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Biochemical and chemical indices of soil transformations on goose farms in years 1996–2011

Elżbieta Jolanta Bielińska[1]*, Agnieszka Mocek-Płóciniak[2]

[1] University of Life Sciences in Lublin, Poland
Institute of Soil Science and Environment Shaping
[2] Poznań University of Life Sciences, Poland
Department of Agricultural Microbiology

*Corresponding author's e-mail: elzbieta.bielinska@up.lublin.pl

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Abstract: The paper presents characterisation of the eco-chemical condition and potential threats to soils of goose farms on the basis of recent monitoring of a 15-year measuring cycle. It was demonstrated that the observed soil enzymatic inactivation progressing with years of investigations on the examined farms was significantly associated with a very high content of mineral nitrogen and available forms of phosphorus. A distinct tendency towards increased content of heavy metals in soils derived from these farms as well as in their direct neighbourhood observed with the passage of time poses a serious hazard to the environment.

Introduction

Soils on goose farm runs are covered with a layer of organic overlay which develops from a mixture of feed as well as birds' excreta and feather. This layer contains high concentrations of easily-soluble macroelements, including nitrogen and phosphorus (Perez 1998, Mcfarland et al. 2001) as well as significant quantities of heavy metals (Ligęza et al. 2000). In the areas of goose farms, the pool of components brought into the soil, as a rule, exceeds soil sorption capacity resulting in both progressing degradation of the soil environment as well as migration of ions found in the infiltrating waters to considerable depths and, by so doing, generating contamination of ground waters (Ligęza and Misztal, 1999, Abrahams and Steigmajer, 2003).

Soil quality evaluation is not easy due to the complexity of the soil environment, changeability of the existing physicochemical and biological conditions and the capability of soils for compensation of these transformations. A key role is played, in this respect, by changing conditions associated with the buffer capacity of the sorptive complex as well as with the retention and accumulation of constituents in soil (Janowska and Czępińska-Kamińska 2004, Bielińska and Pranagal 2007, Ajorlo et al. 2010). Objective approach as well as comprehensive characterisation of processes taking place in the soil environment requires a long-term and complex monitoring and identification of trends (Bielińska and Ligęza 2006, Bielińska and Mocek-Płóciniak 2012).

In order to recognise long-term risks of unfavourable soil changes in goose farms, communicative biochemical indices reflecting specific soil ecosystem processes as well as chemical indices describing actual soil ecochemical conditions were selected. The presented research results comprise an up-to-date, 15-year long measurement cycle (every 5 years). The paper can provide a basis for prognostication of pedosphere transformations as well as for the assessment of the intensity of advancing degradation of the soil environment on long-term goose farms.

Materials and methods

Investigations were carried out on two runs of large goose farms operating since 1978 in the following two locations: in Knyszyn – FK, Podlaskie Voivodeship (53°19′N, 22°55′E) and in Huta Józefów – FHJ, Lublin Voivodeship (50°48′N, 2217′E). Control objects were situated in the vicinity of experimental farms but outside the range of impact of geese, on soils of similar morphological structure left as wasteland.

Soils from both goose farms as well as control soils have a lithological discontinuity and the contact zone of levels of different lithology is located at the depth not exceeding 1 m. The soils from Knyszyn were classified as *Haplic Cambisols* developed from boulder sands, whereas the soils from Huta Józefów – to *Haplic Luvisols* developed from silty material on loam and clay (Ligęza 2009).

In spring 1996, 2001, 2006 and 2011 soil samples for laboratory analyses were collected from humus horizons. The activity of the following enzymes was determined in soil samples: alkaline phosphatase (Tabatabai and Bremner 1969), urease (Zantua and Bremner 1975) and proteases (Ladd and

Butler 1972). The above enzymes play a significant role in continuous mineralisation of organic compounds of nitrogen (urease and proteases) and phosphorus (phosphatases).

Within the framework of the performed chemical analyses, the following parameters were determined: pH in 1 mol·dm^{-3} KCl (ISO 2002); the contents of ammonia and nitrate nitrogen (ISO 1998), and available forms of phosphorus (ISO 1994). The total content of Cd, Cr, Cu, Pb, Ni and Zn was determined with emission spectrometry in the Leeman Labs (PS 950) apparatus with ICP induction in argon. Soil samples were mineralized in a PROLABO microwave oven (Microdigest 3.6, France) by a wet method, which uses a mixture of nitric acid and perchloric acid at the ratio of 1:1 (Baran et al. 2002). All assays were performed in three replications. Statistical analysis was conducted using the Statistica package (Statistica 2007). Statistically significant differences between the results were evaluated on the basis of standard deviation determinations and on the analysis of variance method (ANOVA).

