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COMPARISON OF THE CHEMICAL COMPOSITION OF SOIL-GROUND WATERS FROM FIELDS FERTILIZED WITH LIQUID MANURE AND MINERAL FERTILIZERS

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Summary. The studies were conducted on runoff waters from nine drained fields receiving various rates of fertilizers, located in a former state-owned-farm Nikutowo. Water samples were collected from five fields receiving liquid manure and four fields receiving mineral fertilizers, located in their vicinity. The fields mineral fertilized were situated in the protection zone of the Masurian Landscape Park, where liquid manure application is prohibited. It was found that liquid manure application, compared with mineral fertilization, resulted in a higher content of nitrogen, phosphorus, calcium and magnesium in drainage waters. An increase in the nitrogen content concerned first of all $N\text{-}NO_3$ and $N\text{-}NH_4$. As regards phosphorus, an increase was noted mainly in the content of its organic form.

Keywords: nutrients leaching, soil, slurry, mineral fertilizers.

INTRODUCTION

Agricultural land is often perceived as one of major sources of pollution, leading to eutrophication of surface waters. One of the factors deciding about intensification of soil nutrient migration to surface waters is improper nutrient management in agricultural catchments. It is estimated that at least half of biogenic substances found in surface waters come from fields under cultivation [7,8,12,16,17]. Numerous studies

have already been conducted, both in Poland and abroad, on the impact of agriculture on infiltration water pollution and nutrient loss caused by leaching [3,4,11,15].

Liquid manure belongs to natural fertilizers raising many doubts. Its application at high rates may cause increased nutrient migration to deeper soil layers and their leaching out to ground and surface waters [2,9,10]. This threat is connected first of all with nitrogen loss, as phosphorus and other elements penetrate into drainage waters supplying surface waters.

Soil nutrient loss caused by leaching may be evaluated by various methods [1]. Reliable results can be obtained by determining the ion content in ground waters and drainage streams.

The paper presents the results of investigations concerning the effect of annual application of pig slurry and mineral fertilizers on the quality of ground and drainage waters.

MATERIAL AND METHODS

The studies were conducted on runoff waters from nine drained fields treated by various rates of fertilizers, located in a former state-owned-farm Nikutowo. In order to determine the effect of liquid manure on water pollution, water samples were collected from five fields fertilized by liquid manure and four fields mineral fertilized, located in their vicinity. The fields were situated in the protection zone of the Masurian Landscape Park, where liquid manure application is prohibited. Each experimental object was a separate drainage divide with a drainage well. Runoff water was taken from draining wells located in experimental fields. Only in field No.1. it was collected from a piezometer. The water somples was taken a four times per year (march, may, september and november) during a two years. Drainage ditches collecting waters from manured fields belong to two separated catchment basins, of the Golanka River and Dajna River. The waters from the Golanka River flow into Lake Białe, situated outside the protection zone of the Masurian Landscape Park. The Dajna River, in its upper course, flows through Wągiel Lake located in this Park.

Liquid manure was applied on soils of different types, formed from light loam, loamy sand – strong and light, and sand with a very low content of the claye fraction. Brown soils dominate on arable land, constituting 80% of its total area. The remaining 20% are podsolic and black-earth soils. Organic soils cover 60% of the grassland area, brown soils constitute here 40%.

Liquid manure was applied at the rates 40-50 $m^3 \cdot ha^{-1}$ per year. The dose of 50 $m^3 \cdot ha^{-1}$ of diluted pig slurry contained on average 95 kg NPK·ha^{-1}: 50 kg N, 15 kg P and 30 kg K. Mineral fertilizer rates in experimental objects 2a. – 5a. were: 90, 153, 91 and 238 kg NPK·ha^{-1} respectively.

An analysis of water samples allowed to determine the content of: total nitrogen and organic nitrogen – by the Kjeldahl method; nitrate nitrogen (V) – by a colorimetric method with phenoldisulphonic acid; ammonium nitrogen – by a colorimetric method with indophenol; nitrate nitrogen (III) – by a colorimetric method with sulfanilic acid and a-naphthyleneamine, total phosphorus and phosphates – by a colorimetric method with ammonium molybdate and stannous chloride; calcium and magnesium – by the versenate method; potassium and sodium – by flame photometry.

RESULTS AND DISCUSSION

Table 1 presents the average content of biogenic components in runoff waters from experimental fields.

The data show that fertilization caused increasing in nitrogen (mainly nitrate V) concentration in waters. Its amount in them depended on the kind and rate of fertilizers applied. According to many authors [7,10,11,16], the content of nitrates (V) in soil-ground and surface waters is usually higher than the content of ammonium nitrogen. This is connected with the fact that nitrogen compounds undergo certain changes. The average content of total nitrogen in waters coming from manured fields was by 1.4 times higher than its level in waters coming from fields fertilized with NPK. In the total amount of nitrogen concentrations, its mineral forms constituted on average 90.5%; the rest was organic nitrogen. Nitrate (V) nitrogen constituted 91.6% of mineral nitrogen in water samples collected from soil receiving manure, and 94.5% in those from fields receiving NPK. The concentration of nitrates (V) in infiltration waters is comparable with the results given by Pondel and Terelak [14] for fields where high rates of organic fertilizers were applied. In the investigations carried out by other authors [2,3,13], the content of total nitrogen and its mineral forms in shallow ground waters from fields subjected to intensive manuring was higher than in our study, and varied from 20 to 80 mg $NO_3^- \cdot dm^{-3}$.

