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Lysimetric research of nutrient losses from organic fertilizers

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Abstract. In organic agricultural production high quality and safe agricultural products and foodstuffs are produced. It is believed that organic fertilizers are slower to wash out into water, because their mineralization is slow and hence water contamination with nitrogen compounds is smaller. The aim of this research is to assess the migration of nitrogen compounds in the soil-water system after application of organic fertilizers. The investigations were performed in an established site of eight lysimeters. They are filled with monoliths of equal soil. In July, plants growing in the lysimeters were fertilized with the following organic fertilizers: *Biokalis, Biojodis, Provita, Horn Shavings, Horn Core Powder* and different amounts of slurry. No fertilizers were used in lysimeter No. 8. Water quality parameters NO_2^-, NO_3^- and NH_4^+ values were determined. Results show the influence of different organic fertilizers on the dynamics of nutrients in soil- water systems.

Key words: organic fertilizer, nitrates, nitrites, ammonium ions, lysimetric water

INTRODUCTION

Washing out of nutritional materials from soil has been researched for a long time. It is often done by extracting water solution in different ways (by preparing extracts, pressing, centrifuging, collecting water from drainage of lysimeters and other (Голубев, 1967). Nitrates formed during the process of nitrification are taken up easily by plants. It was found that plants could best take up nitrogen in the form of nitrates when they had dissolved in water. Nitrates are one of the most soluble forms of nitrogen (Tilickis, 2005) and form the weakest connection with soil particles. For this reason, nitrate-nitrogen is easily carried by water (Milius & Baigys, 2001). As nitrates are mobile and are not absorbed by soil, they might be washed away. It was proven by research, that, in clay of moderate heaviness, migration of nitrogen compounds (NO_2^-, NH_4^+) takes place slowly at the speed of 0.2 cm per day (Česonienė & Augėnaitė, 2006). Nitrates are washed away easily from the upper levels of soil, especially when there are no plants growing. Also due to denitrification, nitrogen reduces to molecular nitrogen or N_2O, increasing nitrogen loss in soil even more. In addition, 200 kg·ha^{-1} of nitrogen is carried out yearly with harvest (Powlson, 1993).

Pollution with nitrates depends on the textural composition of the soil (Pocius, 2006; Ахметьева & Штритер, 2002) and on the type: loamy soils hold mineral nitrogen, while sand does not hold mineral nitrogen and around 45% of it leaches out immediately (Rutkovienė et al., 2004). In peat soils, a low concentration of nitrates is found only in deep ground waters (Sapek et al., 2007); transformation of carbon and nitrogen in ground waters strongly correlates with the humification process (Szajdak et al., 2007). Research determined that the concentration of nitrates (NO_3^-) in lysimetric water depends greatly on the amount of nitrogen fertilizers applied. Concentration of nitrates in lysimetric water increased where no phosphorus was applied to horticultural plants. A stronger correlation between concentration of nitrates and amount of nitrogen fertilizers applied was found when corn grew in soil ($R^2 = 0.65–0.67$), sugar beets and annual herbage ($R^2 = 0.63$) (Adomaitis et al., 2004). According to average data of 27 years, nitrogen fertilizer rate of application of 114 kg·N ha^{-1} fertilizers, resulted in 66.8 mg·l^{-1} increase in nitrate concentration in leachate from lysimeters installed to the depth of 40 cm. When the rate of mineral nitrogen fertilizers (ammonium nitrate) was increased to 228 kg·N ha^{-1}, nitrate concentration increased up to 300.8 mg·l^{-1}.Concentration of ammonium (NH_4^+) in lysimetric water was not significantly affected by mineral fertilizers. (Adomaitis et al., 2004).

Investigating the effect of different factors on leaching, soil solution below plant roots (in the depth of 40–60 cm) was analyzed, because once nitrates migrate into this part of the soil, they are inaccessible to plants and are regarded as leached. (Scherer-Lorenzen et al., 2003). In the field without plant cover, leaching of nitrates from 0–20 cm soil layer into deeper soil layers at 20–40 cm and even 40–60 (on average 4 mg·l^{-1}) was found. This was not observed in the case of the field with plant cover (Pocius, 2006). Decrease in pollution of superficial and ground water can be expected only in case of balanced agriculture. Positive tendencies can be expected in most European countries and the USA, where balanced and organic agriculture are being established (Novotny, 1999).

