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CONTENT OF BIOGENIC ELEMENTS IN THE SOIL AT DIFFERENT SITES ON A FARM

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Abstract

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The aim of the study was to evaluate the degree of soil contamination by biogenic elements on a pig farm. The study was conducted on a pig farm in the Lublin voivodeship. The pigs were housed in group pens with straw. Soil samples were collected from the following locations: the dunghill at distances of 5 and 10 m and the fattening house at distance of 5 and 10 m. Samples were collected from three layers, every 20 cm, to a depth of 60 cm. Following mineralization of the samples in fuming nitric and perchloric acid, determinations were made of total nitrogen, phosphorus, and potassium. No increase in these biogenic elements was found in the soil from the farm with respect to their natural content in the soil. Total nitrogen and available phosphorus and potassium in the soil varied by the interaction of the soil layer with the sampling point, distance, and manure storage site. The results of the study confirm that biogenic elements can migrate deep into the soil profile, which in the case of improper manure storage can lead to contamination of the soil and groundwater, particularly by nitrogen and phosphorus compounds.

Key words: soil, pig farm, nitrogen, phosphor, potassium

Introduction

Agriculture, due to its biological character, is closely linked to the natural environment. Both plant and animal production technologies directly and indirectly affect all elements of the environment: the air, water and soil. In recent years, the number of farms in Poland has decreased, while animal density and intensification have increased. Given that the use of inappropriate technology on farms with high animal density can pose a particular threat to the natural environment, the selection of production systems that minimize these risks, as well as constant monitoring of the air, water and soil around animal farms, is of tremendous importance. The greatest risk of chemical and biological contamination of the soil is posed by pig farms and the facilities associated with them, such as dunghills, pens, ramps, and others (Bekier-Jaworska and Szostak, 2003; Sapek and Sapek, 2008). The main source of environmental contaminants is animal waste (Krawczyk and Walczak, 2010), which is stored on farms in the form of solid manure, liquid manure or fermented urine. During storage of animal waste, the active biogenic elements contained in it are subject to substantial losses and changes in form. The level of reduction in the content of biogenic compounds in pig waste is linked to weather conditions, particularly thermal conditions (Czop, 2011).

High animal density creates difficulties in management of waste, particularly liquid manure, and its improper storage or use as natural fertilizer can lead to devastation of the soil and contamination of surface water and groundwater (Gołaś and Kozera, 2008). Disturbances in the balance and relative proportions of elements in soil with large quantities of animal waste are not adequately understood and continue to be the subject of many research studies (Grata and Krzyśko-Łupicka, 2007; Sapek, 2007; Ligęza, 2009; Kondratowicz-Maciejewska and Kobierski, 2011; Bednarek et al., 2012a; Bednarek et al., 2012b). A disturbance in the proportions of biogenic elements in the soil can affect their migration and their role in individual links of the food chain (Anke et al., 2006). Many authors (Kutera, 2001; Sapek and Urbaniak, 2001) emphasize the greater environmental threat posed by

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waste from livestock farming compared to household and commercial wastewater. According to Ross (1998), in a mid-sized community the ratio of the contaminant load in household and commercial wastewater to that of animal waste is 1 to 41 for nitrogen, 1 to 37 for phosphorus, and 1 to 60 for potassium. These values indicate the scale of the potential problem of environmental contamination caused by livestock density.

The choice of research problem was based on earlier observations as well as literature concerning the role of mineral elements in soil contamination around pig farms, which made it possible to formulate the following working hypothesis for the research: the soil on a pig farm may be contaminated with mineral elements originating in the production process and manure storage.

Material and Methods

The study was conducted on a pig farm in the Lublin voivodeship with average annual production of about 1000 pigs. The pigs were housed in group pens with straw, and the manure was removed daily and stored on a dunghill. Soil samples for chemical analysis were collected from the following locations: the dunghill at distances of 5 and 10 m and the fattening house at distances of 5 and 10 m. Samples were taken in three replications from three layers, every 20 cm, to a depth of 60 cm. Following mineralization of the samples in fuming nitric and perchloric acid, determinations were made of total nitrogen (by the Kjeldahl method), phosphorus (by spectrophotometry), and potassium (by photometry).