Table 1. Forms of nitrogen and phosphorus content in soil-ground waters from fields fertilized with liquid manure and mineral fertilizers

No.	Object	Component						
		Total nitrogen	Organic nitrogen	Ammonium nitrogen	Nitrate nitrogen (V)	Nitrate nitrogen (III)	Total phosphorus	Phosphates
		mg $N \cdot dm^{-3}$					mg $P \cdot dm^{-3}$	
		Field fertilized with liquid manure						
1.	Piecki	23.46	2.28	2.92	18.20	0.06	0.58	0.23
2.	Czaszkowo I	31.69	1.03	0.72	29.90	0.04	0.27	0.17
3.	Czaszkowo II	12.15	1.57	0.40	10.16	0.02	0.41	0.12
4.	Machary I	10.30	1.73	1.12	7.44	0.01	0.28	0.10
5.	Machary II	10.92	1.64	1.40	7.85	0.03	0.55	0.35
	Mean	17.70	1.65	1.31	14.71	0.03	0.42	0.20
		Field fertilized with NPK						
2 a.	Czaszkowo I	16.79	0.94	0.23	15.60	0.02	0.34	0.25
3 a.	Czaszkowo II	9.08	0.79	0.26	8.02	0.01	0.20	0.05
4 a.	Machary I	13.19	1.67	0.57	10.90	0.05	0.29	0.17
5 a.	Machary II	10.38	1.50	1.25	7.57	0.06	0.51	0.30
	Mean	12.36	1.23	0.58	10.52	0.03	0.31	0.19

Among the experimental objects where liquid manure was applied (1 - 5) the highest average content of total nitrogen and NO_3^- was noted in water samples collected from a draining well situated in object No.2. It was by almost two times higher than in water samples taken from field 2a. where mineral fertilizers was applied. In the other objects fertilized by liquid manure the content of total nitrogen and its forms in drainage waters was in most cases slightly higher than its level in waters from fields where liquid manure was not applied. An exception was object No.4a. subjected to mineral fertilization where nitrate (V) nitrogen concentration was by about 1.5 times higher than in manured object No.4. In literature concerning surface water pollution ammonium nitrogen is often ignored due to its low concentration in experimental objects [7,8]. Howerer in liquid

manure 50 - 60% of total nitrogen are its mineral forms mainly ammonium nitrogen so it is probable that this form penetrates into ground waters in substantial amounts. In own investigations the average content of NH_4^+ was by several times higher than reported by other authors (2,4,7,13). In the studies conducted by Pondel and Terelak [1981] the NH_4^+ content in drainage waters varied from 0.04 to 0.2 mg·dm^{-3}. Its highest concentration was observed in ground water samples taken from a piezometer where it constituted 12.4% of the total nitrogen content.

Phosphorus introduced to the soil with fertilizers undergoes chemical sorption so it poses a threat to waters first of all due to surface runoff wash from intensively fertilized soils. The phosphorus content in water samples collected from manured fields was on average by 1.3 times higher than its content in samples taken from objects subjected to mineral fertilization only; phosphates constituted 46.4% of total phosphorus. An exception was drainage water from field No.2a. mineral fertilized where phosphorus concentration was by 1.2 times higher than in manured field No.2. Organic forms of phosphorus constituted on average 53.6% of total phosphorus in manured fields and 42.9 % in fields fertilized with NPK.

The concentration of biogenic elements in studied waters ranged from 9.08 to 31.69 mg N·dm^{-3} and from 0.20 to 0.58 mg P·dm^{-3}. According to algologists it is a serious threat because of mass algal blooms [6]. Such a high amount of biogenic substances may accelerate eutrophication of water bodies [5]. The ratio N:P of 10-20:1 [5] which is most conducive to algal blooms was noted in the waters analyzed. This may lead to degradation of rivers Dajna and Golanka as well as Białe and Wągiel lakes since the area investigated belongs to their catchment basins.

A comparison between infiltration waters from fields with and without manuring shows that this kind of fertilization did not alter their pH value, but caused an increase in their total hardness and chemical oxygen demand (COD) (Tab. 2). Manuring resulted also in a slight increase in sulfate content (by 5.4% on average). The concentration of chlorides was by 21.6% higher in waters from fields where mineral fertilizers were applied compared with manured ones.

Mineral fertilization and manuring caused a substantial increase in the alkaline cations content in water except potassium (Tab. 3).

Its lower content resulted from the fact that pig slurry is poor in this element. In the case of manuring total cation concentrations in waters increased on average by 26% as compared with the objects with NPK fertilization. Among cations, calcium concentrations increased to the highest degree. Its content in drainage waters was at a level described by Pondel and Terelak [14].

