of low fertilization to the II quality class (good), and the water from the catchment of the intensely fertilized drainage area close to rural buildings to the soil quality class V (poor).

4. The conducted research indicates that the area of the tested catchments, which was classified on the basis of phosphate content in the water as being at particular risk, also constitutes a potential threat due to its high phosphorus concentrations.

Acknowledgement

This study was carried out as part of the R&D project np. N N305 1056 33, financed by the Ministry of Science and Higher Education.

References

[1] Szpakowska B. and Życzyńska-Błoniak I.: *Migracja składników mineralnych w różnych ekosystemach*. [In:] Produkcja pierwotna, zasoby zwierząt i wymywanie materii organicznej w krajobrazie rolniczym, Bałazy S. and Ryszkowski L. (Eds.), ZBSRiL, Poznań 1992, 17–27.

[2] Igras J.: *Fosfor w wodach gruntowych w Polsce*. [In:] Chemia. Związki fosforu w chemii, rolnictwie i medycynie. Pr. Nauk. Akad. Ekonom. we Wrocławiu, 2001, (888), 86–90.

[3] Koc J. and Szymczyk S.: *Wpływ intensyfikacji rolnictwa na odpływ wapnia i magnezu z gleb*. J. Elementol., 2003, **8**(4), 231–238.

[4] Lipiński J.: *Drenowanie gleb mineralnych a środowisko przyrodnicze*. Wiad. Melior. Łąk., 2003, (2), 74–76.

[5] Dyrektywa Rady 91/676/EWG z dnia 12 grudnia 1991 r. w sprawie ochrony wód przed zanieczyszczeniem powodowanym przez azotany pochodzące ze źródeł rolniczych.

[6] Rozporządzenie nr 5/2004 Dyrektora Regionalnego Zarządu Gospodarki Wodnej w Warszawie z dnia 20 kwietnia 2004 r. w sprawie wprowadzenia programu działań mających na celu ograniczenie odpływu azotu ze źródeł rolniczych dla obszaru szczególnie narażonego w gminach: Giżycko i Węgorzewo.

[7] Hermanowicz W., Dojlido J., Dożańska W., Koziorowski B. and Zerbe J.: Fizyczno-chemiczne badanie wody i ścieków. Arkady, Warszawa 1999, 556.

[8] Szymczyk S. and Cymes I.: *Wpływ ilości opadów i sposobu użytkowania terenu na odpływ składników nawozowych siecią drenarską z gleb ciężkich*. Nawozy i Nawoż., 2004, **2**(19), 20–30.

[9] Rozporządzenie Ministra Środowiska z dnia 11 lutego 2004 r. w sprawie klasyfikacji dla prezentowania stanu wód powierzchniowych i podziemnych, sposobu prowadzenia monitoringu oraz sposobu interpretacji wyników i prezentacji stanu tych wód. Dz. U. nr 32, poz. 284.

WPŁYW GOSPODARSTWA ROLNEGO NA ODPŁYW FOSFORU SIECIĄ DRENARSKĄ

Katedra Melioracji i Kształtowania Środowiska
Uniwersytet Warmińsko-Mazurski w Olsztynie

Abstrakt: Celem badań było określenie wpływu intensywnej gospodarki rolnej na sezonowe zmiany stężeń w wodach drenarskich odpływających ze zlewni zakwalifikowanych do obszarów szczególnie narażonych na zanieczyszczenie wód ze źródeł rolniczych.

Badania nad wpływem gospodarstwa rolnego na odpływ fosforu siecią drenarską prowadzono w latach 2005–2006 w zlewni jeziora Dobskiego. Obiekt badań położony jest w obrębie Pojezierza Mazurskiego, w miejscowości Doba. Tereny rolnicze w otoczeniu wsi użytkowane są przez gospodarstwo rolne, które specjalizuje się w chowie trzody chlewnej.

W czasie 2-letniego okresu badań stwierdzono, iż ilość fosforu odprowadzanego siecią drenarską uzależniona była przede wszystkim od warunków atmosferycznych, pory roku oraz intensyfikacji rolniczego użytkowania terenu.

Słowa kluczowe: zlewnia, dział drenarski, fosfor