Discussion of research results shows that amounts of leached nitrogen compounds depend on the kind and amount of applied nitrogen fertilizers, textural composition of soil and aeration area, plant cover of soil and humidity regime during the period of vegetation, season and so on. One of the means to decrease pollution is organic production. This is a system of farming ensuring production of high quality agricultural produce without synthetic fertilizers, pesticides and other technical materials. Soil is improved with organic fertilizers, crop rotation is implemented, and biological means are taken to fight diseases and pests. Materials used in organic production must meet certification standards. The aim of this research is to assess the migration of nitrogen compounds in the soil-water system after application of organic fertilizers.

MATERIALS AND METHODS

To determine regularity of nutritional materials leached, tests were carried out in the system of undisturbed soil with different organic fertilizers used. Tests were carried out in an established experimental eight-lysimeter site. Lysimeters are dug into the ground, their surface area is 1 m^2, depth of the lysimeters is 1 m. Every lysimeter is connected by a tube which leads into a well, where collecting containers for leachate are installed. Each lysimeter contains an equal monolith of soil. Every lysimeter has water-proof metal walls, and bottom, making exchange with water from surrounding soil or deeper layers impossible. The top of each lysimeter protrudes 2–3 cm above the surface of the ground, which protects lysimeters from surface water or running on or running off.

On May 13, 2005 plants (red clover) growing in lysimeters were fertilized as follows: No.1 lysimeter – liquid organic fertilizer *Biokal* (115 kg N ha^{-1}), No.2 – liquid organic fertilizer *Biojodis* (110 kg N ha^{-1}), No.3 – 2 l of sewage (230 kg N ha^{-1}), No. 4 –3 l of sewage (390 kg N ha^{-1}), No. 5 – 4 l of sewage (520 kg N ha^{-1}), No. 6 – 5 l of sewage (650 kg N ha^{-1}), No.7 – 6 l of sewage (780 kg N ha^{-1}), and no fertilizers were applied to lysimeter No.8, so it was called control. In June 2008, the same lysimeters were fertilized as follows: No.1 *Provita* (90 N kg ha^{-1}); lysimeter No.2 *Provita* (180 N kg ha^{-1}); lysimeter No.3 – *Horn Shavings* (90 N kg ha^{-1}); lysimeter No.4 – *Horn Shavings* (180 N kg ha^{-1}); lysimeter No.5 – *Horn Shavings* (270 N kg ha^{-1}); lysimeter No. 6 – *Horn Core Powder* (90 N kg ha^{-1}); lysimeter No. 7 – *Horn Core Powder* (180 N kg ha^{-1}); lysimeter No. 8 – control.

On the lysimetric site, the soil is 70% sand and 30% moderate loam. Perennial grasses (red clover) were grown in lysimeters.

The following indexes of water quality were determined: Nitrates mg l^{-1}(NO_3^-) (LST ISO 7890-3:1998), Nitrites (NO^-_2) mg l^{-1} (LST EN ISO 13395:2000) , concentration of ammonium ions (NH^+_4) mg l^{-1} (LST ISO 7150-1:1998).

To express substantiality of interdependence of different soil parameters coefficients *r* were calculated and statistical significance of this relationship was assessed according to *P* coefficient (when $P > 0.05$ correlation was regarded as statistically significant) Assessing significance of differences of quality parameters from different lysimeters, *Student's t-criterion* was used (statistical programme *STATISTICA).* If $t > 0.05$ the difference was held significant.

RESULTS

Tests of leached nutrients were carried out on the lysimetric site when different amounts of organic fertilizers (sewage), liquid organic fertilizers *Biojodis* and *Biokalis*, organic fertilizers *Provita*, *Ragu Drozles (Horn Shavings)* and *Ragu Geluoniu Miltai (Horn Core Powder)* were used. The above mentioned fertilizers are permitted for use in organic production. Ammonium ion concentrations in leachate from lysimeters are shown in Fig. 1 a–c.