Results and discussion

Soils in the runs for geese showed higher pH values in comparison with control soils by: 1.7–2.4 pH units in 1 mol·dm^{-3} KCl in Knyszyn and by 0.2–1.5 units in 1 mol·dm^{-3} KCl in Huta Józefów (Table 1). Soil alkalization in the runs for geese was associated with the microbiological decomposition of the uric acid secreted by the birds into ammonia (Speir and Cowling 1984). In addition, bird excreta are rich in basic elements (Ligęza and Misztal 1999). With the passage of time, a distinct tendency was observed for the increase of pH_{KCl} in the examined soils both within boundaries of the runs as well as in the case of control soils (Table 1).

In soils derived from the bird runs, very high concentrations of mineral nitrogen were determined, especially in the case of NO_3^- (Table 1), caused, primarily, by uric acid secreted by geese. Uric acid is the main source of bird nitrogen (Ligęza 2009). At increased supply of nitrogen to the soil, N immobilization declines in the biomass of microorganisms and mineralization of this component increases (Tietema and Van Dam 1996). Nitrification, which is the results of enhanced mineralization, is the main cause of the increase of nitrate nitrogen in the soil environment (De Boer et al. 1990). Excess of the constituent in soils contributes to advancing degradation of hydrobiological systems in water reservoirs, including contamination of waters possible for utilization as drinking or municipal water (Ligęza 2009, Brankov et al. 2012). The concentration of ammonia nitrogen increased significantly together with the passage of time both in soils of the examined farms as well as in soils situated in direct vicinity of these goose farms (control soils). In the case of nitrate nitrogen, this effect was observed only in soils collected from the birds' runs (Table 1). Nitrates (V) are considerably more exposed to losses than ammonia salts due to a greater diversity of processes leading to losses. Apart from losses in gaseous form (NO, N_2O and N_2), a significant role is also played by leaching from soil by precipitation waters as well as ease of diffusive migration.

Moreover, very high phosphate concentrations in soils contribute to growing environment eutrophisation (Ligęza and Misztal 1999, Mcfarland et al. 2001, Sobczyński 2009). In the described studies, exceptionally high accumulation of phosphorus was recorded in soils collected from the runs, although a relatively high content of available forms of phosphorus found in control soils, increasing significantly with the passage of time (Table 1), may indicate translocation

Table 1. Concentration of nitrogen (NH_4^+ and NO_3^-), available phosphorus forms (P) and pH in soils

Locality	Object	Years	pH	N-NH_4^+	N-NO_3^-	P
			KCl	(mg·kg^{-1})		
Knyszyn	Farm	1996	6.3	56.28b	274.08c	256.25d
		2001	6.4	65.47b	290.14c	319.47d
		2006	6.5	99.83c	477.18d	567.38e
		2011	6.7	105.12c	544.53d	592.69e
	Control	1996	4.3	39.28a	16.28a	26.34a
		2001	4.3	46,57a	17.15a	33.16a
		2006	4.4	71.32b	20.52a	60.51b
		2011	4.6	76.74b	28.43a	94.22b
Huta Józefów	Farm	1996	6.4	82.06b	166.62b	285.47d
		2001	6.4	89.32b	172.04b	392.11d
		2006	6.6	121.78d	241.78c	640.18e
		2011	6.8	132.61d	269.92c	668.42e
	Control	1996	5.3	34.79a	4.23a	64.73b
		2001	5.4	42.08a	5.44a	88.29b
		2006	5.7	63.45b	10.19a	144.58c
		2011	6.2	67.31b	12.23a	152.93c

Values in the column followed by the same letter do not differ significantly at $p < 0.05$, t-test.

of this constituent from goose farms. McFarland et al. (2001) emphasise that it is the content of phosphorus in soils as well as surface run-off that constitute the main factors threatening the environment on the part of goose farms.

The concentrations of the determined heavy metals in soils collected from the runs for geese were significantly higher in comparison with the control soils (Table 2). Heavy metals may be added to pasture soils by animal direct defecation and urination (Abrahams and Steigmajer 2003, Wilkinson et al. 2003, Ajorlo et al. 2010). Other researchers also reported increased heavy metal concentrations in soils on which birds were kept (Headley 1996, Perez 1998, Ligęza et al. 2000). With the passage of time, a clear tendency was observed for increased contents of heavy metals, in soil samples collected both from the geese runs as well as control plots. Statistically significant differences were found only in the case of cadmium in soils derived from the runs for geese (Table 2).

