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INFLUENCE OF MUNICIPAL SEWAGE SLUDGE ON CONCENTRATION OF NITRATES(V) IN SOIL

WPŁYW KOMUNALNEGO OSADU ŚCIEKOWEGO NA ZAWARTOŚĆ AZOTANÓW(V) W GLEBIE

Abstract: In a four-year, microplot experiment (1 m^2) carried out on anthropogenic soil, the influence of sewage application on concentration of nitrates in soil was investigated. Municipal sewage sludge at the doses of 0, 70, 140, 210 and 280 Mg · ha^{-1} of fresh weight was introduced to soil in autumn 2004, after which grass mix was sown. The waste used in the research originated from the wastewater treatment plant in Olsztyn. In 2005–2008, soil for chemical analysis was sampled four times during each growing season (April, July, September and November). The content of nitrates in fresh soil matter was determined by colorimetric method with phenoldisulphonic acid.

Each year, nitrates in soil increased proportionally to a sewage sludge dose. Thus, the application of the highest dose, ie 280 Mg · ha^{-1}, raised the average $N\text{-}NO_3$ content in soil nearly two-fold higher than determined in the control soil. The highest accumulation of the mineral form of nitrogen was found in soil sampled in July, which could have been connected with a more intensive transformation of N compounds introduced to soil with sewage sludge. The determined values of $N\text{-}NO_3$ in soil fluctuated throughout the experiment, with the highest content of nitrates found in 2005, while in 2006 and 2007 the mean $N\text{-}NO_3$ concentrations were similar. In 2008, an insignificant increase of this nutrient in soil was determined.

Keywords: sewage sludge, nitrate in soil

Municipal sewage sludge is a waste fertilizer, which is rich in nutrients, including nitrogen compounds. Nitrogen is an elementary component essential for all organisms. Nitrate, as a one of the nitrogen mineral forms in soil, represents a small percentage of its total content. In contrast to NH_4^+, NO_3^- is poorly absorbed in soil and nitrates are easily leached into deeper horizons of soil. This process may endanger the quality of groundwater and surface waters [1]. When using sewage sludge for soil fertilization, nitrogen content, both in soil and in the applied dose of sludge, should be considered. The date of sludge application should also be taken into consideration so as to prevent potential adverse effects of nitrates(V) on the environment [2].

The purpose of the study has been to determine the impact of municipal sewage sludge doses on changes in the concentration of $N\text{-}NO_3$ in soil within four years.

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Material and methods

A four-year, microplot experiment (1 m^2) was established in 2004 on anthropogenic soil originating from clay. Sewage sludge was applied in autumn at the doses of 0, 70, 140, 210 and 280 Mg · ha^{-1} of fresh weight. Afterwards, grass mix was sown. In 2005–2008, soil for chemical analysis was sampled four times during each growing season (April, July, September and November). The waste fertilizer used in the research, which came from the wastewater treatment plant in Olsztyn, contained 27.61 % of dry matter, 33.30 g · kg^{-1} of total N, and its value of pH in water suspension was 8.39. Before the experiment, the soil contained 2.6 g · kg^{-1} of total nitrogen and its pH in 1 M KCl was 7.36. The content of $N\text{-}NO_3$ in soil was determined by colorimetric method with phenoldisulphonic acid.

Results and discussion

The study showed high variation of nitrate in soil depending on a dose of sewage sludge in the subsequent years (Table 1). The results are confirmed by the findings of Baran et al [3], who demonstrated considerable variation over time of $N\text{-}NO_3$ concentration in soil after application of sewage sludge.

Table 1

The content of $N\text{-}NO_3$ in soil [mg · kg^{-1}] in the subsequent years of the research depending on a dose of sludge

Sewage sludge dose [Mg · ha^{-1}]	Years				Mean
	2005	2006	2007	2008	
0	10.98	2.23	1.73	6.53	5.37
70	23.98	2.55	2.40	7.96	9.22
140	41.98	3.50	2.82	8.89	14.29
210	53.39	5.04	3.34	10.17	17.99
280	61.71	5.44	4.15	11.22	20.63
Mean	38.41	3.75	2.89	8.95	

