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THE EFFECT OF SOIL CONTAMINATION WITH DIESEL OIL AND PETROL ON THE NITRIFICATION PROCESS

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Abstract

The effect of soil contamination with diesel oil and petrol on the nitrification process was investigated in a laboratory experiment. Samples of typical brown soil developed from loamy sand, of pH of 6.6 in 1M KCl, Hh –11.38 mmol$^+$ kg^{-1} soil, S – 77.67 mmol$^+$ kg^{-1} soil and C_{org} – 8.50 g kg^{-1} were analyzed. The experiment was performed in three replications, and for each test 100 g air-dry soil sample was placed in 150 cm^3 beakers. Soil samples were contaminated with diesel oil and petrol with the addition of rapeseed oil and ethanol. The source of nitrogen was ammonium sulfate in the amount of 0 and 250 mg N per kg^{-1} soil. The content of N-NO_3^- and N-NH_4^+ was determined on experimental days 14, 28 and 42. Soil moisture was kept constant at 50% capillary water capacity throughout the experiment.

Fertilizer nitrogen was subject to strong immobilization in soil contaminated with diesel oil and petrol. Both pollutants strongly inhibited the nitrification process. Diesel oil had a much stronger inhibitory effect on nitrification than petrol. Rapeseed oil also proved to be a powerful inhibiting factor. On experimental day 42, diesel oil reduced ammonium cation oxidation by 99%, and petrol – by 88%.

Key words: diesel oil, petrol, soil, nitrification, N-NH_4^+, N-NO_3^-.

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PROCES NITRYFIKACJI W GLEBIE ZANIECZYSZCZONEJ OLEJEM NAPÊDOWYM I BENZYN¥

Abstrakt

W doœwiadczeniu laboratoryjnym badano wp³yw zanieczyszczenia gleby olejem napêdowym i benzyn¹ na przebieg procesu nitryfikacji. Do badañ wykorzystano próbki gleby brunatnej w³aœciwej wytworzonej z piasku gliniastego o pH w 1M KCl 6,6, Hh – 11,38 mmol$^+$ kg^{-1} gleby, S – 77,67 mmol$^+$ kg^{-1} gleby, C_{org} – 8,50 g kg^{-1}. Badania wykonano w trzech powtórzeniach, umieszczaj¹c w zlewkach o pojemnoœci 150 cm^3 po 100 g powietrznie suchej gleby. Próbki glebowe zanieczyszczono olejem napêdowym, benzyn¹ i domieszk¹ oleju rzepakowego i etanolu. Jako Ÿród³o azotu zastosowano siarczan amonu w iloœci 0 i 250 mg N kg^{-1} gleby. Zawartoœæ N-NO_3^- i N-NH_4^+ oznaczono w 14., 28. i 42. dniu za³o¿enia doœwiadczenia. Przez ca³y okres trwania badañ utrzymywano sta³¹ wilgotnoœæ gleby na poziomie 50% kapilarnej pojemnoœci wodnej.

Stwierdzono, ¿e w glebie zanieczyszczonej olejem napêdowym i benzyn¹ zachodzi³a silna immobilizacja azotu nawozowego. Obydwa zanieczyszczenia silnie hamowa³y proces nitryfikacji. Zdecydowanie wiêksze zak³ócenia w przebiegu procesu nitryfikacji powodowa³ olej napêdowy ni¿ benzyna. Równie¿ silnym inhibitorem nitryfikacji okaza³ siê olej rzepakowy. W 42. dniu trwania doœwiadczenia olej napêdowy zmniejsza³ utlenianie kationu amonowego o 99%, a benzyna o 88%.

S³owa kluczowe: olej napêdowy, benzyna, gleba, nitryfikacja, N-NH_4^+, N-NO_3^-.

INTRODUCTION

The nitrification process plays a key role in the nitrogen cycle, and nitrifying bacteria are particularly sensitive to environmental conditions. Soil quality can be evaluated in view of the counts of nitrifying bacteria and the intensity of the nitrification process (Castaldi et al. 2009, Dincer, Kargi 2000, Kucharski 2000, Simek 2000). Soil type also affects the process as soils with a high sorptive capacity can inhibit the toxic effect of polluting substances, thus enhancing the intensity of nitrification (Myœków et al. 1996, Wyszkowska, Kucharski 2001).

Increased concentrations of oil-derivative compounds in soil modify the soil's physical and chemical properties, its structure, as well as the composition and populations of soil microbes (Kucharski et al. 2004, Wyszkowska, Kucharski 2001). According to Barabasz (1992), nitrogen mineralization plays an important role in supplying plants with nutrients, but environmental pollution caused by oil-derivative products which reach the soil as a result of extraction and further processing may lead to adverse changes in the process of nitrogen transformation (Amadi et al. 1996, Jorgensen et al. 2000).