As can be seen from the data presented in Fig. 1 a–c, ammonium concentrations varied depending on the amount of fertilizers applied. When greater amounts of fertilizer were applied, there were greater concentrations of ammonium in the leachate (correlation coefficients respectively: $r = 0.9465$, $P = 0.000$; $r = 0.9839$, $P = 0.000$). In the first year of research, ammonium concentrations in all lysimeters were greater than that in the control lysimeter ($t < 0.005$), except for lysimeter No. 3, which received 2 liters of sewage (260 kg N ha^{-1}). In the second year of research after application of organic fertilizers (2006), ammonium concentrations in leachate were significantly greater than concentrations in the first year (2005). In the third year (2007) of research ($t = 0,0006$; $t = 0.0032$), ammonium concentrations from all lysimeters were greater than from the control lysimeter ($t < 0,005$).

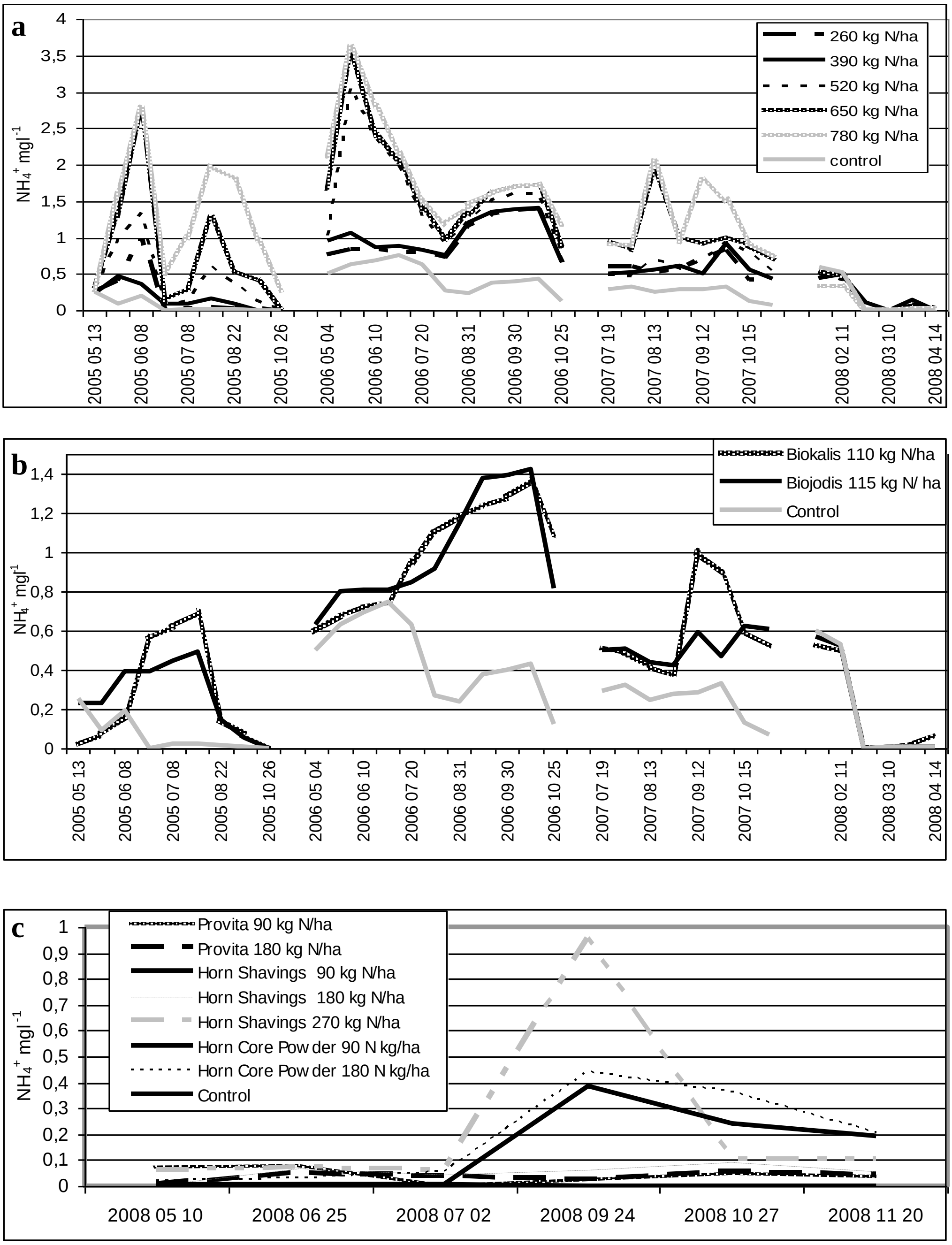

Fig. 1. Concentration of ammonium ions in lysimeter leachate:

