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EFFECT OF COMPOST, BENTONITE AND CaO ON SOME PROPERTIES OF SOIL CONTAMINATED WITH PETROL AND DIESEL OIL

WPŁYW KOMPOSTU, BENTONITU I CaO NA NIEKTÓRE WŁAŚCIWOŚCI GLEBY ZANIECZYSZCZONEJ BENZYNĄ I OLEJEM NAPĘDOWYM

Abstract: The aim of the study has been to determine the effect of compost, bentonite and calcium oxide on the acidity and selected properties of soil contaminated with petrol and diesel oil. Increasing rates of petrol and diesel oil were tested: 0, 2.5, 5 and 10 $cm^3 \cdot kg^{-1}$ of soil. The experiment was carried out in four series: without soil amendments, and with compost (3 %), bentonite (2 % relative to the soil mass) and calcium oxide in a dose corresponding to one full hydrolytic acidity.

Soil contamination with petrol and diesel oil as well as soil amendments had significant effect on the analyzed physicochemical properties of soil. Soil contamination with petrol caused an increase in pH and base saturation as well as a decrease in hydrolytic acidity, sum of exchangeable base cations and base saturation. The effect of diesel oil on the above soil properties was much weaker than that of petrol, although hydrolytic acidity increased while exchangeable base cations, cation exchange capacity and base saturation decreased under the effect of this pollutant. Among the tested soil amending substances, the strongest and most beneficial influence on the analyzed soil properties was produced by bentonite and calcium oxide, especially in respect of hydrolytic acidity. The effect of compost, although generally positive, was weaker than that of bentonite or calcium oxide.

Keywords: contamination, petrol, diesel oil, soil, compost, bentonite, calcium oxide, soil properties

Rapidly developing global economy has led to a considerable increase in consumption of petrochemical products [1, 2]. The dynamic growth of motor transport in Poland, like elsewhere in the world, raises the demand for fuels, and since the fuel resources in our country are more than modest, most oil or gas is imported. This involves such issues as the transport of crude oil over large distances as well as petrol processing, storage and distribution of petrol products, which at any stage can permeate into the environment, including soils [3]. On each occasion, the actual degree of soil contamination depends on the amount of petrol products spilled into soil, the depth of a soil layer

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penetrated with the pollutants and their chemical composition [4] as well as the properties of soil, such as its structure, texture and moisture [5]. Maximum pollution of soil with petroleum products affects mainly the water properties of soil, especially the air and water system. Soil permeability in respect of petrol or diesel oil increases as the water content in soil increases, opposite to the absorption of these substances, which then declines [5]. Petrol and other oil-derived products, when penetrating deeper into soil, clog the spaces through which water and air are transported, as a result of which soil particles turn into lumps and consequently the physical, chemical and biological properties of soil change, leading to a depressed productivity and fertility of soil [6–10]. It is therefore important to search for methods which will reduce the impact of petrol products on soil properties.

Thus, the aim of the present study has been to determine the effect of compost, bentonite and calcium oxide on the acidity and selected properties of soil contaminated with petrol and diesel oil.