The supply of foreign substances to the soil environment may alter the soil's biochemical properties. This study attempted to determine the effect of soil contamination with diesel oil and petrol on the content of mineral nitrogen.

MATERIAL AND METHODS

The effect of soil contamination with diesel oil and petrol on the nitrification process was determined in the study. Samples were collected from the humus horizon of soil classified under natural conditions as typical brown soil developed from loamy sand, of pH of 6.6 in 1M KCl, hydrolytic acidity (Hh) of 11.38 mmol^{+} kg^{-1}, total exchangeable alkaline cations (S) of 77.67 mmol^{+} kg^{-1} and organic carbon content (C_{org}) of 8.50 g kg^{-1}.

The variable experimental factors were:

1. Type of pollutant in cm^{3}·kg^{-1} d.m. soil:
   - 0 (control),
   - DO (diesel oil – 10 cm^{3}),
   - P (petrol – 10 cm^{3}),
   - R (rapeseed oil – 1 cm^{3}),
   - E (ethanol – 1 cm^{3}),
   - DOR (DO 9 cm^{3} + R 1 cm^{3}),
   - PE (P 9 cm^{3} + E 1 cm^{3}).
2. Ammonium sulfate dose in mg N kg^{-1} soil: 0 and 250.
3. Time of analysis – days 0, 14, 28, 42.

The experiment was conducted in 3 replications. For each test, 100 g of air-dried soil was placed in 150 cm^{3} beakers. Soil samples were contaminated (variable 1) and fertilized with ammonium sulfate (variable 2). All components were thoroughly mixed with the soil. The moisture content of soil was brought to 50% capillary water capacity. The beakers were incubated at a temperature of 25^{o}C, and N-NH_4^{+} and N-NO_3^{-} levels were determined in the soil on different days of the experiment (variable 3). The detailed procedure of extracting and determining mineral nitrogen is presented by Kucharski et al. (2009). The quantity of nitrified nitrogen and % inhibition of the nitrification process were determined based on the results (Wyszkowska 2002).

The results were processed statistically with the use of Duncan's multiple range test and a three-factorial analysis of variance. A statistical analysis was performed in the Statistica application (StatSoft, Inc. 2006).

RESULTS AND DISCUSSION

The results of the experiment indicate that soil contamination with oil-derivative products modified the nitrification process. Diesel oil and petrol with the addition of rapeseed oil and ethanol had a varied effect on N-NH_4^{+} and N-NO_3^{-} concentrations (Tables 1 and 2).

Table 1

The effect of soil contamination with oil-derivative substances, rapeseed oil and ethanol on $N\text{-}NH_4^+$ levels (mg kg^{-1} soil)

Type of pollutant *	Time of analysis (days)			
	0	14	28	42
0 mg N kg^{-1} d.m. soil				
0	28.60 ± 0.46	24.63 ± 0.45	22.57 ± 0.59	4.08 ± 0.37
DO	28.83 ± 0.15	23.03 ± 0.23	21.20 ± 1.00	5.52 ± 0.37
P	65.60 ± 0.17	40.90 ± 0.72	21.60 ± 0.70	19.20 ± 1.86
R	28.47 ± 0.23	27.10 ± 0.36	22.23± 0.35	11.76 ± 0.37
E	23.83 ± 0.06	23.20 ± 0.44	20.70 ± 0.44	3.24 ± 0.39
DOR	23.97 ± 0.60	22.17 ± 0.55	20.33 ± 0.40	11.28 ± 0.37
PE	64.27 ± 0.25	37.37 ± 0.49	22.57 ± 0.06	15.60 ± 1.86
250 mg N kg^{-1} d.m. soil				
0	217.67 ± 0.58	155.33 ± 3.06	30.77 ± 0.81	5.40 ± 0.39
DO	221.00 ±1.73	211.00 ± 7.21	37.83 ± 0.75	20.64 ± 0.37
P	236.00 ± 2.65	154.33 ± 3.21	103.00 ± 1.73	24.72 ± 2.71
R	218.33 ± 2.89	34.87 ± 0.55	20.90 ± 0.36	4.56 ± 0.37
E	227.33 ± 2.52	190.67 ± 2.08	52.77 ± 0.35	7.56 ± 0.39
DOR	234.67 ± 2.52	34.03 ± 0.32	23.70 ± 0.17	11.40 ± 0.59
PE	236.00 ± 3.61	146.33 ± 3.51	94.60 ± 0.26	23.04 ± 2.28
$LSD_{0.01}$**	a – 1.29, b – 0.69, c – 0.97, $a \cdot b$ – 1.82, $a \cdot c$ – 2.57, $b \cdot c$ – 1.37, $a \cdot b \cdot c$ – 3.63			

*DO – diesel oil, P – petrol, R – rapeseed oil, E – ethanol
**$LSD_{0.01}$ for: a – type of oil-derivative substance and the addition of rapeseed oil and ethanol, b – nitrogen source, c – time of analysis.