a) after application of organic fertilizers (sewage);

b) after application of liquid organic fertilizers (*Biojodis* and *Biokalis*);

c) after application of organic fertilizers *Horn Shaving*, *Horn Core Powder and Provita.*

In the first year of research (2005), ammonium concentrations in leachate after application of liquid organic fertilizers “Biokal” and “Biojodis” reached their maximum in July, while in the second and the third years of research (2006–2007) ammonium concentrations were greatest in the period September–October. Dynamics of ammonium ions is similar in all the years of research after application of *Biojodis* and *Biokal* (there is no significant difference $t \geq 0.005$). During the period of 2005–2007 ammonium concentrations after application of fertilizers were greater than in the control lysimeter (no fertilizers were used, differences are reliable $t < 0.05$) In the first year of research after application of *Biojodis* and *Biokal*, similar concentrations of ammonium were found in the leachate as after application of 2–5 liters of sewage, Horn Shavings N270 (differences insignificant $P > 0.05$) When 6 liters of sewage were applied, ammonium concentrations in lysimeter leachate were significantly greater than when *Biojodis* or *Biokal* fertilizers were applied ($t = 0.009$; $t = 0.007$). In the second year of research, similar ammonium concentrations occurred in leachate with *Biokal* and *Biojodis* applications as with the application of 1 to 2 liters of sewage (differences were not significant $P > 0.05$). Application of 3 to 6 liters of sewage resulted in a significantly greater ammonium concentrations in lysimeter leachate than with the application of *Biojodis* or *Biokal* ($t < 0.05$). When *Biojodis* fertilizers were used, similar ammonium concentrations occurred in the leachate during the third year as with of 1–5 liters of sewage (differences were found insignifficant $P > 0.05$). When 6 liters of sewage were applied, ammonium concentrations in lysimeter leachate were significantly greater than with the application of 0.5 liter of *Biojodis* fertilizers ($t = 0.027$).

Although ammonium ions are greatly adsorbed by soil and therefore do not get into water in huge amounts, as stated in many literature sources, application of organic fertilizers *Biojodis* and *Biokal* increased ammonium concentrations in lysimeter leachate. The greatest ammonium concentrations were found in the second year of research; they decreased slightly in the third year of research. However, they still remained higher than the ammonium concentrations measured in the first year of research (differences are statistically significant, $t < 0.05$) The second reason for a decrease in ammonium concentrations might be the process of nitrification, during which ammonium ions are turned into nitrates and nitrites. Ammonium concentrations may have decreased by being taken up by the plants growing in lysimeters during their period of vegetation.

After application of organic fertilizer *Provita* N90, similar ammonium concentrations in lysimeter leachate were observed as when double the amount of the same fertilizer *Provita* N 180, 2 to 5 liters of sewage, *Biokal,* Horn Shavings N180 and all the concentrations of Horn Core Powder were applied (differences were not significant, $P > 0.05$).

After application of organic fertilizers in 2005, nitrites in lysimeter leachate remained similar in years 2006 and 2006 (differences were found insignificant $t > 0.05$). In the first year of research, nitrite concentrations in leachate were similar from all lysimeters, including the control lysimeter ($t > 0.005$) except for lysimeter where 6 liters of sewage (780 kg N ha^{-1}) were applied ($P = 0.011$). In the second year of research, nitrite concentrations from all lysimeters were greater than the concentration from the control lysimeter ($t < 0.005$). In the third year of research, nitrite concentrations from all lysimeters were similar to the control lysimeter ($t > 0.005$)

except for lysimeters where 5–6 liters of sewage were applied (650–780 mg l^{-1} Nb) (*P* = 0.036, *P* = 0.046).