In the light of current standards (Kabata-Pendias et al. 1993), the examined soils were characterised by natural concentrations of the majority of analysed heavy metals. According to these standards (Kabata-Pendias et al. 1993), the natural cadmium concentration in soils should not exceed 0.3 $mg \cdot kg^{-1}$. However, during the performed investigations, cadmium concentration in the soil derived from the goose farm in Huta Józefów ranged from 0.35–0.49 $mg \cdot kg^{-1}$ DM (Table 2). Cadmium is characterized by considerable mobility in a basic environment which is of special significance in the case of soils derived from the runs for geese which undergo alkalization. Kabata-Pendias et al. (1993) emphasise that, together with increasing soil alkalinity, cadmium sorption declines as a result of displacement of this element from the sorption complex by cations of alkaline metals, such as, e.g., Ca^{2+}, in which soils on goose farms are enriched (Ligęza et al. 2000).

The examined soils were characterised by low nickel concentrations ranging from 0.11 to 0.30 $mg \cdot kg^{-1}$ DM (Table 2), which could have been associated with a particularly high affinity of this metal to organic matter (Kabata-Pendias et al. 1993). Also Ligęza et al. (2000) reported very low Ni concentration in soils following long-term occupation by birds: geese (goose farms), cormorants, herons and rooks.

The layer of faeces deposited on the runs for geese exerted a negative influence on the enzymatic activity of the examined soils (Table 3). In the case of the Huta Józefów goose farm, the activity of all the examined enzymes turned out to be approximately 1.5 times lower in comparison with control soils, irrespective of the number of study-years (Table 3). In the case of the goose farm in Knyszyn, a significantly lower activity of the examined enzymes in soils from the runs in comparison with the control soil was observed only in years 2001 and 2011. This indicates the occurrence of a site drift caused by the supply to the soil environment of excess component from the layer of organic overlay deposited on the runs because earlier (1996 and 2001) the enzymatic activity of soils in Knyszyn was on a significantly higher level than in the control soil (Table 3). The observed soil enzymatic inactivation on the examined farms was associated with very high concentrations of mineral nitrogen and available forms of phosphorus (Table 1) as evidenced by coefficient values of negative correlation between the activity of the examined enzymes and the concentrations of these components in soils (Table 4). A high supply to the soil environment of biogenic substances can cause increase of soil microbiological activity

Table 2. Concentration of heavy metals in $mg \cdot kg^{-1}$ DM

Locality	Object	Years	Cd	Cr	Cu	Pb	Ni	Zn
Knyszyn	Farm	1996	0.14b	6.69c	5.29b	10.82b	0.22b	26.41c
		2001	0.16b	6.78c	5.36b	10.90b	0.24b	26.78c
		2006	0.18b	7.12c	5.86b	10.98b	0.21b	26.93c
		2011	0.22c	7.34c	6.10b	11.02b	0.30b	32.11c
	Control	1996	0.08a	2.09a	4.86a	6.78a	0.12a	8.33a
		2001	0.09a	2.12a	4.91a	6.91a	0.12a	8.29a
		2006	0.10a	2.28a	4.96a	6.94a	0.14a	8.52a
		2011	0.11a	2.30a	5.14a	7.13a	0.16a	8.67a
Huta Józefów	Farm	1996	0.34d	4.08b	5.79b	13.09c	0.23b	16.34b
		2001	0.35d	4.12b	5.85b	13.21c	0.22b	16,56b
		2006	0.38d	4.23b	5.92b	13.18c	0.24b	17,21b
		2011	0.49e	4,55b	5.99b	13.26c	0.28b	17.88b
	Control	1996	0.21c	2.02a	3.62a	9.88b	0.11a	8.55a
		2001	0.23c	2.08a	3.90a	9.86b	0.13a	8.76a
		2006	0.24c	2.10a	3,98a	10.21b	0.12a	8.93a
		2011	0.26c	2,15a	4.02a	10.64b	0.15a	9.15a

Values in the column followed by the same letter do not differ significantly at $p < 0.05$, t-test.

and, simultaneously, decrease the activity of some enzymes (Bandick and Dick 1999, Domżał and Bielińska 1997, Gostkowska et al. 1998). Excess of inorganic phosphorus in soil inhibits synthesis of phosphatases (Gostkowska et al. 1998, Bielińska and Mocek-Płóciniak 2012) and an elevated level of mineral nitrogen confines the activity of ureases and protease (Domżał and Bielińska 1997).