Ammonia nitrogen levels decreased on successive days of the experiment. The highest $N\text{-}NH_4^+$ concentrations were noted on day 1, and the lowest – on day 42. Petrol contamination had a more profound effect on the content of ammonia nitrogen than diesel oil pollution. In a treatment with petrol without ammonium sulfate, high levels of NH_4^+ (40.90 mg kg^{-1}) were noted over 14 days, whereas in treatments with ammonium sulfate – over 28 days (103 mg $N\text{-}NH_4^+$ kg^{-1} d.m. soil). A reverse tendency was observed in respect of the nitrate nitrogen content of soil. The lowest quantities were determined in soil analyzed on the first day, and the highest – on the last (42^{nd}) day of the experiment. Nitrate nitrogen concentrations were higher in soil contaminated with petrol than with diesel oil throughout the entire experiment.

Table 2

The effect of soil contamination with oil-derivative substances, rapeseed oil and ethanol on $N\text{-}NO_3^+$ levels (mg kg^{-1} soil)

Type of pollutant *	Time of analysis (days)			
	0	14	28	42
0 mg N kg^{-1} d.m. soil				
0	7.39 ± 0.03	9.29 ± 0.07	21.53 ± 0.15	26.13 ± 1.07
DO	7.10 ± 0.10	9.11 ± 0.03	0.00 ± 0.00	0.83 ± 0.00
P	7.28 ± 0.06	9.16 ± 0.02	11.37 ± 0.35	24.06 ± 1.07
R	6.61 ± 0.02	8.83 ± 0.08	10.23 ± 0.12	2.13 ± 0.17
E	6.52 ± 0.11	8.36 ± 0.04	9.57 ± 0.04	19.59 ± 1.13
DOR	7.32 ± 0.04	9.27 ± 0.05	0.00 ± 0.00	1.86 ± 0.23
PE	7.32 ± 0.03	8.77 ± 0.04	10.27 ± 0.21	20.28 ± 0.84
250 mg N kg^{-1} d.m. soil				
0	8.47 ± 0.37	41.57 ± 0.15	146.00 ± 1.73	240.97 ± 2.03
DO	7.33 ± 0.03	14.87 ± 0.47	0.00 ± 0.00	3.03 ± 0.21
P	7.54 ± 0.26	18.33 ± 0.21	47.53 ± 0.32	29.91 ± 1.13
R	6.83 ± 0.15	14.37 ± 0.15	43.47 ± 0.06	89.72 ± 1.13
E	6.67 ± 0.09	26.27 ± 0.15	125.67 ± 4.93	212.44 ± 1.84
DOR	7.96 ± 0.05	11.53 ± 0.32	0.00 ± 0.00	2.27 ± 0.23
PE	7.58 ± 0.23	17.43 ± 0.31	34.73 ± 0.45	24.06 ± 1.07
$LSD_{0.01}$**	a – 0.71, b – 0.38, c – 0.53, $a \cdot b$ – 0.99, $a \cdot c$ – 1.41, $b \cdot c$ – 0.75, $a \cdot b \cdot c$ – 1.99			

*DO – diesel oil, P – petrol, R – rapeseed oil, E – ethanol
**$LSD_{0.01}$ for: a – type of oil-derivative substance and the addition of rapeseed oil and ethanol, b – nitrogen source, c – time of analysis.

Soil contamination with diesel oil and petrol had an adverse effect on nitrified ammonium sulfate levels (Table 3). The addition of rapeseed oil and ethanol contributed to the above trend. Diesel oil administered separately and with the addition of rapeseed oil proved to be a stronger inhibitor. In these treatments, negligent quantities of nitrate nitrogen were noted on day 42.

Diesel oil and petrol strongly inhibited the nitrification process (Table 4). Diesel oil had a much stronger inhibitory effect on nitrification than petrol. The addition of rapeseed oil as well as ethanol strongly contributed to the adverse effect of oil derivatives on the nitrification process. On day 42, diesel oil reduced cation oxidation by 99%, and petrol – by 88% in treatments with ammonium sulfate. The tested substances inhibited nitrification in the following order: diesel oil > diesel oil + rapeseed oil > rapeseed oil > petrol + ethanol > petrol > ethanol.