In the first year of research, nitrite concentrations (0.001-0.1 mg l^{-1}) in lysimeter leachates were slight; there were no significant differences between application of *Biojodis* and *Biokal* or control lysimeter (*t* > 0.005). In the first year of research, nitrite concentrations in leachate after application of *Biokal* and *Biojodis* were similar to leachate concentrations after application of 1 to 5 liters of sewage (differences were found insignificant *P* > 0.05). With the application of 6 liters of sewage, nitrite concentrations in lysimeter leachate were much greater than when *Biojodis* or *Biokal* were applied (*t* = 0.01; *t* = 0.009). In the second year after application of *Biokal,* nitrite concentrations in lysimeter leachate were much greater than when *Biojodis* fertilizers had been applied (difference was significant *t* = 0.02). It was also greater than that of the control lysimeter (difference was significant *t* = 0.0122). Nitrite concentrations after application of *Biojodis* were greater than from the control lysimeter (difference was significant *t* = 0.0001). In the second year of research, nitrite concentrations in leachate after application of *Biokal* were similar to leachate concentrations when 2 to 3 liters of sewage were applied (differences were found insignificant *P* > 0.05). Application of 4–6 liters of sewage resulted in much greater nitrate concentrations in lysimeter leachate than when *Biokal* was used (*t* < 0.05). Application of *Biojodis* fertilizers resulted in nitrite concentrations in lysimeter leachate that were similar to the ones obtained when 2 to 6 liters of sewage were applied (differences were not significant *P* > 0.05). In the third year of research, application of *Biokal* and *Biojodis* resulted in nitrite concentrations in lysimeter leachate similar to the ones that resulted from application of 2–3 liters of sewage and the control (differences were not significant *P* > 0.05). Application of 3 to 6 liters of sewage resulted in much greater nitrite concentrations than was obtained from application of *Biokal* or of *Biojodis* (*t* < 0.05). Nitrite concentrations in lysimeter leachate were the greatest in the second year of research (differences were significant *t* < 0.05); they decrease in the third year and become similar to concentrations registered in the first year of research (differences were not insignificant *t* > 0.05). After application of liquid organic fertilizers, nitrites leached most intensively during the second year.

Nitrite concentrations (0.001–0.1 mg l^{-1}) in lysimeter leachate were slight after application of liquid organic fertilizers *Biokal, Biojodis, Provita, Horn Shavings, Horn Core Powder.* Significant differences were not found anong the lysimeters and with the control lysimeter (differences were statistically not significant *t* > 0.05).

In the second year of research, lysimeters where 2–3 liters of sewage were applied had nitrate concentrations similar to that in the control lysimeter (differences were not significant *t* > 0.05). In lysimeters where 4 to 6 liters of sewage were applied, nitrate concentrations in leachate were greater than the concentrations in the control lysimeter (differences were not significant *t* < 0.05). In the third year of research, all lysimeters had nitrate concentrations similar to the control (differences were not insignificant *t* > 0.05).

In the first year of research after application of *Biojodis,* nitrate concentrations (44–310 mg l^{-1}) in lysimeter leachate were much greater than after application of *Biokal* (3–29 mg l^{-1}) (difference was significant *t* = 0.005), greater than in control lysimeter and in lysimeters where 2 to 3 liters of sewage were applied (1–50 mg l^{-1}) (differences were significant, *t* < 0.05). Nitrate concentrations after application of

Biojodis were similar to that obtained when 4 to 5 liters of sewage were applied (differences were not significant $t > 0.05$). Nitrate concentrations after application of *Biokal* were greater than in the control lysimeter and in lysimeters, where 2 to 6 liters of sewage were used (differences were not significant $t < 0.05$). In the second year of research, nitrate concentrations were greater in lysimeter leachate where *Biokal* was applied than in leachate from lysimeters where *Biojodis* was applied, (difference was significant $t = 0.038$). Lysimeters where *Biokal* was applied also had greater nitrate concentrations than the control lysimeter and lysimeters where 2 to 5 liters of sewage were applied (differences were significant $t < 0.05$).

