SOIL SCIENCE ANNUAL
2023, 74(2), 169923

https://doi.org/10.37501/soilsa/169923

Evaluating potential of municipal sewage sludge for agricultural use

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Received: 2023-04-04
Accepted: 2023-07-24
Published online: 2023-07-24
Associated editor: J. Lasota

Keywords:

Solanum tuberosum
Sewage sludge
Farmyard manure
Soil
Properties

Abstract

The vegetation experiment investigated the effect of municipal sewage sludge and farmyard manure on the yielding and chemical composition of potatoes of Irga cultivar, as well as selected physico-chemical soil properties. The soil was subject to the determination of pH, organic carbon content, total nitrogen, available P and K, and exchangeable cations. The yield of fresh and dry mass of potatoes and content of N, P, and K in the tubers were also determined. Moreover, the soil and potato tubers were subject to the determination of heavy metals (Cd, Cu, Cr, Fe, Mn, Ni, Pb, Zn). The conducted analyses showed high fertiliser value of municipal sewage sludge, approximate to that of manure. Its application had a positive effect on all the analysed soil properties, and resulted in a doubling the yield of potato tubers in comparison to the control object. As a result of the applied fertilisation with sewage sludge and manure, the content of heavy metals in potato tubers significantly increased in comparison to control. The content of Cd and Pb in potato tubers varied from 0.11 to 0.14 μg Cd kg^{-1} FM, and from 0.03 to 0.15 μg Pb kg^{-1} FM, and was considerably lower than the acceptable value (0.1 mg kg^{-1} FW) pursuant to the EU Regulation, hence it posed no threat for the health of consumers. In reference to the possibility of accumulation of heavy metals in soil, it was evidenced that the analysed sewage sludge can be safely applied for a period of 27 years before the Pb content exceeds the limit for soils under agricultural use. In the case of other metals, the period is considerably longer, and for Cu it reaches 2340 years. In the conditions of application of manure, Pb content will exceed the limit after 87 years, and Zn after 4699 years.

1. Introduction

Sewage sludge is a by-product resulting from treatment of municipal and industrial wastewater. It is a non-uniform semi-liquid mixture of microorganisms, and organic and mineral substances, both dissolved and suspended (Muter et al., 2022). The amount of produced sewage sludge is continuously increasing with the growth in population, urbanisation, and construction of new wastewater treatment plants (Izydorczyk et al., 2021; Iticescu et al., 2021). The amount of sewage sludge produced in the EU has increased over the last 10 years by 1.5 million Mg dry matter from 11.5 million Mg in 2010 to 13.0 million Mg in 2020 (Buta et al., 2021). In 2021, 1025.8 thousand Mg dry matter of sewage sludge was produced in Poland. In comparison to 2010, it accounted for an increase by approximately 15% (Statistics Poland, 2022). The produced sewage sludge is neutralised by means of various methods such as incineration, composting, application in agriculture, or landfilling. In recent years, sewage sludge has been increasingly frequently reused instead of being landfilled. In the European Union, almost 45% of sewage sludge is used in agriculture and composting, approximately 33% is neutralised thermally, and only 9% is subject to landfilling (Buta et al., 2021; Muter et al., 2022). Such an approach is in accordance with the concept of the circular economy (CE), and particularly the new CE Action Plan adopted by the European Union in 2020 (European Comission, 2020; Rosiek, 2020; Smol, 2020).

Dewatered sewage sludge usually shows high applicability in agriculture. It contains 20–40% DM, up to 70% organic matter, and considerable amounts of nutrients such as nitrogen (3.5–4%), phosphorus (1.75–2.5%), and potassium (0.5–1.7%), and its pH is within a range of 6.5–7.0 (Kumar et al., 2017; Aleisa et al., 2021).

Sludge applied in agriculture has a positive effect on physical, chemical, and biological soil properties. The application of sewage sludge results in an increase in the content of organic matter in the soil. Sewage sludge can also be a source of nutrients for plants (Eid et al., 2021). Organic matter introduced to the soil with sewage sludge positively affects its physical properties such as structure and porosity, improves the air-water relations, increases water capacity of the soil, and cation exchange capacity CEC (Kominko et al., 2017). By improving soil properties, application of sewage sludge may have a positive effect on crop yielding. A positive effect of the application of sewage sludge on the yield of crops has been evidenced in many studies (Antonkiewicz et al., 2020; Boudjabi and Chenchouni, 2021; da Silva et al., 2021; Eid et. al., 2021).

