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AGRICULTURAL USABILITY OF SEWAGE SLUDGE AND VERMICOMPOST OF TANNERY ORIGIN

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ABSTRACT

Sludge and vermicompost of organic origin were examined in a field experiment aimed at determining their suitability as soil fertilisers. The experiment was performed in three consecutive years (1996-98) on the sludge originating from a biological and chemical tannery sewage treatment plant and vermicompost based on the sewage sludge to which fruit tree leaves and wheat straw were added. Comparison to the farmyard manure proved that higher abundance of organic matter, nitrogen, calcium and sodium was found for both untreated tannery sludge and sludge composted by *Eisenia fetida*; the content of potassium was, however, much lower while phosphorus and magnesium were found in the amounts similar to farmyard manure. Contamination with heavy metals, apart from chromium, remained within the acceptable limits. The yield forming effects of the

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untreated biological sludge and vermicomposts were equal to the ones obtained for the mineral treatment, whereas chemical sludge gave results similar to farmyard manure. Organic materials applied as soil fertilisers affected the content of potassium, calcium, magnesium and sodium in the yields of plants more effectively than a farmyard manure and they did not diversify the content of heavy metals.

Key words: sewage sludge, vermicompost, yield, macroelements, heavy metals

INTRODUCTION

The problems resulting from increasing amounts of deposited sewage sludge have lead to launching studies concerned with their biological and agricultural utilisation [6, 7]. Such sewage sludge can be applicable in agriculture as long as the following four rules are respected and obeyed: a good agricultural practice is maintained, a long-term soil productivity is preserved, public nuisance due to sludge application is eliminated, and last but not least, all the regulations concerned with protection of underground waters, safety of both human and animal health, as well as soil environment are observed. Prior to applying sewage sludge in agriculture, the sludge must be either treated biologically, chemically or thermally, put to a long-term storage or be exposed to any other processes reducing the number of pathogenic microorganisms [18].

A method of a biological treatment of organic waste, which involves *Eisenia fetida* earthworm [2, 14], has been recently gaining more scientific interest. The main task of the earthworms in vermicomposting is to transform in their digestive systems the plant mass, or its derivatives, to an amorphous state. Though the effect of employing earthworms for composting 'raw' sewage sludge is not particularly effective, its importance cannot be denied when the sewage sludge is initially composted together with plant mass or other organic components. The method facilitates the effective change of compost properties and enables to obtain useful fertilisers called vermicomposts.

The paper presents the results of a three-year field experiment in which vermicompost based on a biological sludge from a tannery waste treatment plant as well as untreated tannery sludge from biological and chemical treatment plant were applied as fertilisers.

MATERIAL AND METHODS

The field experiment was conducted from 1996 till 1998 in Sędziszów Małopolski near Rzeszów (fig. 1). We used an untreated sewage sludge originating from a mechanical-and-biological treatment plant of Krakow Tannery and sewage sludge-based vermicompost with wheat straw and fruit tree leaves added. Straw and leaves altogether constituted 20% of the sludge dry weight. The composting lasted 9 months and was followed by a 6-month vermicomposting with *Eisenia fetida* earthworm. Apart from the enumerated materials, untreated tannery sludge from "MAT" tannery sludge chemical treatment plant in Cerekiew near Radom was used. In order to compare yield forming effect of tannery organic materials, a farmyard manure and mineral treatment were applied.

Fig. 1. Experiment location

An experimental set up (presented in table 2) of a randomised block method including 7 treatments in four replications with each plot area equal to 24 m^2 was customised.

Table 1. Chemical composition of organic material used in experiment

Determination	FYM	Not converted deposit		Vermicompost*	
		Biological	Chemical	Straw	Leaf
Dry mass %	26.25	34.15	23.17	43.75	46.88
% in dry mass					
Organic - C	27.3	23.6	16.2	19.0	18.0
Total - N	1.79	3.95	4.72	1.79	2.43
C : N	15.2	6.0	3.4	10.6	7.4
P_2O_5	0.93	0.96	0.21	1.22	0.83
K_2O	1.37	0.13	0.01	0.45	0.38
Ca	0.93	9.87	4.19	9.38	7.66
Mg	0.39	0.27	0.06	0.35	0.26
Na	0.95	0.44	0.34	0.27	0.23
$mg \cdot kg^{-1}$ dry mass					
Cu	8.38	28.20	4.53	64.5	47.3
Cr	150	7121	400	9584	7084
Pb	9.24	25.4	18.5	28.8	24.4
Cd	0.55	0.64	0.07	0.78	0.54

*** prepared from biological deposit**

Table 2. Yields of dry mass of plants ($t \cdot ha^{-1}$)

Fertilizer objects	Fodder beets			Potatoes	Maize
	1996			1997	1998
	leaf	roots	total	tubers	green forage
A. Control	3.54	9.13	12.67	3.18	10.64
• Mineral fertilizaton	4.61	9.88	14.49	3.33	16.98
• FYM	4.10	9.68	13.96	3.49	19.92
• Straw vermicompost*	4.35	10.22	14.57	3.69	16.95
• Leaf vermicompost*	4.33	10.50	14.83	3.45	16.37
• Biological deposit	4.65	9.61	14.26	3.50	16.62
• Chemical deposit	4.28	11.19	15.47	3.31	21.11
$LSD_{0.05}$	0.41	0.94	1.11	0.29	1.72