After application of 6 liters of sewage, nitrate concentrations in lysimeter leachate were similar to that from lysimeters receiving *Biokal* (difference was not significant, $t > 0.05$). Nitrate concentrations after application of *Biojodis* (10–20 mg l^{-1}) were greater than in the control lysimeter (1–9 mg l^{-1}) (difference was significant $t = 0.045$), but lower than in the lysimeter where 6 liters of sewage were applied (50–310 mg l^{-1}) (difference was significant $t = 0.008$). Nitrate concentrations in lysimeter leachate after application of *Biojodis* were similar to the ones obtained after application of 1 to 5 liters of sewage (45–290 mg l^{-1}) (differences were not significant $t \geq 0.05$). In the third year of research, there were no significant differences between nitrate concentrations in lysimeter leachate from lysimeters receiving *Biojodis, Biokal,* 2 to 6 liters of sewage and the control lysimeter (1–320 mg l^{-1}) .

The greatest nitrate concentrations in lysimeter leachates after application of fertilizers were observed in the first year of research. They decrease in the second year, with nitrate concentrations still being greater than that in control lysimeter. In the third year of research, nitrate concentrations in all the lysimeters were similar to the control lysimeter (differences were not significant $t > 0.05$). After application of liquid organic fertilizers, nitrate leached out in two years.

Nitrate concentrations in lysimeter leachate wth the application of organic fertilizer *Provita* N90, were similar to the nitrate concentrations in leachate when *Provita* N180, 2–5 liters of sewage, Horn Shavings N180 and N270 and Horn Core Powder N90 and N180 were applied (10–80 m mg l^{-1}) (differences were not significant, $P > 0.05$). Nitrate concentrations in lysimeter leachate after application of Biokal, and Horn Shavings N90 (44–310 mg/l) were greater than in the control lysimeter leachate (1–11 mg l^{-1}). Nitrate concentrations in leachate from lysimeters receiving 5 to 6 litres of sewage and *Biojodis* were lower than in the control lysimeter leachate (differences were significant $t < 0.05$).

After application of double the amount of the organic fertilizers *Provita*, N180, nitrate concentrations in lysimeter leachate were similar to nitrate concentrations in leachate from lysimeters receiving *Provita* N90, *Biojodis*, 5–6 liters of sewage, Horn Shaving N270 (differences were not significant $P > 0.05$). Nitrate concentrations in leachate from lysimeters receiving Biokal, 2–4 liters of sewage, Horn Shavings N90 and N180 were greater than nitrate concentrations in leachate from the control lysimeter (differences were significant $t < 0.05$).

CONCLUSIONS

Having studied the leaching of nitrogen compounds after application of organic fertilizers *Biokal*, *Biojodis*, *Provita, Horn Shavings* and *Horn Core Powder*, and having compared leaching tendencies when different amounts of organic fertilizers (sewage) were used, it has been found that:

1. Application of both *Biojodis* and *Biokal* fertilizers led to similar dynamics of ammonium concentrations in each year of research; there were similar ammonium concentrations in lysimeter leachate when 2–3 liters of sewage were applied. Application of organic fertilizers *Horn Shavings*, *Horn Core Powder* and *Provita* led to very low ammonium concentrations in leachate, which were similar to the control lysimeter. However, with regard to the fact, that the leaching effect of fertilizers tends to be very slow, a need for further research in several consecutive years should be noted.
2. Application of *Biokal* resulted in significant increase in nitrite concentration (0.005–0.1) in lysimeter leachate compared to application of *Biojodis* (0.001-0.2 mg l^{-1}). In the case of *Biokal,* nitrite concentrations in leachate were similar to the concentrations in leachate after application of 2 to 3 liters of sewage. Nitrite concentrations in lysimeter leachate after application of organic fertilizers *Provita*, *Horn Shavings, Horn Core Powder* were very low, similar to the concentrations in the control lysimeter (0.001–0.05 mg l^{-1}).
3. The greatest concentrations of nitrates (40–310 mg l^{-1}) in lysimeter leachate occurred after application of organic fertilizers *Provita* N180, *Biojodis*, 5–7 liters of sewage, H*orn Shavings* N270. After application of organic fertilizers *Horn Core Powder* N90 and N180, nitrate concentrations in lysimeter leachate were very low, similar to concentrations after application of *Biokal,* 2-4 liters of sewage, *Provita* N90, Horn Shavings N90, N180 and N270 (3–70 mg l^{-1}).

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