Material and methods

A vegetation pot experiment with 4 replicates was conducted in a greenhouse at the University of Warmia and Mazury in Olsztyn (Poland). The experiment was set up on typical brown soil developed from loamy sand, of the following properties: 5.20 pH in 1 mol KCl $\cdot$ dm^{-3}, 27 mmol H^+ $\cdot$ kg^{-1} hydrolytic acidity, 100 mmol(+) $\cdot$ kg^{-1} *exchangeable base cations* (EBC), 127 mmol(+) $\cdot$ kg^{-1} *cation exchange capacity* (CEC), 78.7 % *base saturation* (BS), 5.5 g $\cdot$ kg^{-1} organic carbon content, and the contents of available phosphorus 21.7 mg $\cdot$ kg^{-1}, potassium 55.5 mg $\cdot$ kg^{-1} and magnesium 32.5 mg $\cdot$ kg^{-1}. Increasing rates of petrol and diesel oil were tested: 0, 2.5, 5 and 10 cm^3 $\cdot$ kg^{-1} of soil. The experiment was carried out in four series: without soil amendments, and with compost (3 % relative to the soil mass), bentonite (2 %) and calcium oxide (which contains 50 % CaO) in a dose corresponding to one full hydrolytic acidity. Compost was made from leaves (44 %), cattle manure (33 %) and peat (23 %) and matured for 6 months. A detailed specification of the substances added to soil (including the petroleum-based pollutants) was given in Authors previous paper [10]. When the experiment was established, soil in all the pots was enriched with macro- and micronutrients added in the following amounts (per 1 kg of soil): 150 mg N ($CO(NH_2)_2$), 30 mg P (KH_2PO_4), 70 mg K (KH_2PO_4 + KCl), 50 mg Mg ($MgSO_4 \cdot 7H_2O$), 5 mg Mn ($MnCl_2 \cdot 4H_2O$), 5 mg Mo ($(NH_4)_6Mo_7O_{24} \cdot 4H_2O$) and 0.33 mg B ($H_3BO_3$). The petroleum substances and the other substances analyzed in this research as well as the macro- and micronutrients introduced to soil, all prepared as aqueous solutions, were mixed with 9.5 kg of soil and placed in polyethylene pots. Having prepared the soil, spring barley (*Hordeum vulgare*) Polish cv. 'Ortega' was sown in each pot, grown until full maturity and divided into grain, straw and roots. Throughout the whole experiment, the soil moisture was maintained at the level of 60 % of soil capillary capacity. During the harvest of spring barley, soil samples were taken for analyses.

The following were determined in the soil samples: reaction (pH) by potentiometry in aqueous solution of KCl at a concentration of 1 mol · dm^{-3}, hydrolytic acidity (HA) and sum of exchangeable base cations (EBC) using Kappen's method [11]. Based on the hydrolytic acidity (HA) and exchangeable base cations sum (EBC), the cation exchangeable capacity (CEC) and base cations saturation of soil (BS) were calculated from the following formulas: CEC = EBC + HA; BS = EBC · 100 · CEC^{-1}. The results of the tests underwent statistical analysis, which involved a three-factor (1^{st} factor – kind of petroleum substances, 2^{nd} factor – petroleum dose, 3^{rd} factor – kind of neutralizing substance) ANOVA variance test performed with the software package Statistica [12]. Dependences between soil contamination with petrol or diesel oil versus the analyzed soil properties were tested using Pearson's simple correlation coefficients.

Results and discussion

The results of our experiments indicate that soil pollution with petrol and diesel oil, as well as the application of soil amendments such as compost, bentonite and CaO had a significant effect on the reaction of soil cropped with spring barley (Table 1). Soil on which spring barley was grown was characterized by a higher sum of exchangeable base cations, higher cation exchange capacity and higher base saturation in the pots contaminated with petrol than the ones polluted with diesel oil, as opposite to hydrolytic acidity.

Soil contamination with petrol or diesel oil had a significant influence on the analyzed soil properties (Table 1). The value of pH in the series without soil amending substances was positively correlated with the rate of petrol (r = 0.914) and, to a small extent, with the rate of diesel oil (r = 0.200). In this series, subsequently higher rates of petrol caused a small but successive growth in the pH.

The highest pH was obtained when soil was polluted with 10 cm^3 of petrol per kg of soil. However, in the analogous series involving diesel oil, after spring barley harvest the pollutant was not demonstrated to have produced such an unambiguous effect on soil reaction. The statistical analysis of the results indicate that there is a negative and usually significant correlation between the increasing soil contamination with petrol or diesel oil and the hydrolytic acidity of soil. There was, however, one exception, namely the trials with diesel oil and without soil amendments, where this correlation was positive (r = 0.704). As regards diesel oil, the highest hydrolytic acidity was determined in soil polluted with the dose of 10 cm^3 · kg^{-1} of soil. In the analogous series, the increasing rates of petrol caused a successive and significant decrease in hydrolytic acidity of soil (r = –0.925).