In addition to the positive effect on soil properties and growth of plants, sewage sludge can pose a threat for the environment due to the presence in it of various pollutants such as polyaromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), polychlorinated dibenzo-pdioxins and -furans (PCDD/F), heavy metals, and pathogens (Lamastra et al., 2018; Buta et al., 2021). Such pollutants can migrate to plants and pose a threat to consumers. Therefore, their level in sewage sludge used in agriculture as well as in soil and plants should be subject to strict control (Lamastra et al., 2018; Antonkiewicz et al., 2020; Antonkiewicz et al., 2022).

The objective of the study was the assessment of the effect of application of municipal sewage sludge on yielding of potatoes and selected soil properties. The implementation of the study objective involved conducting a vegetation experiment where the effect of municipal sewage sludge was assessed in comparison to the basic natural fertiliser, namely farmyard manure.

2. Material and methods

2.1. Experiment description

The research was based on a field experiment established in Nowe Kozłowice in the Wiskitki Commune, Żyrardowski poviat in central Poland on Haplic Luvisol soil. The experiment was established in 2022, in a completely random system, and conducted in three repetitions in plots with an area of 50 m^2. The crop cultivated in the experiment were potatoes of Irga cultivar. The experiment covered the following combinations: control – object not subject to fertilisation, SS – municipal sewage sludge, FYM – farmyard manure (cattle manure). Sewage sludge and manure were applied in a dose corresponding to 170 kg N ha^{-1} one month before planting potatoes. No mineral fertilisation was applied. During vegetation of plants, integrated plant protection against weeds and pests was implemented.

2.2. Chemical analysis of the soil, plants, and fertilisers

Soil samples for the determination of chemical and physicochemical properties were collected twice – before establishing the experiment and after harvesting potatoes. Soil was collected from the layer 0–20 cm by means of a soil probe rod. The soil was then air dried, ground in a porcelain mortar, and sieved through 2 mm mesh. The resulting soil samples were subject to the determination of: pH in a solution of 1 mol dm^{-3} KCl by means of the potentiometric method, content of organic carbon, total nitrogen and sulphur by means of an elementary analyser Vario MAX CNS, content of available phosphorus and potassium by means of the Egner-Riehm method, content of exchangeable forms of Na, K, Ca, Mg after extraction with 1 mol dm^{-3} ammonium acetate, and content of heavy metals (Ni, Fe, Cd, Mn, Zn, Pb, Cu, Cr) after extraction in a solution of 1 mol dm^{-3} HCl. Concentrations of metals in the obtained extracts was determined by means of the AAS method. In order to validate the method for accuracy and precision, certified reference material RTC SQC-001 – Metals in soil was analysed.

After harvesting the plants, the yield of potato tubers was determined by means of the weight method, and then samples of plant material were dried in a drier with constant air circulation at a temperature of 80°C, subject to dry mass determination, and ground by means of a laboratory grinder. The resulting plant material was subject to the determination of content of nitrogen and carbon by means of an elementary analyser Vario MAX CNS. After mineralisation of the plant material in a mixture of acids HNO_3 and $HClO_4$, content of phosphorus was determined by means of the vanadium-molybdenum method, and content of K, Mg, Ca, Ni, Cd, Pb, Cr, Cu, Fe, Mn and Zn by means of the AAS method (Certified ERM CD281). The same analyses were conducted for the purpose of determination of the chemical composition of the manure.

The basic properties of soil, sewage sludge, and manure are presented in Table 1 and 2. Both the soil and sewage sludge met the requirements specified in the Regulation of the Minister of the Environment (2015) for the application of municipal sewage sludge in agriculture.