The null hypothesis (H_0) states that the manure storage sites (fattening house and dunghill) and the distances from the fattening house or dunghill (5 m and 10 m) can be compared, because their effect with respect to the analysed characteristics is similar. A lack of similarity may be expressed in the form of an alternative hypothesis (H_1) (formulas 1 and 2):

$$(1^0)\ H_0: \mathbf{\Lambda}_{\text{fattening house}} = \mathbf{\Lambda}_{\text{dunghill}} \quad \text{versus the alternative} \quad (2^0)\ H_1: \mathbf{V}_{\text{fattening house}} \neq \mathbf{V}_{\text{dunghill}} \tag{1}$$
$$F^0 \geq F\alpha \qquad\qquad F^0 < F\alpha$$

$$(1^0)\ H_0: \mathbf{\Lambda}_{\text{dist. 5 m}} = \mathbf{\Lambda}_{\text{dist. 10 m}} \quad \text{versus the alternative} \quad (2^0)\ H_1: \mathbf{V}_{\text{dist. 5 m}} \neq \mathbf{V}_{\text{dist. 10 m}}, \tag{2}$$
$$F^0 \geq F\alpha \qquad\qquad F^0 < F\alpha$$

where: H_0 – effects of the storage site are zero, Λ – for each,
H_1 – effects of the storage site, V – existing;
F^0 – Snedecor's F-test calculated in analysis of variance;
$F\alpha$ – F-test distribution (*α=0.05, ** α=0.01).

Statistical analysis

The null hypothesis H_0 was testing using analysis of variance with Snedecor's F-test. F-distribution probability was calculated as well. Significance of differences was determined using Tukey's test (α = 0.05, α =0.01). Also calculated was the coefficient of variation (CV%), which is a measure of the dispersion of the results, as the quotient of the standard deviation and the arithmetic mean, as well as the statistical error. Correlation and determination were analysed to determine the dependencies and relationships between the characteristics investigated. The statistical analysis was carried out using Excel 7.0 and Statistica (StatSoft Polska'97) software.

Results and Discussion

The analysis of variance found statistically significant differences in the total nitrogen content in the soil depending on the soil layer (the level at which the samples were collected). The available potassium content depended significantly on the soil sampling point and the storage site. The analysis of variance did not find a statistically significant interaction between the experimental factors for any of the characteristics discussed (Table 1). Total nitrogen content in the soil varied most by the interaction of the soil layer with the sampling point (CV% = 21.99), distance (CV% = 20.81), and manure storage site (CV% = 19.15). High variation in the results was also caused by the soil layer (the level at which the samples were taken) (CV% = 17.79), while the remaining factors caused less variation in nitrogen content (CV% = 6.44 to 12.41).

Available phosphorus content in the soil also varied most by the interaction of the soil layer with the sampling point (CV% = 70.89), distance (CV% = 66.91), and manure storage site (CV% = 70.18). High variation in the results was caused by the sampling point, soil layer, and manure storage site (CV% = 32.05 to 49.27). The least variation in phosphorus content in the soil was caused by the distance from the storage site (CV% = 8.31).

Available potassium content in the soil varied most by the interaction of the soil layer with the sampling point (CV% = 16.20) and with the manure storage site (CV% = 15.69). Moreover, it was directly dependent on the sampling point and the manure storage site (on average CV% = 14.78), while the remaining factors caused less variation in potassium content (CV% = 2.54-6.39).

The greatest variation in results was noted for the phosphorus content in the soil (CV% = from 8.31 to 70.89). Vari-

Table 1
Results of statistical calculations for the chemical characteristics analysed in the soil on the pig farm