The activity of the examined enzymes declined systematically with the passage of time both on the runs as well as in the control soils but majority of important changed were determined in the case of soils on goose farms (Table 3).

The activity of the examined enzymes exhibited a negative, highly significant dependence on the content of N-NH_4^+ (r = 0.82–0.92*), N-NO_3^- (r = 0.80–0.95*) and P (r = 0.82–0.96*) as well as a positive correlation with the total content of the analysed trace elements (Table 4). The action of heavy metals depends on the degree of soil contamination. If heavy metals occur in soils in quantities close to natural values, then they can stimulate the activity of soil enzymes and only their excessive amounts become their inhibitors (Khan et al. 2006, Liao and Xie 2007). A negative impact of heavy metals on soil enzymatic activity is alleviated by high concentrations of organic matter as well as neutral pH (Siebielec et al. 2009). Soils on the runs for geese are continually enriched in organic compounds supplied to the environment together with bird excreta. The important role of organic substance in the detoxification process of soils contaminated by heavy metals was also reported by other researchers (Castaldi et al. 2009, Egli et al. 2010).

Recapitulating, it should be emphasised that enzyme activity ought to be taken into consideration when assessing the quality of soils in goose farms as indicated also by the fact that many chemical compounds assume toxic properties

Table 3. Enzymatic activity of soils

Locality	Object	Years	PhA	UA	PA
Knyszyn	Farm	1996	13.59c	12.06d	18.30e
		2001	12.72c	11.52d	17.29d
		2006	8.46a	8.34b	12.46b
		2011	8.04a	8.11b	11.24b
	Control	1996	11.57b	10.67c	14.12c
		2001	11.23b	10.04c	13.68c
		2006	10.48b	9.86c	13.42c
		2011	10.51b	9.61c	13.17c
Huta Józefów	Farm	1996	7.82a	9.25c	9.01a
		2001	7.53a	8.24b	8.49a
		2006	6.15a	5.46a	7.88a
		2011	6.20a	5.24a	6.92a
	Control	1996	11.64b	13.87d	13.21b
		2001	11.28b	12.49d	12.72b
		2006	10.46b	8.18b	11.65b
		2011	9.64b	8.72b	10.43b

PhA – alkaline phosphatase in mmol PNP·kg^{-1}·h^{-1},
UA – urease in mg N-NH_4^+·kg^{-1}·h^{-1},
PA – protease in mg tyrosine·g^{-1}·h^{-1},
values in the column followed by the same letter do not differ significantly at $p < 0.05$, t-test.

Table 4. Correlation coefficients between the activity of the examined enzymes and concentration of nitrogen (NH_4^+ and NO_3^-), phosphorus (PO_4^{3-}) and heavy metals

Enzymes	NH_4^+	NO_3^-	PO_4^{3-}	Cd	Cr	Cu	Pb	Ni	Zn
Phosphatase	-0.82*	-0.80*	-0.96*	0.52*	0.58*	0.57*	0.46*	0.56*	0.55*
Urease	-0.92*	-0.95*	-0.84*	0.54*	0.62*	0.61*	0.44*	0.58*	0.51*
Protease	-0.86*	-0.89*	-0.82*	0.56*	0.61*	0.53*	0.49*	0.55*	0.54*

* significant at p = 0.05.

following metabolic transformations that occur in living organisms. Frequently, metabolites are characterised by properties which are more noxious than contaminants from which they developed. Soil enzymatic activity reflects levels of environmental contamination which poses hazard to living organisms without the need to identify many compounds.

Conclusions

1. Long-term investigations (1996–2011) conducted in two goose farms revealed strong contamination of soils with nitrogen and phosphorus compounds. High, significantly increasing with the passage of time, concentrations of N and P in soil samples collected from the runs but also in control soils neighbouring with the examined farms indicates translocation of these compounds.
2. A distinct tendency for the increase in heavy metal concentrations in the examined soils observed with the passage of time constitutes a significant threat for the environment on the part of goose farms.
3. The layer of excrements deposited on the goose runs exerted a negative influence on soil enzymatic activity in the examined farms. The activity of the examined enzymes decreased systematically with the passage of time both in the case of soils on the runs and in the control soils.
4. Soil enzymatic inactivation in the examined farms was significantly associated with very high contents of mineral nitrogen and available forms of phosphorus.
5. The obtained results confirmed that appropriate storage and management of excreta produced in goose farms is necessary from the point of view of environmental protection.