Table 1
Soil properties

pH	Corg	Ntot	S	P_{E-R}	K_{E-R}	Na_{ex}	Ca_{ex}	K_{ex}	Mg_{ex}
		g kg^{-1}		mg kg^{-1}			cmol$_{(+)}$$kg^{-1}$		
6.73	20.1	1.84	0.39	71.01	80.43	0.16	1.81	0.24	0.09
Cd	Cu	Cr	Fe	Mn	Ni	Pb	Zn		
				mg kg^{-1}					
0.52	11.75	17.82	194.62	18.68	6.44	23.83	33.31		

*Corg – organic carbon; Ntot – total nitrogen; P_{E-R}, K_{E-R} – available phosphorus and potassium; Na_{ex}, Ca_{ex}, K_{ex}, Mg_{ex} – exchangeable forms

Table 2
Chemical composition of the sewage sludge and manure

Parameter	Unit	Sewage sludge*	Farmyard manure
Dry matter	g kg^{-1}	243	210
pH	–	12.5	7.7
$C_{org.}$	g kg^{-1}	298.0	273.6
$N_{tot.}$		37.3	23.81
$P_{tot.}$		3.4	9.53
$K_{tot.}$		1.23	17.12
$Ca_{tot.}$		360	9.07
$Mg_{tot.}$		2.3	1.6
$Ni_{tot.}$	mg kg^{-1}	6.44	3.5
$Cd_{tot.}$		0.411	0.34
$Pb_{tot.}$		4.49	2.24
$Hg_{tot.}$		0.11	–
$Cr_{tot.}$		9.67	2.82
$Zn_{tot.}$		1126.2	225.1
$Cu_{tot.}$		84.4	52.4

* according to Sewage Sludge Treatment Plant in Guzów

2.3. Statistical analysis

Results of the chemical analyses were subject to statistical analysis with the application of single factor variance analysis ANOVA. The assessment of differences between means employed a Tuckey test at a significance level of $p = 0.05$.

For the purpose of assessment of the threat to the environment related to the introduction of heavy metals to the soil with sewage sludge, it was calculated after what time, with annual application of the analysed sludge in a dose corresponding to 170 kg N ha^{-1}, the acceptable content of heavy metals in the soil specified in the Regulation of the Minister of the Environment (2015) will be exceeded. Such calculations were also performed for manure. The calculations were made assuming that the amount of metals introduced into the soil each year is fully accumulated in the topsoil layer (0–20 cm).

3. Results and discussion

3.1. Soil properties

The application of both manure and sewage sludge affected the analysed soil properties (Table 3). Organic fertilisation resulted in no observed significant changes in soil pH in comparison to the control object. In the conditions of application of sewage sludge, however, the soil reaction changed from neutral to alkaline. According to studies by other authors, soil pH can decrease due to systematic application of sewage sludge, as a result of release of hydrogen ions during the decomposition of organic matter (Nahar and Hossen, 2021; Shan et al., 2021).

Short-term research shows an increase in soil pH due to the application of sewage sludge, particularly sanitised with lime, characterised by alkaline reaction. The decomposition of organic matter introduced to the soil with sewage sludge is simultaneously accompanied by release of alkaline cations to the soil solution (Barbosa et al., 2017; Curci et al., 2020), which also contributed to a rapid increase in pH, particularly on soils with low buffer capacity. With an increase in pH values, the content of exchangeable forms of Ca and Mg in the soil also increased. Considerably higher content of Ca^{2+} and Mg^{2+} in soil fertilised with SS was recorded in comparison to soil fertilised with FYM. No effect of organic fertilisation on the content of exchangeable potassium and sodium in the soil was evidenced (Table 3). Sludge applied in the experiment was sanitised with lime, and contained considerably more Ca and Mg than manure. According to Barbosa et al. (2017), alkalinised sewage sludge can also be a good source of these elements for plants. Potassium in sewage sludge occurs in the smallest amounts among all macroelements, because during wastewater treatment it remains in the wastewater in a dissolved form (Bittencourt et al., 2014). Due to this, in the conditions of application of sewage sludge in agriculture, potassium should be supplied to plants from other sources.

The application of manure and sludge contributed to an increase in the content of organic carbon (by 13,7% – FYM and 5,7% – SS) and total nitrogen (by 1,6% and 14,3%) in the soil in comparison to control. No considerable differences were recorded in the content of Corg and Ntot between objects fertilised with FYM and SS (Table 3). Irrespective of the applied fertilisation, the ratio of carbon to nitrogen was narrow, approximate to optimal for microbiological transformations.