$LSD_{0.05}$ years 0.29
$LSD_{0.05}$ doses 0.37
$LSD_{0.05}$ interaction 0.72

Increased amounts of waste introduced into soil resulted in a significant increase of concentration of $N\text{-}NO_3$ in soil (from 5.3 mg · kg^{-1} in the control object to about 20.5 mg · kg^{-1} after application of the highest dose). Slightly different results were obtained by Bożym and Pulikowski [4] in a lysimetric experiment. These authors reported that an increase of a sewage sludge dose resulted in a nitrate content increase in soil only in the first year of the experiment. In our study, an increase in the accumulation of this form of mineral nitrogen in soil was directly proportional to a dose of the waste. This effect was noticed each year during the study (Table 1). However, the content of $N\text{-}NO_3$ in soil in the first year of the study was several-fold higher than in the subsequent years. Baran et al [3] showed an evident reduction in the amount of nitrate nitrogen(V) in soil in the

second year of the experiment. In our study, the concentrations of nitrate in the soil collected in 2006 and 2007 were on an approximately identical level, which was a result of a considerable uptake of mineral forms of nitrogen by grass, as verified by Delibacak et al [2]. It is estimated that between 20 % to 55 % of organic nitrogen in soil undergoes mineralization in the first year after the application of sewage sludge [5, 6]. It was only in the final year of the experiment that an increasing accumulation of the analyzed nutrient in the soil occurred, but not to such a high level as in 2005 (Table 1). The concentration of $N\text{-}NO_3$ changed over time under the influence of sewage sludge doses (Table 1). In the first and in the last year of the research, the concentration of $N\text{-}NO_3$ grew most proportionally to the quantity of waste introduced to soil. Such dependence, albeit on a minimum level, remained in soil in the third year after sludge application.

The content of nitrate nitrogen(V) in soil changed significantly during the growing season, from April to November (Table 2). The highest concentration of this component was found in soil collected in July, on average around 17 mg · kg^{-1}. Such high accumulation of $N\text{-}NO_3$ in soil at that time can be explained by the increasing nitrification and mineralization processes of the nitrogen introduced to soil with sludge. In soil collected in April and September, the $N\text{-}NO_3$ content was on a lower level (about 13 mg · kg^{-1}), while in November it was the lowest.

Table 2

Seasonal changes of $N\text{-}NO_3$ content in soil [mg · kg^{-1}] depending on a dose of sludge

Sewage sludge dose [Mg · ha^{-1}]	Month				Mean
	April	July	September	November	
0	4.44	5.94	6.29	4.80	5.37
70	8.68	12.83	9.46	5.92	9.22
140	12.52	18.17	14.94	11.55	14.29
210	16.47	23.06	17.76	14.66	17.99
280	19.55	25.87	20.38	16.71	20.63
Mean	12.33	17.17	13.77	10.73	

$LSD_{.05}$ doses 0.37
$LSD_{0.05}$ month 0.21
$LSD_{0.05}$ interaction 0.44

Fluctuations of $N\text{-}NO_3$ content in soil depending on a sewage sludge dose and time of sampling were proved to be significant at the level of $p = 0.05$ (Table 2). In each of the four dates of soil sampling, the accumulation of $N\text{-}NO_3$ increased proportionally to a dose of the introduced waste. In the literature, no results confirming seasonal changes of nitrate concentrations in soil were found [4]. On the other hand, Sienkiewicz et al [7] attributed seasonal changes in the $N\text{-}NO_3$ content in soil to the changing conditions which determine N transformations in soil and to the changeable uptake of N by plants.

The concentration of $N\text{-}NO_3$ in soil fluctuated seasonally in the following years of the experiment (Table 3). A characteristic feature was the high content of nitrate in soil collected in all periods in the first year of study, especially in soil samples collected in July 2005. On all sampling dates in 2006 and 2007, the accumulation of nitrate

nitrogen(V) in soil was similar. There was an increase in the concentration of $N\text{-}NO_3$ in soil collected in July and September 2008 (Table 3).

Table 3

Seasonal changes of $N\text{-}NO_3$ in the soil [mg · kg^{-1}] in successive years

Year	Month				Mean
	April	July	September	November	
2005	33.19	51.35	40.64	28.44	38.41
2006	6.53	2.75	2.61	3.11	3.75
2007	2.67	2.08	1.41	5.40	2.89
2008	6.95	12.50	10.41	5.96	8.95
Mean	12.33	17.17	13.77	10.73	

$LSD_{0.05}$ years 0.29
$LSD_{0.05}$ month 0.21
$LSD_{0.05}$ interaction 0.51

When examining the seasonal changes of nitrate in soil in the subsequent years of the research, depending on a dose of sewage sludge, a significant difference in the quantity