Variables		Content, g/kg		
		Total nitrogen	Phosphorus	Potassium
		1	2	3
CV%	P	12.41	33.54	14.90
	L	17.79	49.27	5.22
	S	6.44	32.05	14.66
	D	10.60	8.31	2.54
	P × L	21.99	70.89	16.20
	S × L	19.15	70.18	15.69
	D × L	20.81	66.91	6.39
F calc.	P	3.84	5.09	11.48*
	L	11.83*	16.50*	2.11
	S	3.10	13.96*	33.37**
	D	8.40	0.94	1.00
	P × L	0.16	3.34	0.34
	S × L	0.21	6.66	0.20
	D × L	0.11	0.01	0.37
p-value	P	0.1493	0.1071	0.0375
	L	0.0377	0.0241	0.2676
	S	0.1764	0.0334	0.0103
	D	0.0626	0.4040	0.3909
	P × L	0.9706	0.1751	0.8771
	S × L	0.8812	0.0768	0.8897
	D × L	0.9481	0.9987	0.7794
$LSD_{0.05}$	P	n.s.	n.s.	7.5
	L	0.52	2.57	n.s.
	S	n.s.	2.10	5.20
	D	n.s.	n.s.	n.s.
	P × L	n.s.	n.s.	n.s.
	S × L	n.s.	n.s.	n.s.
	D × L	n.s.	n.s.	n.s.
$LSD_{0.01}$	P	n.s.	n.s.	n.s.
	L	n.s.	n.s.	n.s.
	S	n.s.	n.s.	9.54
	D	n.s.	n.s.	n.s.
	P × L	n.s.	n.s.	n.s.
	S × L	n.s.	n.s.	n.s.
	D × L	n.s.	n.s.	n.s.

Variables: P – sampling point (df_1 = 3, df_2 = 3), L – layer (df_1 = 2, df_2 = 3), S – manure storage site (df_1 = 1, df_2 = 3), D – distance (df_1 = 1, df_2 = 3), P × L – sampling point × layer (df_1 = 6, df_2 = 3),S × L – manure storage site × layer (df_1 = 2, df_2 = 3), D × L – distance × layer (df_1 = 2, df_2 = 3): where df_1 – degrees of variable freedom, df_2 – degrees of freedom for error; CV% – coefficient of variation; F calculated in analysis of variance: significant differences at *α=0.05, ** α=0.01; F distribution p-value, NIR – least significant difference; n.s. – not significant

ation in total nitrogen and available potassium was similar (CV% = 2.54 to 21.99).

Table 2 presents total nitrogen content in the soil at different sites on the farm. Richest in nitrogen were the soil samples taken at a distance of 5 m from the dunghill (2.13 g/kg). Nitrogen content in the soil at the sites analysed decreased with the depth of the soil profile. The highest nitrogen content at a depth of 60 cm was noted 5m from the dunghill. Soils on farms are microbiologically active, which is confirmed by their level of enzymatic activity (Bielińska and Ligęza, 2003). Conversion of soil nitrogen takes various directions, depending on environmental factors. Nitrification is often the dominant process (Szostak et al., 2005; Ligęza, 2009). Nitrification products, i.e. nitrates and nitrites, can leach deep into the soil profile and pose a threat to land in the direct vicinity of the farms and to groundwater (Gaines and Gaines, 1994). This has been confirmed by Sapek (1996) and Kuszelewski (1997). In our study, nitrogen content in the soil of the pig farm significantly depended on the collection point, distance from the manure storage site, and depth of the soil profile.

Table 3 shows the phosphorus content in the soil samples collected from the pig farm. The highest phosphorus content was noted in the top layer of the soil 5 and 10 m from the dunghill: 10.2 and 9.35 g/kg, respectively. Phosphorus showed a tendency to accumulate in the deeper soil layers, at a depth of 60 cm. The highest phosphorus content at a depth of 60 cm was noted in the soil samples taken 5 m from the dunghill (2.69 g/kg) and 5 m from the fattening house (2.15g/kg). Phosphorus concentration in the soil samples significantly depended on the distance from the manure storage site and the soil layer as well as on the interaction between these two factors. Reducing excess phosphorus occurring in animal waste is particularly difficult because the degree of phosphorus utilization from natural fodder is low, at 10-35%. The potential threat that phosphorus from animal waste poses to the environment, particularly groundwater, has been described by Mroczek (2001).

Table 4 shows the potassium content in the soil on the pig farm. The highest potassium concentration was observed in the top layer of the soil at distances of 5 and 10 m from the dunghill (38.9 and 35.2 g/kg). It should be noted that at these distances from the dunghill the potassium content remained at the same level in all layers of the soil profile. Potassium content depended significantly on the distance from the manure storage site and the depth of the soil profile, as well as on the interaction between these two factors. Sapek and Urbaniak (2001) noted 50-fold higher potassium content by a dunghill, and also observed a tendency for potassium to accumulate at a depth of 60-100 cm. It is likely that the large amount of leakage from waste accumulated on the dunghill increases the level of potassium in the soil. Bednarek (2012) reports that fertilization with liquid manure significantly increases potassium content in the soil.