Table 3
Effect of fertilisation with sewage sludge and manure on soil reaction, content of organic carbon, total nitrogen, available P and K, and content of exchangeable cations in the soil

	pH	Corg	Ntot	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}
			g kg^{-1}		mg kg^{-1}			cmol$_{(+)}$ kg^{-1}		
Control	6.73a	19.96a	1.89a	10.6ab	69.22a	74.54a	1.89a	0.06a	0.23a	0.15a
FYM	6.99a	22.70b	1.92ab	11.8b	94.26ab	102.11b	2.83b	0.11b	0.26a	0.17a
SS	7.05a	21.09b	2.16b	9.8a	86.43b	84.77b	4.71c	0.16c	0.24a	0.17a

FYM – farmyard manure; SS – sewage sludge

Content of available phosphorus and potassium in the soil increased as a result of the applied fertilisation. The content of available phosphorus in soil increased by 36% as a result of application of manure, and by 25% due to the application of sewage sludge. The content of available potassium in soil increased by 37% for FYM and 14% for SS, respectively (Table 3). Many studies have evidenced that organic fertilisation contributes to an increase in the content of organic carbon and nutrients in the soil (Assefa and Tadesse, 2019; Thomas et al., 2019; Singh et al., 2020; Oueriemmi et al., 2021). Curci et al. (2020), applying sewage sludge compost in a dose of 12 Mg ha^{-1} on sandy-loam soil, obtained a 66% increase in the content of organic carbon in the soil, and a 34% increase in total nitrogen. The same study evidenced that the content of available phosphorus in the soil doubled, and potassium content increased by approximately 15% (Curci et. al., 2020). Oueriemmi et al. (2021), comparing the effect of farmyard manure and sewage sludge compost, reported a similar effect of manure and sewage sludge on an increase in the content of organic carbon (more than 3-fold in comparison to control) and total nitrogen in the soil (approximately 45–48%). The content of available phosphorus and potassium increased to a greater degree as a result of manure application (for P the increase was even 11-fold, and for K double) than sewage sludge compost.

After fertilisation with manure and sewage sludge, an increase in the content of all the analysed heavy metals was observed in the soil in comparison to the control object (Table 4). In the conditions of manure application, an increase in the content of metals in the soil was within a range from 4% for Fe to 34% for Pb, and was lower than in the conditions of application of sewage sludge (Fe 13% and Pb 51%). In terms of an increase in the soil content in comparison to control, the analysed metals were ordered in the following sequence: Pb (34.3%) > Ni (28.8%) > Zn (28.2%) > Mn (23.0%) > Cu (22.0%) > Cd (9.8%) > Cr (5.3%) > Fe (3.9%) in the case of application of FYM, and Pb (50.8%) > Cu (48.0%) > Zn (47.7%) > Ni (36.2%) > Mn (26.2%) > Cd (13.7%) > Cr (14.0%) > Fe (12.8%). In their short-term experiment, Nahar and Hossen (2021) also determined a significant (more than double for Pb and Ni and 1.5-fold for Cd) increase in heavy metals in the soil after the application of municipal sewage sludge. Similarly, in their field experiment involving cultivation of tomatoes, Eid et al. (2021) evidenced that after 120 days of vegetation, as a result of application of sewage sludge, the content of heavy metals in the soil increased by 16% for Mn, 21% Fe, 27% Zn, 70% Ni, and Pb content increased more than 3-fold. Achkir et al. (2023) determined the following sequence of increasing content of heavy metals in soil as a result of application of municipal sewage sludge: Cu > Pb > Zn > Ni > Cd > Cr. Values of the contamination factor (CF) pointed to a low to moderate risk of pollution of soils with heavy metals. The greatest threat to soil quality was determined by the authors for Zn (CF = 37.74), and the lowest for Cr (CF = 2.40). In terms of risk of soil pollution, the metals were ordered as follows: Zn > Pb > Ni > Cu > Cd > Cr (Achkir et al., 2023). Authors of many studies report that municipal sewage sludge can be a source of heavy metals, and their agricultural use can result in an increase in the content of these elements in the soil. At the same time, like in the conducted own research, the observed increase in the content of heavy metals in the soil does not lead to the exceedance of the acceptable values for soils under agricultural use (Wierzbowska et al., 2018; Yang et al., 2018; Dhanker et al., 2021; Nunes et al., 2021; Achkir et al., 2023). The study showed an increase in the content of heavy metals in the soil after the application of manure in comparison to the control object (Table 4). Many studies point to a decrease in the content of mobile forms of heavy metals in the soil due to the application of manure (Assefa and Tadesse, 2019; Lwin et al., 2018; Thomas et al., 2019). Long-term application of manure, however, can lead to an increase in total or approximate to total (as in the presented study) contents of forms of heavy metals in the soil (Malan et al., 2015; Wierzbowska et al., 2018; Zhen et al., 2020; Köninger et al., 2021).