Table 3

The effect of soil contamination with oil-derivative substances, rapeseed oil and ethanol on the levels of nitrified nitrogen in soil fertilized with ammonium sulfate (%)

Type of pollutant *	Time of analysis (days)		
	14	28	42
0	12.91 ± 0.08	49.79 ± 0.75	85.94 ± 0.81
DO	2.30 ± 0.20	0.00 ± 0.00	0.88 ± 0.09
P	3.67 ± 0.08	14.47 ± 0.10	2.34 ± 0.62
R	2.21 ± 0.08	13.29 ± 0.02	35.04 ± 0.49
E	7.16 ± 0.07	46.44 ± 1.98	77.14 ± 0.87
DOR	0.91 ± 0.11	0.00 ± 0.00	0.17 ± 0.00
PE	3.47 ± 0.11	9.79 ± 0.10	1.51 ± 0.62
$LSD_{0.01}$**	*a* – 0.56, *b* – 0.42, *a* · *b* – 1.12		

*DO – diesel oil, P – petrol, R – rapeseed oil, E – ethanol
**$LSD_{0.01}$ for: *a* – type of oil-derivative substance and the addition of rapeseed oil and ethanol, *b* – nitrogen source, *c* – time of analysis.

The results of the study indicate that diesel oil was a more powerful inhibitor of the nitrification process than petrol. The adverse effect of oil-derivative substances on nitrification was noted by Kucharski et al. (2004). The above authors found that leaded and unleaded petrol administered in the amount of 6 cm^3 kg^{-1} d.m. soil had a stronger inhibitory effect on nitrification than diesel oil. An opposite effect was noted in this study, most probably due to higher doses (10 cm^3 kg^{-1} d.m. soil) of the tested oil-derivative substances than those applied in the above cited experiment.

The studies carried out by Amadi et al. (1996), Niewolak and Kozie££o (1998) validated the negative effect of oil-derivative substances on the nitrification process. The above authors observed that nitrifying bacteria were highly sensitive to soil contamination with crude oil. The adverse effect of pollution with oil-derivative substances on the soil's biological activity was also noted by Xu et al. (2000). The results of the above study pointed to the high sensitivity of bacteria of the genera *Nitrosomonas* and *Nitrobacter* to the tested substances.

Kucharski et al. (2004), Niewolak and Kozie££o (1998) argued that the dynamics of the nitrification process increases over time as hydrocarbon levels decrease due to evaporation and mineralization. Another crucial factor is the selection of microbes resistant to the toxic effect of soil pollutants. The findings of Schie and Young (1998) indicate that low-biodegradable fuel compounds may be metabolized by microorganisms.

Table 4

The nitrification-inhibiting effect of oil-derivative substances, rapeseed oil and ethanol (%)

Type of pollutant *	Time of analysis (days)		
	14	28	42
0 mg N kg^{-1} d.m. soil			
0	1.90 ± 0.42	100.00 ± 0.00	96.84 ± 0.13
DO	1.40 ± 0.56	47.21 ± 1.77	7.91 ± 0.33
P	4.95 ± 0.57	52.48 ± 0.36	91.84 ± 0.61
R	10.04 ± 0.56	55.54 ± 0.50	24.89 ± 5.35
E	0.21 ± 0.18	100.00 ± 0.00	92.68 ± 0.73
DOR	5.63 ± 0.23	52.32 ± 1.01	22.22 ± 5.23
PE			
0	64.23 ± 1.25	100.00 ± 0.00	98.74 ± 0.10
DO	55.89 ± 0.38	67.44 ± 0.30	87.59 ± 0.37
P	65.44 ± 0.37	70.23 ± 0.38	62.76 ± 0.61
R	36.81 ± 0.23	13.90 ± 4.06	11.83 ± 1.18
E	72.25 ± 0.78	100.00 ± 0.00	99.06 ± 0.09
DOR	58.06 ± 0.82	76.21 ± 0.40	90.02 ± 0.39
PE	a – 1.68, b – 0.97, c – 1.37, $a \cdot b$ – 2.37, $a \cdot c$ – 3.36, $b \cdot c$ – 1.94, $a \cdot b \cdot c$ – 4.75		

*DO – diesel oil, P – petrol, R – rapeseed oil, E – ethanol
**LSD $_{0.01}$ for: a – type of oil-derivative substance and the addition of rapeseed oil and ethanol, b – nitrogen source, c – time of analysis.

CONCLUSIONS

1. Soil contamination with diesel oil and petrol has a negative effect on the nitrification process.

2. Diesel oil is a stronger inhibitor of the nitrification process than petrol.

3. The addition of rapeseed oil to diesel oil and the addition of ethanol to petrol reinforces the adverse effect of the studied oil-derivative substances on the dynamics of ammonium nitrogen nitrification in soil.

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