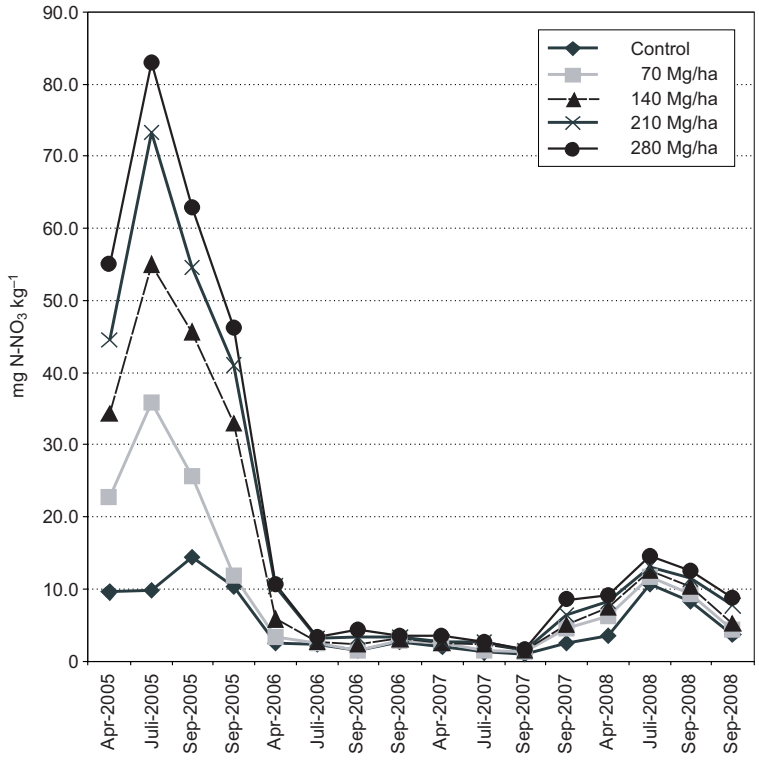

Fig. 1. Seasonal changes of $N\text{-}NO_3$ in soil in the subsequent years of the research depending on a dose of sewage sludge

of the component in the soil collected in 2005 compared with the remaining years of research can be observed (Fig. 1). In the first year of the experiment, an increase in the $N\text{-}NO_3$ concentration in soil with a dose of sewage sludge was the highest. In 2006 and 2007, irrespective of the dose of the fertilizer or the date of soil sampling, the content of nitrate nitrogen(V) in soil remained on a similar level. Another characteristic event was the increase in the quantity of $N\text{-}NO_3$ in soil in the last year of the experiment, although the changes associated with the doses of sludge were no longer as big as observed in the soil collected in 2005. In July of the first and the last year of the research, the greatest increase was observed in the analyzed form €of mineral nitrogen in soil, compared with the remaining dates of soil sampling soil in all the years of the experiment.

Conclusions

1. The content of nitrate in soil increased every year proportionally to a dose of sludge. The dose of 280 Mg · ha^{-1} of sewage sludge raised the average $N\text{-}NO_3$ content over two-fold higher than determined in the control soil.

2. The highest concentration of nitrate nitrogen(V) occurred in soil collected in July.

3. Accumulation of $N\text{-}NO_3$ in soil changed in the subsequent years, being the in the first year after sludge application, whereas in the years 2006 and 2007, the average $N\text{-}NO_3$ content was similar. In 2008, a slight increase in the concentration of $N\text{-}NO_3$ in the soil was found.

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WPŁYW KOMUNALNEGO OSADU ŚCIEKOWEGO NA ZAWARTOŚĆ AZOTANÓW(V) W GLEBIE

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Abstrakt: W czteroletnim doświadczeniu mikropoletkowym (1 m^2) prowadzonym na glebie antropogennej badano wpływ dawki osadu ściekowego na zmiany koncentracji azotu azotanowego(V) w glebie. Komunalny osad ściekowy zastosowano jednorazowo jesienią 2004 r. w dawkach: 0, 70, 140, 210 i 280 Mg · ha^{-1} świeżej masy. Następnie wysiano mieszankę traw gazonowych. Osad ściekowy wykorzystany w badaniach pochodził z miejskiej oczyszczalni ścieków w Olsztynie. W latach 2005–2008 glebę do analiz chemicznych pobierano

czterokrotnie w każdym okresie wegetacyjnym (IV, VII, IX i XI). Zawartość azotanów(V) w świeżej masie gleby oznaczono metodą kolorymetryczną z wykorzystaniem kwasu fenolodisulfonowego.

Zawartość azotanów(V) w glebie zwiększała się w każdym roku proporcjonalnie wraz z dawką osadu. W wyniku zastosowania 280 Mg · ha^{-1} odpadu średnia zawartość $N\text{-}NO_3$ była ponad dwukrotnie większa niż w glebie obiektu kontrolnego. Największa koncentracja tej formy azotu mineralnego występowała w glebie pobieranej w lipcu, co mogło być spowodowane intensywnymi przemianami związków N dostarczonych w osadzie (mineralizacja i nitryfikacja). Nagromadzenie $N\text{-}NO_3$ w glebie zmieniało się w kolejnych latach – najwięcej było w 2005 r., natomiast w latach 2006 i 2007 średnie zawartości $N\text{-}NO_3$ kształtowały się na zbliżonym poziomie. W 2008 r. stwierdzono nieznaczny wzrost koncentracji tego składnika w doświadczalnej glebie.

Słowa kluczowe: osad ściekowy, azotany(V) w glebie