The conducted calculations showed that in the conditions of application of both manure and sewage sludge, the acceptable content of heavy metals in the soil in the layer 0–20 cm will be exceeded the fastest in the case of lead (Table 5). The content of Pb in soil will be exceeded after 27 years of annual application of sewage sludge, and after 87 years of application of manure. The acceptable content of Zn and Cu in soil will be exceeded after more than 2000 years of annual application of sewage sludge, after more than 3000 years for Cu, and approximately 4700 years for Zn in the conditions of manure application. The content of heavy metals in soil will increase faster in the conditions of application of sewage sludge than manure. An exception is only Cd the acceptable content of which in the soil will be exceeded faster in the conditions of application of manure (593 years) than municipal sewage sludge (761 years).

According to Yang et al. (2018), after the application of 1 Mg ha^{-1} year^{-1} of municipal sewage sludge, the content of Hg, Zn, Cu, Pb, and Cd in soil increased by 6.20, 619, 92.9, 49.2, and

Table 4
Effect of fertilisation with sewage sludge and manure on the content of heavy metals in the soil

	Cd	Cu	Cr	Ni	Pb	Zn	Fe	Mn
				mg kg^{-1}				
Control	0.51a	12.25a	18.46a	5.27a	19.14a	33.31a	185.11a	18.41a
FYM	0.56b	15.01a	19.44ab	6.79b	25.70b	42.72b	192.34ab	22.65b
SS	0.58b	18.13b	21.04b	7.18b	28.87c	49.21c	208.82b	23.23b

FYM – farmyard manure; SS – sewage sludge

Table 5
Number of years after which the acceptable content of heavy metals in the soil will be exceeded at the annual application of municipal sewage sludge and manure at a dose of 170 kg N ha^{-1}

			Cd	Cu	Cr	Ni	Pb	Zn
Content in soil		mg kg^{-1} DM	0.52	12.25	18.46	6.44	23.83	33.31
Permissible content in the soil*		mg kg^{-1} DM	1	25	50	20	40	80
Amount introduced to soil with	FYM	μg kg^{-1} DM	0.63	129.9	14.88	9.91	6.91	1733.2
	SS		0.81	124.7	6.72	8.35	5.33	535.7
Number of years to exceed the permissible content in the soil	FYM	years	761	3033	102	1623	87	4699
	SS		593	2340	98	1368	27	2119

* according to Regulation of the Minister of the Environment (2015); FYM – farmyard manure; SS – sewage sludge

0.500 μg kg^{-1}, respectively. Based on this, the authors evidenced that in the case of Hg, sewage sludge at a dose of 7.5 Mg ha^{-1} could be safely introduced to the soil for 18 years before the content exceeds the quality norms of the soil environment in China (1 mg kg^{-1}). The safe period of application for Zn is 51 years, and for other heavy metals it is even longer, reaching 112 years for Cu, 224 years for Cd, and 902 years for Pb.

3.2. Yielding and chemical composition of plants

The application of organic fertilisation in the form of manure and sewage sludge had a positive effect on yielding potatoes. The obtained yields of tubers were high, reaching approximately 16 Mg ha^{-1} on the control object, and considerably increased as a result of fertilisation to 31 Mg ha^{-1} in the conditions of application of sewage sludge, and 32.3 Mg ha^{-1} on the object fertilised with manure (Figure 1). No significant differences were determined in the yield of potatoes from objects fertilised with sewage sludge and manure.