Introduction of successively increasing rates of petrol and diesel oil led to a significant depression in the sum of exchangeable base cations and cation exchange capacity compared with the control treatments (unpolluted). The lowest value of cation exchange capacity was observed in the pots where the doses of 10 cm^3 · kg^{-1} of soil of either petrol or diesel oil were introduced to soil, in which it was 15 % (r = –0.946) and 9 % (r = –0.936) lower, respectively, than in the control (unpolluted pots). In this series, the increasing doses of petrol caused a slight increase (r = 0.900) in base saturation. In

Table 1

Effect of tested factors on the properties of the soil

Dose of pollutant [$cm^3 \cdot kg^{-1}$ of soil]	Amendments of soil polluted with									
	Petrol					Diesel oil				
	Without additions	Compost	Bentomite	Calcium oxide	Average	Without additions	Compost	Bentomite	Calcium oxide	Average
	pH_{KCl}									
0	5.62	5.85	6.77	6.48		5.62	5.85	6.77	6.48	
2.5	5.75	6.46	6.89	6.90		5.47	5.97	6.58	6.75	
5	6.00	6.30	7.01	7.02		5.46	5.81	6.66	7.01	
10	6.04	6.15	7.07	6.92		5.63	5.98	6.65	6.80	
r	0.914**	0.248	0.946**	0.661*		0.200	0.440	–0.385	0.582	
	Hydrolitic acidity (HA) [mmol $H^+ \cdot kg^{-1}$]									
0	35.6	33.0	19.9	18.4	26.7	35.6	33.0	19.9	18.4	26.7
2.5	32.3	23.3	15.8	16.5	22.0	33.8	31.5	19.1	19.1	25.9
5	28.1	26.6	13.1	12.8	20.2	35.3	34.5	17.3	15.4	25.6
10	27.0	28.5	12.0	14.3	20.5	37.5	31.5	15.0	15.8	24.9
Average	30.8	27.9	15.2	15.5	22.3	35.5	32.6	17.8	17.2	25.8
r	–0.925**	–0.214	–0.910**	–0.730*	–0.783**	0.704*	–0.255	–0.992**	–0.753**	–0.968**
LSD	a – 0.3*, b – 0.4**, c – 0.4*, a · b – 0.6*, a · c – 0.6**, b · c – 0.9**, a · b · c – 1.2**									

Table 1 contd.

Dose of pollutant [$cm^3 \cdot kg^{-1}$ of soil]	Amendments of soil polluted with									
	Petrol					Diesel oil				
	Without additions	Compost	Bentomite	Calcium oxide	Average	Without additions	Compost	Bentomite	Calcium oxide	Average
Exchangeable base cations (EBC) [mmol(+) $\cdot kg^{-1}$]										
0	78.0	76.0	70.0	74.0	74.5	78.0	76.0	70.0	74.0	74.5
2.5	76.0	84.0	88.0	76.0	81.0	76.0	68.0	78.0	56.0	69.5
5	72.0	78.0	100.0	96.0	86.5	70.0	66.0	60.0	72.0	67.0
10	70.0	68.0	104.0	98.0	85.0	66.0	66.0	68.0	66.0	66.5
Average	74.0	76.5	90.5	86.0	81.8	72.5	69.0	69.0	67.0	69.4
r	–0.962**	–0.694*	0.901**	0.888**	0.792**	–0.975**	–0.779**	–0.343	–0.121	–0.860**
LSD	a – 3.2**, b – 4.6**, c – 4.6*, a · b – 6.5*, a · c – 6.5**, b · c – 9.1**, a · b · c – 12.9**									
Cation exchange capacity (CEC) [mmol(+) $\cdot kg^{-1}$]										
0	113.6	109.0	89.9	92.4	101.2	113.6	109.0	89.9	92.4	101.2
2.5	108.3	107.3	103.8	92.5	103.0	109.8	99.5	97.1	75.1	95.4
5	100.1	104.6	113.1	108.8	106.7	105.3	100.5	77.3	87.4	92.6
10	97.0	96.5	116.0	112.3	105.5	103.5	97.5	83.0	81.8	91.4
Average	104.8	104.4	105.7	101.5	104.1	108.0	101.6	86.8	84.2	95.2
r	–0.946**	–0.986**	0.899**	0.817**	0.660*	–0.936**	–0.803**	–0.546	–0.238	–0.914**
LSD	a – 3.6**, b – 5.1**, c – 5.1*, a · b – 7.2**, a · c – 7.2**, b · c – 10.2**, a · b · c – 14.5*									

Table 1 contd.