Analysis of correlation and determination showed high significant positive correlations between the elements tested in the soil (Table 5). This means that if the concentration of one element increases, this is linked to an increase in the others. The results obtained indicate that if soil becomes contaminated with elements originating in storage of pig manure, the contamination involves total nitrogen as well as available phosphorus and potassium. In the present study, however, no

Table 2
Total nitrogen content in the soil on the pig farm, g/kg

Storage site	Distance	Layer			Mean
		1	2	3	
Fattening house (A)	5 m (1)	2.31a	1.81a	1.61a	1.91A
	10 m (2)	1.91a	1.51a	1.11a	1.51A
Dunghill (B)	5 m (1)	2.51a	2.18a	1.70a	2.13A
	10 m (2)	2.12a	1.90a	1.25a	1.76A
Mean for storage site	A	2.11a	1.66a	1.36a	1.71a
	B	2.31a	2.04a	1.48a	1.94a
Mean distance	1	2.41a	1.99a	1.65a	2.02*a*
	2	2.01a	1.71a	1.18a	1.63*a*
Mean		2.21*A*	1.85*A*	1.42*BA*	1.82

Table 3
Phosphorus content in the soil on the pig farm, g/kg

Storage site	Distance	Layer			Mean
		1	2	3	
Fattening house (A)	5 m (1)	3.22a	2.82a	2.15a	2.73A
	10 m (2)	3.10a	2.50a	1.90a	2.50A
Dunghill (B)	5 m (1)	10.20a	3.92a	2.69a	5.60A
	10 m (2)	9.35a	2.82a	1.49a	4.55A
Mean for storage site	A	3.16a	2.66a	2.02a	2.61a
	B	9.78a	3.37a	2.09a	5.08b
Mean distance	1	6.71a	1.68a	2.42a	4.16*a*
	2	6.23a	1.33a	1.69a	3.53*a*
Mean		6.47*A*	3.01*B*	2.06*B*	3.84

Table 4
Potassium content in the soil on the pig farm, g/kg

Storage site	Distance	Layer			Mean
		1	2	3	
Fattening house (A)	5 m (1)	31.4a	27.1a	25.6a	28.0A
	10 m (2)	27.3a	29.2a	24.1a	26.9A
Dunghill (B)	5 m (1)	38.9a	39.6a	35.3a	37.9B
	10 m (2)	35.2a	37.1a	34.2a	35.8B
Mean for storage site	A	29.3a	28.2a	24.9a	27.4a
	B	37.0a	38.8a	34.7a	36.9b
Mean distance	1	35.2a	33.4a	30.5a	33.0*a*
	2	31.2a	33.6a	29.1a	31.3*a*
Mean		33.2A	33.5A	29.8A	32.2

Table 5
Coefficients of correlation and determination in the experiment

Element (n=48)	Coefficient	Available phosphorus	Available potassium
Total nitrogen	R	0.6720**	0.5560**
	R^2	0.4515**	0.3091**
Available phosphorus	R	-	0.4611**
	R^2	-	0.2126**

R – correlation coefficient – significant at α=0.05*
R ≥ 0.2875, significant at α=0.01**
R ≥ 0.3387; R^2 – coefficient of determination

increase in the content of these elements was noted above their natural content in the soil. Nevertheless, the study indicates that elements can migrate deep into the soil profile, which in the case of improper manure storage can lead to contamination of the soil and groundwater, particularly by nitrogen and phosphorus. Potassium, which is considered to be subject to leaching, was the most stable in this study and did not undergo substantial migration.

Conclusion

In conclusion it can be said that in the soil from the pig farm analysed no increase in the content of biogenic elements was observed with respect to their natural content in the soil. Content of total nitrogen and of available phosphorus and potassium in the soil on the pig farm varied by the interaction of the soil layer with the sampling point, distance, and manure storage site. The greatest variation in the results was noted for the phosphorus content in the soil. The results of the study confirm that biogenic elements can migrate deep into the soil profile, which in the case of improper storage of animal waste can lead to contamination of the soil and groundwater, particularly by nitrogen and phosphorus compounds.

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