Dry mass content in potato tubers was not dependent on the applied fertilisation, and reached 22% on the control object, 20.5% in the conditions of application of manure, and 23% in the conditions of fertilisation with sewage sludge, respectively. The dry mass yield resulting from organic fertilisation significantly increased in comparison to the control object (Figure 1).

Through its positive effect on the physical, chemical, and biological soil properties, organic fertilisation improves the conditions of growth and development of plants, therefore positively affecting their yielding (Assefa and Tadesse, 2019; Boudjabi and Chenchouni, 2021). Keçeci et al. (2022) evidenced that the dose of municipal sewage sludge optimal for potatoes in terms of yielding is within a range between 20 and 80 Mg ha^{-1}. In the conducted own study, sewage sludge applied at a dose of 19 Mg ha^{-1} caused a significant increase in the yield in comparison to the control object. According to Hlisnikovský et al. (2021), in the conditions of exclusive application of manure, the yield of potato tubers obtained in variable soil and climate conditions was within a range from 6.6 to 42 Mg ha^{-1}, and was significantly higher than yields obtained from non-fertilised objects.

The content of macroelements in potato tubers was dependent on the applied fertilisation (Figure 2). Nitrogen content in potato tubers was within a range from 14.89 to 18.40 g kg^{-1} DM, and increased in comparison to the control object, both in terms of application of manure and sewage sludge. However, only the application of sewage sludge caused a significant (23%) increase in the content of the element in the tubers in comparison to control.

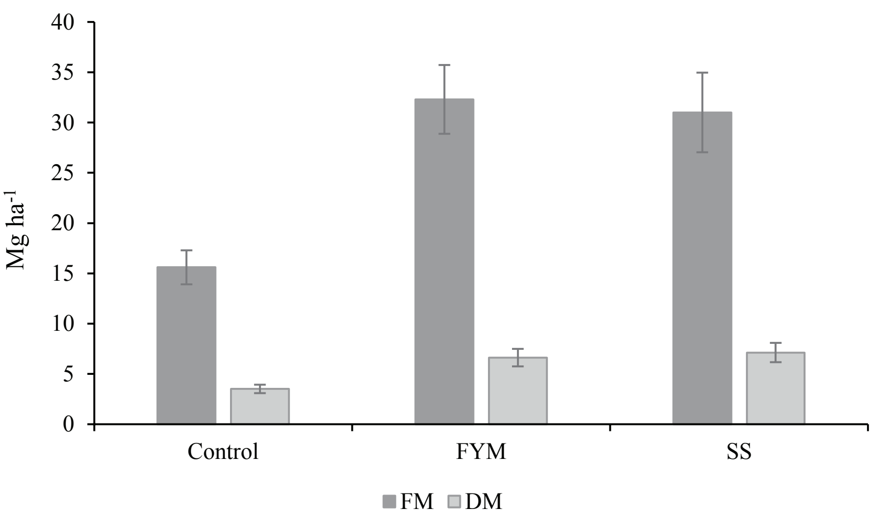

Fig. 1. Yield of fresh matter and dry matter of potatoes. Explanations: FM – fresh matter, SS – sewage sludge, FYM – farmyard manure, SS – sewage sludge, error bars – SD (standard deviation)