Dose of pollutant [$cm^3 \cdot kg^{-1}$ of soil]	Amendments of soil polluted with									
	Petrol					Diesel oil				
	Without additions	Compost	Bentomite	Calcium oxide	Average	Without additions	Compost	Bentomite	Calcium oxide	Average
Base saturation (BS) [%]										
0	68.7	69.7	77.9	80.1	74.1	68.7	69.7	77.9	80.1	74.1
2.5	70.2	78.3	84.8	82.2	78.9	69.2	68.3	80.3	74.5	73.1
5	71.9	74.6	88.4	88.2	80.8	66.5	65.7	77.7	82.4	73.1
10	72.2	70.5	89.7	87.3	79.9	63.8	67.7	81.9	80.7	73.5
Average	70.7	73.3	85.2	84.4	78.4	67.0	67.9	79.5	79.4	73.4
r	0.900**	–0.180	0.883**	0.756**	0.706*	–0.929**	–0.502	0.691*	0.334	–0.368
LSD	a – 0.7**, b – 1.1**, c – 1.1**, a · b – 1.5**, a · c – 1.5*, b · c – 2.2**, a · b · c – 3.1**									

LSD for: a – kind of petroleum substances, b – petroleum dose, c – kind of neutralizing substance; * and ** – significant at p = 0.05 and p = 0.05, respectively; r – correlation coefficient.

the analogous series with the other petroleum pollutant, a dose of 10 cm^3 of diesel oil per 1 kg of soil led to a decrease in base saturation (r = –0.929) compared with the control.

According to Siuta [13], the soil content of biologically active forms of organic compounds, including petroleum products, affects the dynamics of fluctuations in the oxidation-reduction potential, which largely shapes the changes in the soil environment reaction. The results of our tests on soil pH are supported by the findings cited by Baran et al [14, 15], who studied soils near point pollution sources oozing petroleum-derived products, localized on the grounds of the military airport in Deblin, and found raised pH, sum of exchangable base cations and cation exchange capacity compared with less polluted soils. In another experiment, run by Wyszkowski and Ziolkowska [16], soil contamination with diesel oil depressed soil pH, exchangeable base cations, total cation exchange capacity and base saturation; it also created a tendency for increasing hydrolytic acidity. The influence of petrol on the physicochemical properties of soil was clearly weaker than that of diesel oil.

The soil pH and other properties were obviously affected by the addition of soil amending substances, which alleviated the negative effects of soil contamination with petroleum products (Table 1). The soil amendments such as compost, bentonite and CaO significantly influenced soil pH and hydrolytic acidity in pots polluted with petrol or diesel oil. The highest changes were observed after application of bentonite and calcium oxide to soil. In the petrol and diesel oil contained soil, application of the above soil amending substances contributed to a considerable and significant increase in the value of soil pH and to a decrease in hydrolytic acidity as compared with the control series (without any soil amendments). A weaker but positive effect on the hydrolytic activity of soil was produced by compost. Addition of amending substances to soil cropped with spring barley proved to be much more effective in the pots polluted with petrol than the ones contaminated with diesel oil. The mean values of exchangeable cation bases in the series with added soil amending substances were significantly higher than in the series where such substances had not been applied, but only when soil had been contaminated with petrol. In the pots where soil was polluted with diesel oil, bentonite and CaO decreased the cation exchange capacity of soil. The substances added to soil to neutralize the pollutants such as petrol and diesel oil (especially bentonite and CaO) had a positive effect on the base saturation of soil, therefore largely improving this parameter as compared with the control (without soil amending substances).