References

[1] Abrahams, P.W. & Steigmajer, J. (2003). Soil ingestion by sheep grazing in the metal enriched floodplain soils of mid-wales, *Environmental Geochemistry and Health*, 25, pp. 17–26.
[2] Ajorlo, M., Abdullah, R.B., Hanif, A.H.M., Halim, R.A. & Yusoff, M.K. (2010). How cattle grazing influences heavy metal concentrations in tropical pasture soils, *Polish Journal of Environmental Studies*, 19, 5, pp. 895–902.
[3] Bandick, A.K. & Dick, R.P. (1999). Field management effects on soil enzyme activities, *Soil Biology & Biochemistry*, 31, pp. 1471–1479.
[4] Baran, S., Oleszczuk, P., Lesiuk, A. & Baranowska, E. (2002). Trace metals and polycyclic aromatic hydrocarbons in the surface sediment samples from the River Narew (Poland), *Polish Journal of Environmental Studies*, 11, pp. 299–308.
[5] Bielińska, E.J. & Ligęza, S. (2006). Changes of enzymatic activity of soils in a catchment basin of a mesotrophic lake (differences after 20 years), *Polish Journal of Environmental Studies*, 15, 5d, pp. 271–275.
[6] Bielińska, E.J. & Mocek-Płóciniak, A. (2012). Impact of the tillage system on the soil enzymatic activity, *Archives of Environmental Protection*, 38, 1, pp. 75–82.
[7] Bielińska, E.J. & Pranagal, J. (2007). Enzymatic activity of soil contaminated with triazine herbicides, *Polish Journal of Environmental Studies*, 16, 2, pp. 295–300.
[8] Brankov, J., Miliašević, D. & Milanović, A. (2012). The assessment of the surface water quality using the water pollution index: a case study of the Timok river (the Danube river basin), Serbia, *Archives of Environmental Protection*, 38, 1, pp. 49–55.
[9] Castaldi, P., Melis, P., Silvetti, M., Deiana, P. & Garau, G. (2009). Influence of pea and wheat growth on Pb, Cd, and Zn mobility and soil biological status in a polluted amended soil, *Geoderma*, 117, pp. 53–61.
[10] De Boer, W., Klein Gunnewiek, P.J.A. & Troelstra, S.R. (1990). Nitrification in Dutch heath soils, ii characteristics of nitrate production, *Plant Soil* 127, pp. 193–199.
[11] Domżał, H. & Bielińska, E.J. (1997). Influence of cultivation and fertilization on the enzymatic activity and contents of active mineral nitrogen forms, *Polish Journal of Soil Science,* 30/2, pp. 23–28.
[12] Egli, M., Sartori, G., Mirabella, A., Giaccai, D., Favilli, F., Scherrer, D., Krebs, R. & Delbos, E. (2010). The influence of weathering and organic matter on heavy metals liability in silicatic alpine soils, *Science of The Total Environment*, 408, pp. 931–938.
[13] Gostkowska, K., Furczak, J., Domżał, H. & Bielińska, E.J. (1998). Suitability of some biochemical and microbiological tests for the degradation degree of podzolic soil on the background of it differentiated usage, *Polish Journal of Soil Science,* 30 (2), pp. 69–78.
[14] Headley, A.D. (1996). Heavy metal concentrations in peat profiles from the high arctic, *Science of The Total Environment*, 177 (1–3), pp. 105–111.
[15] ISO 10390 (2002). International Standard Organization. Soil quality – Determination of pH.
[16] ISO 14255 (1998). International Standard Organization. Soil quality – Determination of nitrate nitrogen, ammonia nitrogen and total soluble nitrogen in air-dry soils.
[17] ISO 11263 (1994). International Standard Organization. Soil quality –Determination of phosphorus.
[18] Janowska, E. & Czępińska-Kamińska, D. (2004). Trace elements dynamics in the upper soil horizons of the Puszcza Kampinoska biosphere reserve, *Polish Journal of Environmental Studies*, 13, pp. 367–372.