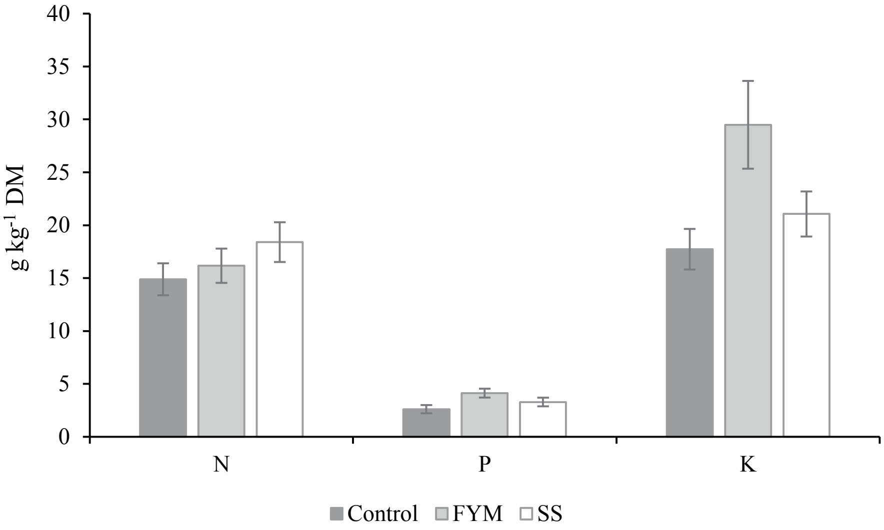

Fig. 2. Content of nitrogen, phosphorus and potassium in potato tubers. Explanations: FYM – farmyard manure, SS – sewage sludge, error bars – SD (standard deviation)

The highest content of phosphorus in potato tubers (4.13 g kg^{-1} DM) was determined in the conditions of manure application. On the control object and in the conditions of application of sewage sludge, P content in potato tubers was considerably lower. Like in the case of phosphorus, the highest potassium content occurred in tubers of potatoes fertilised with manure. It was significantly (66%) higher than on the control object, and 20% higher than in tubers of potatoes fertilised with sewage sludge.

Organic fertilisation contributes to an increase in the content of nutrients in plants in comparison to non-fertilised objects (Makarewicz et al., 2018; Thomas et al., 2019; Antonkiewicz et al., 2020; Keçeci et al., 2022). Manure and sewage sludge supply plants with nutrients. Their effect depends on the rate of the mineralisation process, and is usually distributed over 2–3 vegetation seasons (Assefa and Tadesse, 2019). In the first year, natural and organic fertilisers may release up to 30% of nitrogen, largely meeting the nutritional needs of plants towards the element (Harraq et al., 2022). Like nitrogen, phosphorus occurs in organic and natural fertilisers primarily in organic bonds, and is released from those compounds through mineralisation to the amount of 0.9–4.2 mg kg^{-1} day^{-1} (Oehl et al., 2004). The amount of potassium supplied in manure can exceed the needs of plants, and sewage sludge is poor in this element (Bittencourt et al., 2014), which might have been the cause of significantly higher K content in tubers of potatoes fertilised with FYM in comparison to SS.

The application of manure and sewage sludge caused an increase in the content of heavy metals in potato tubers in comparison to the control object (Table 6).

In the conditions of manure application, the content of the Cd increased 2.5-fold, and in the case of the remaining elements from 10% for Zn to 46% for Pb and Cu. As a result of application of sewage sludge, Cd content in potato tubers increased 4-fold, and an increase in the content of the remaining metals varied from 21% (Zn) to 96% (Pb). Studies by many authors evidenced the contribution of the application of sewage sludge to an increase in the content of heavy metals in plants, often in amounts exceeding acceptable values (Liu et al., 2018; Yang et al., 2018; Antonious, 2020; Buta et al., 2021; Eid et al., 2021; Kołodziej et al., 2023). Manure, in turn, is considered as a fertiliser that poses no threat for the environment in terms of content of heavy metals. In recent years, however, attention has been paid to the possibility of occurrence of heavy metals in manure in amounts exceeding the acceptable values, which has a direct effect on their accumulation in plants (Irshad et al., 2013; Malan et al., 2015; Antonious, 2020; Zhen et al., 2020).

The acceptable content of Cd and Pb in peeled potato tubers according to the Commission Regulation EU (2021a, 2021b) is 0.10 mg kg^{-1} FW. The content of Cd and Pb in non-peeled potato tubers reported in own research varied from 0.11 to 0.14 µg kg^{-1} FM for Cd, and 0.03–0.15 µg kg^{-1} FM for Pb, i.e. they were considerably lower than the acceptable values, and posed no threat to the health of consumers.