Table 2. Physicochemical properties chloride and sulfate content in soil-ground waters from fields fertilized with liquid manure and mineral fertilizers

No.	Object	PH	Total hardness mval·dm^{-3}	COD mg O_2·dm^{-3}	Chlorides mg Cl·dm^{-3}	Sulfates mg SO_4·dm^{-3}
			Field fertilized with liquid manure			
1.	Piecki	7.2	9.2	82.2	15.3	102.8
2.	Czaszkowo I	7.2	10.2	70.7	43.7	154.9
3.	Czaszkowo II	7.4	9.8	84.8	41.1	85.6
4.	Machary I	7.4	5.9	95.9	43.5	92.7
5.	Machary II	7.3	7.0	127.8	28.0	126.5
	Mean	7.3	8.4	92.3	34.3	112.5
			Field fertilized with NPK			
2 a.	Czaszkowo I	7.2	7.3	39.1	52.6	126.5
3 a.	Czaszkowo II	7.4	9.8	70.6	37.7	47.3
4 a.	Machary I	7.2	5.2	69.3	44.2	134.9
5 a.	Machary II	7.3	6.9	93.2	32.2	116.8
	Mean	7.3	7.3	68.1	41.7	106.4

Table 3. Alkaline cation content in soil-ground waters from fields from fields fertilized with liquid manure and mineral fertilizers

No.	Obiekt	K^+	Ca^{2+}	Mg^{2+}	Na^+	Cation total
		mg·dm^{-3}				
			Field fertilized with liquid manure			
1.	Piecki	21.2	68.9	7.8	8.2	106.1
2.	Czaszkowo I	8.8	163.4	21.4	13.3	206.9
3.	Czaszkowo II	2.5	163.4	17.5	7.7	191.1
4.	Machary I	11.9	86.5	81.7	7.2	187.3
5.	Machary II	10.9	105.7	18.5	8.6	143.7
	Mean	11.0	117.6	29.4	9.0	167.0
			Field fertilized with NPK			
2 a.	Czaszkowo I	16.5	116.9	15.6	10.9	159.9
3 a.	Czaszkowo II	7.4	121.7	20.4	8.7	158.2
4 a.	Machary I	18.1	17.5	17.7	11.7	65.0
5 a.	Machary II	11.9	102.5	19.4	9.9	143.7
	Mean	13.5	89.6	18.3	10.3	131.7

Also magnesium had a relatively high share in total cation contents. Its concentration in infiltration waters was similar to that given by Pondel et al. (1991) and higher than reported by other authors [2,3]. Manuring compared with mineral fertilization. did not intensify sodium leaching.

CONCLUSIONS

The results presented in this paper indicate that the negative effect of manuring is visible not only when it is applied at rates exceeding the permissible standards and at a time preceding sowing or planting but also in the case of its long-term application especially at high rates. This results in accumulation of mineral forms of nitrogen and phosphorus in the soil increasing the probability of their leaching out to ground waters.

The field investigations allow to formulate the following conclusions:

1. Liquid manure application resulted in a higher content of total nitrogen and phosphorus in drainage and ground waters. Their average concentration was by 5.34 mg $N \cdot dm^{-3}$ (total N) and 0.11 mg $P \cdot dm^{-3}$ (total P) higher in water samples collected from manured fields than in those samples from fields subjected to mineral fertilization.
2. An increase in the nitrogen content concerned first of all $N\text{-}NO_3$ and $N\text{-}NH_4$. The content of nitrate (V) and ammonium nitrogen in waters coming from fields fertilized with liquid manure was by 1.4 and 2.3 times higher respectively than in waters coming from fields fertilized with NPK. As regards phosphorus an increase was noted mainly in the content of its organic form.
3. Manuring caused alkaline cations leaching from the soil to drainage and ground waters. The cations content, especially calcium and magnesium, in drainage waters from manured fields increased considerably in relation to their content in waters from fields where mineral fertilizers were applied.

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PORÓWNANIE SKŁADU CHEMICZNEGO WÓD GLEBOWO-GRUNTOWYCH POCHODZĄCYCH Z PÓL NAWOŻONYCH GNOJOWICĄ I NAWOZAMI MINERALNYMI

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Streszczenie. Badaniami objęto wody odpływowe pochodzące z 9 zdrenowanych pól o zróżnicowanym nawożeniu położonych na terenie byłego PGR Nikutowo. Próbki wód pobierano z 5 pól nawożonych gnojowicą oraz z 4 pól położonych w ich pobliżu, na których stosowano nawożenie mineralne. Pola te znajdowały się w strefie ochronnej Mazurskiego Parku Krajobrazowego objętej zakazem stosowania gnojowicy. Stwierdzono. że nawożenie gnojowicą w porównaniu z nawożeniem mineralnym zwiększało zawartość azotu, fosforu wapnia i magnezu w wodach drenarskich. Wzrost zawartości azotu odnosił się głównie do $N\text{-}NO_3$ i $N\text{-}NH_4$. W przypadku fosforu wzrosła głównie zawartość organicznej formy tego składnika.

Słowa kluczowe: wymywanie składników nawozowych, gleba, gnojowica, nawozy mineralne.