In the present experiment, introduction of calcium oxide to soil increased soil pH, which confirms the results reported by Czekala [17], Kuziemska and Kalembasa [18] and Wyszkowski and Radziemska [19]. All of these researchers found positive relationships between the soil reaction and application of some organic substances to soil, for example compost or manure. In the authors' own research, reported earlier, it was demonstrated that application of compost to soil polluted with petrol, in contrast to the contaminated one with diesel oil, raised soil pH. Szulc et al [20] claim that composts can improve soil pH. Many authors [13, 16, 18, 19, 21] have demonstrated that calcium oxide introduced to polluted soil decreased its hydrolytic acidity but raised the sum of exchangeable base cations and base saturation, the observations which have been verified by the present study. The effect produced by compost was weaker, but in general positive. Szulc et al [20] as well as Baran et al [15] demonstrated that the sum of exchangeable base cations rose under the influence of compost. The limiting effect of organic matter added to soil, and especially calcium oxide, on hydrolytic acidity, exchangeable base cations and cation exchange capacity has also been evidenced by Wyszkowska [22] and Wyszkowski and Radziemska [23]. The substances mentioned above had a generally positive influence on exchangeable base cations and base saturation, with the application of bentonite and calcium being most effective in pots containing petroleum contaminated soil.

Conclusions

1. Soil contamination with petrol and diesel oil as well as soil amendments had significant effect on the analyzed physicochemical properties of soil.
2. Soil contamination with petrol caused an increase in pH and base saturation as well as a decrease in hydrolytic acidity, sum of exchangeable base cations and base saturation.
3. The effect of diesel oil on the above soil properties was much weaker than that of petrol, although hydrolytic acidity increased while exchangeable base cations, cation exchange capacity and base saturation decreased under the effect of this pollutant.
4. Among the tested soil amending substances, the strongest and most beneficial influence on the analyzed soil properties was produced by bentonite and calcium oxide, especially in respect of hydrolytic acidity. The effect of compost, although generally positive, was weaker than that of bentonite or calcium oxide.

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WPŁYW KOMPOSTU, BENTONITU I CaO NA NIEKTÓRE WŁAŚCIWOŚCI GLEBY ZANIECZYSZCZONEJ BENZYNĄ I OLEJEM NAPĘDOWYM

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Abstrakt: Celem badań było określenie wpływu kompostu, bentonitu i tlenku wapnia na kwasowość i wybrane właściwości gleby zanieczyszczonej benzyną i olejem napędowym. Gleba została zanieczyszczona benzyną i olejem napędowym w następujących ilościach: 0, 2,5, 5 i 10 mg · kg^{-1} gleby. Do gleby wprowadzano: kompost i zeolit w ilości 3 % w stosunku do masy gleby oraz tlenek wapnia w ilości równoważnej 1 kwasowości hydrolitycznej (Hh).

Zanieczyszczenie gleby benzyną i olejem napędowym oraz zaaplikowane substancje miały istotny wpływ na badane właściwości fizykochemiczne gleb. Zanieczyszczenie gleby benzyną wywołało wzrost wartości pH i stopnia jej wysycenia kationami o charakterze zasadowym oraz zmniejszenie kwasowości hydrolitycznej, sumy wymiennych kationów zasadowych i całkowitej pojemności wymiennej. Wpływ oleju napędowego na te właściwości był zdecydowanie mniejszy niż benzyny, jednakże zaobserwowano zwiększenie kwasowości hydrolitycznej oraz obniżenie wartości sumy wymiennych kationów zasadowych, całkowitej pojemności wymiennej i stopnia wysycenia gleby kationami o charakterze zasadowym. Spośród zastosowanych substancji neutralizujących najsilniejszym i korzystnym działaniem na badane właściwości gleby odznaczały się bentonit i tlenek wapnia, szczególnie w przypadku kwasowości hydrolitycznej. Wpływ kompostu jakkolwiek na ogół pozytywny był mniejszy niż bentonitu i tlenku wapnia.

Słowa kluczowe: zanieczyszczenie, benzyna, olej napędowy, gleba, kompost, bentonit, tlenek wapnia, właściwości gleby