Table 6
Effect of fertilisation with sewage sludge and manure on the content of heavy metals in potato tubers

	Cd	Cu	Cr	Fe	Mn	Ni	Pb	Zn
	mg kg^{-1}							
Control	0.02a	1.11a	0.24a	18.58a	12.37a	0.85a	0.32a	26.48a
FYM	0.05b	1.62b	0.32b	21.43a	15.25a	1.12b	0.35a	29.25a
SS	0.10c	1.98c	0.41c	32.52c	20.63b	1.56c	0.47b	32.07b

FYM – farmyard manure; SS – sewage sludge

4. Conclusions

The study evidenced that municipal sewage sludge applied in agriculture shows an approximate to that of manure, positive effect on physico-chemical soil properties. It leads to an increase in the content of organic carbon, total nitrogen, and available forms of P and K. It also improves the sorption properties of the soil, increasing the content of exchangeable forms of Ca, Mg, K, and Na. Through the positive effect on soil properties, sewage sludge improves the conditions of plant growth. In the conditions of application of sewage sludge, the yield of fresh and dry mass of potato tubers doubled in comparison to the non-fertilised object. Content of N, P, and K in potato tubers also increased.

The application of sewage sludge also increased the content of heavy metals in potato tubers, although no exceedance of acceptable contents of Cd and Pb in potatoes were recorded pursuant to the Regulation of the EU Commission.

The application of sewage sludge with content of heavy metals not exceeding the acceptable limit causes an increase in the content of these elements in soil. In the short-term, however, it does not lead to the exceedance of their acceptable content in soil. The analysed sewage sludge can be safely applied for a period of 27 years before the content of Pb exceeds the limit for soils under agricultural use.

Municipal sewage sludge can be successfully used in agriculture as an organic fertiliser. Nonetheless, the threats related to an increase in heavy metals, particularly in the case of its long-term use, point to the necessity of monitoring of the content of these elements in sewage sludge, soil, and plants, for the purpose of minimising the risk of pollution of the food chain.

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Ocena możliwości rolniczego wykorzystania komunalnych osadów ściekowych

Słowa kluczowe

Solanum tuberosum
Osady ściekowe
Obornik
Gleba
Właściwości

Streszczenie

W doświadczeniu wegetacyjnym badano wpływ komunalnych osadów ściekowych i obornika na plonowanie i skład chemiczny ziemniaków odmiany Irga oraz wybrane właściwości fizykochemiczne gleby. W glebie oznaczono odczyn, zawartość węgla organicznego, azot ogólny, przyswajalny P i K oraz kationy wymienne. Określono również plon świeżej i suchej masy ziemniaków oraz zawartość N, P i K w bulwach. Ponadto w glebie i bulwach ziemniaka oznaczono metale ciężkie (Cd, Cu, Cr, Fe, Mn, Ni, Pb, Zn). Przeprowadzone analizy wykazały wysoką wartość nawozową komunalnych osadów ściekowych, zbliżoną do obornika. Jego zastosowanie pozytywnie wpłynęło na wszystkie analizowane właściwości gleby i spowodowało dwukrotny wzrost plonu bulw ziemniaka w porównaniu z obiektem kontrolnym. W wyniku zastosowanego nawożenia osadami ściekowymi i obornikiem zawartość metali ciężkich w bulwach ziemniaka istotnie wzrosła w porównaniu z kontrolą. Zawartość Cd i Pb w bulwach ziemniaka dla Cd wahała się od 0,11 do 0,14 µg kg^{-1} ŚM, a dla Pb od 0,03 do 0,15 µg kg^{-1} ŚM i była znacznie niższa od wartości dopuszczalnej (0,1 mg kg^{-1} ŚM) zgodnie z Rozporządzeniem UE, a więc nie stanowi zagrożenia dla zdrowia konsumentów. W odniesieniu do możliwości akumulacji metali ciężkich w glebie wykazano, że analizowany osad ściekowy może być bezpiecznie użytkowany przez okres 27 lat, zanim zawartość Pb przekroczy normę dla gleb użytkowanych rolniczo. W przypadku innych metali okres ten jest znacznie dłuższy, a dla Cu sięga 2340 lat. W warunkach stosowania obornika zawartość Pb przekroczy normę po 87 latach, a Zn po 4699 latach.