[19] Kabata-Pendias, A., Motowicka-Terelak, T., Piotrowska, M., Terelak, H. & Witek, T. (1993). Evaluation of soil and plant contamination with heavy metals and sulphur, general recommendation for agriculture, IUNG Puławy, 35, pp. 5–15. (in Polish)

[20] Khan, S., Cao, Q., Hesham, A.E.-L., Xia, Y. & He, J.Z. (2006). Soil enzymatic activity and microbial community structure with different application rates of Cd and Pb, *Journal of Environmental Sciences*, 19, pp. 834–840.

[21] Ladd, N. & Butler, J.H.A. (1972). Short-term assays of soil proteolytic enzyme activities using proteins and dipeptide derivatives as substrates, *Soil Biology & Biochemistry*, 4, pp. 19–30.

[22] Liao, M. & Xie, X.M. (2007). Effect of heavy metals on substrate utilization pattern, biomass, and activity microbial communities in a reclaimed mining wasteland of red soil area, *Ecotoxicology and Environmental Safety*, 66, pp. 217–224.

[23] Ligęza, S. (2009). Nitrogen and phosphorus in soil and soil solution on the area of goose farms, *Zeszyty Problemowe Postępów Nauk Rolniczych*, 535, pp. 261–268. (in Polish)

[24] Ligęza, S. & Misztal, M. (1999). Changes of soil properties occurring under the influence of deposit geese manure, *Folia Universitatis Agriculturae Stetinensis*, 200 Agricultura (77), pp. 207–212. (in Polish)

[25] Ligęza, S., Misztal, M. & Smal, H. (2000). Concentration of selected heavy metal forms in soils on the areas of bird nestling habitats, *Zeszyty Problemowe Postępów Nauk Rolniczych*, 471, pp. 1039–1044. (in Polish)

[26] Mcfarland, A., Bethel, B. & Hauck, L. (2001). Evaluating phosphorus control practices in the goose branch microwatershed, USDA, TIAER (Teras Institute for Applied Environmental Research), 46, pp. 11–19.

[27] Perez, X.L.O. (1998). Effects of nesting yellow-legged gulls (Larus Cachinnans Pallas) on the heavy metal content of soils in the Cies Islands (Galicia, North-West Spain), *Marine Pollution Bulletin*, 36 (4), pp. 267–275.

[28] Siebielec, G., Stuczyński, T. & Korzeniowska-Pucułek, R. (2009). Metal bioavailability in long-term contaminated Tarnowskie Gory soils, *Polish Journal of Environmental Studie*s, 15, (1), pp. 121–129.

[29] Sobczyński, T. (2009). Phosphorus release from lake bottom sediments affected by abiotic factors, *Archives of Environmental Protection*, 35, 2, pp. 67–74.

[30] Speir, T.W. & Cowling, J.C. (1984). Ornithogenic soils of the cape bird Adelie penguin rookeries, Antartica 1, *Chemical Properties Polar Biology*, 2, pp. 199–212.

[31] STATISTICA (2007). Data analysis, version 8.0. www.statsoft.pl. StatSoft, Inc. (28.10.2012).

[32] Tabatabai, M.A. & Bremner, J.M. (1969). Use of p-nitrophenyl phosphate for assay of soil phosphatase activity, *Soil Biology & Biochemistry*, 1, pp. 301–307.

[33] Tietema, A. & Van Dam, D. (1996). Calculating microbial carbon and nitrogen transformations in acid forest litter with 15N enrichment and dynamic simulation modeling, *Soil Biology & Biochemistry*, 27, pp. 111–120.

[34] Wilkinson, J.M., Hill, J. & Phillips, C.J.C. (2003). The accumulation of potentially-toxic metals by grazing ruminants, *Proceedings of the Nutrition Society*, 62, 267–274.

[35] Zantua, M.I. & Bremner, J.M. (1975). Comparison of methods of assaying urease activity in soils, *Soil Biology & Biochemistry*, 7, pp. 291–295.

Biochemiczne i chemiczne wskaźniki przeobrażeń gleb na terenie ferm gęsi w latach 1998–2011

W pracy przedstawiono charakterystykę ekochemicznego stanu i potencjału zagrożenia gleb na terenie ferm gęsi, na podstawie monitoringu obejmującego dotychczasowy, 15-letni cykl pomiarowy. Wykazano, że postępująca z upływem lat badań inaktywacja enzymatyczna gleb na fermach wiązała się istotnie z bardzo wysoką zawartością azotu mineralnego i przyswajalnych form fosforu. Obserwowana z upływem czasu wyraźna tendencja do wzrostu zawartości metali ciężkich w glebach na fermach i w ich bezpośrednim sąsiedztwie stanowi poważne zagrożenie dla środowiska.