*** prepared from a biological deposit**

The experiment was performed on a medium compact, brown proper soil, with 40% of floatable particles. The pH of 5.29 in 1 mol · dm^{-3} KCl solution, cation exchange capacity (CEC) of the soil and its hydrolytic acidity equal to 138.6 mmol(+) · kg^{-1} and 22.9 mmol(+) · kg^{-1}, respectively, were used. The soil contained total nitrogen, organic carbon, available phosphorus and potassium in the amounts of 1.70 g N · kg^{-1}, 14.50 g C · kg^{-1}, 95.9 mg · kg^{-1}, and 109.6 mg · kg^{-1}, respectively. The heavy metal contents remained within the natural content range.

The content of nitrogen was a parameter determining a dose of sewage sludge and vermicompost applied in the first year of the experiment. It was equivalent to the amount of nitrogen in a dose of a farmyard manure. The dose of 100 kg N · ha^{-1} was applied. Doses of phosphorus and potassium were supplemented with mineral fertilisers to reach the highest level for the organic fertilisers, namely 71.7 kg P_2O_5 · ha^{-1} in combination “D” and 127 kg K_2O · ha^{-1} in combination “C”. Mineral (treatment “B”) and supplementary fertilisation for the other treatments, except the control one, was applied in the following forms: N in the ammonium nitrate, P in a granulated simple superphosphate and K in a 60% potassium salt. Following the organic fertilisation of soil crops such as fodder beets - Poly Past c.v., potatoes - Koral c.v. and a silage maize - Koński ząb c.v. were cultivated in the first, second, and third year of the experiment, respectively. A uniform supplementary fertilisation for all plots except the control one was applied in the second year and dosed 100 kg N, 90 kg P_2O_5 and 150 kg K_2O · ha^{-1}, whereas in the third year the doses were equal to 100 kg N, 70 kg P_2O_5 and 120 kg K_2O · ha^{-1}.

Each year the mass of obtained yield for each harvested crop was determined and evaluated statistically according to a one factor analysis of variance, where significance of differences between mean values was estimated with the t-Student test at the level of significance α=0.05.

Samples of plant material for chemical analyses were prepared as a weighted average of four replications for each treatment.

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To obtain a dry mass weight for all the organic materials (sludge, composts and vermi-composts) used in the experiment were dried in a warm airflow dryer at the temperature of 70^{o}C; further analyses were conducted on a dried and crushed material. Kjeldahl's and Tiurin's methods were applied to determine the total amount of nitrogen and concentration of organic coal in organic materials, respectively. Automatic Kjeltec II Plus apparatus was used in Kjeldahl's method.

Following dry mineralisation of the organic material and plants relevant methods were applied to determine the content of chemical elements. Namely, a calorimetrical vanadium-molybdenum method and a Backman DU 640 apparatus for phosphorus, flame photometry (FES) for potassium, calcium and sodium, while atomic absorption spectrophotometry in Philips PU 9100X apparatus for the other elements such as magnesium, copper, cadmium, chromium and lead (Mg, Cu, Cd, Cr and Pb).

For nitrogen, phosphorus and potassium (N, P and K) approximate percentage values of utilisation coefficients for the crops of fodder beets, potatoes and maize were computed by means of a differential method e.i. by deducting the component uptake for the untreated control (no fertilisers applied) from the component uptake for each individual plot, and subsequent division of the result by the amount of the respective component with the fertilisers applied.

RESULTS

Table 1 presents the chemical composition of the materials used in the field experiment.

The dry matter weight ranged from 23.17 to 46.88%. Both kinds of vermicompost contained the highest amount of dry matter; the lowest was found in the chemical tannery sludge.

The content of organic carbon exceeded 20% for the farmyard manure and biological sludge but was lower than that for the chemical sludge and vermicomposts.

Fertilisers used for the experiment were abundant in nitrogen (1.79–4.72%). The highest amount of total nitrogen (in dry matter) was found for the untreated sludge from the biological treatment plant of Krakow Tannery and the sludge from a chemical Tannery treatment plant Mat near Radom: 3.95% N and 4.72% N, respectively.

C to N ratio calculated for the discussed organic materials was low and ranged between 3.4 and 10.6, except for the farmyard manure (15.2).

Phosphorus content in the applied materials varied, in some cases reaching even higher level than determined for the farmyard manure, i.e. 0.93% P_2O_5. The untreated biological sludge contained 0.96% P_2O_5, while for straw vermicompost 1.22% of P_2O_5 was found. The least content of phosphorus was found in the chemical sludge (0.21% P_2O_5).

Amongst all the determined macroelements only potassium was found in deficient amounts; it ranged between 0.01 and 0.45% K_2O. For the farmyard manure phosphorus reached the highest amount of 1.37%.

The content of calcium both in the sludge and two types of vermicompost was found to be 10 times higher than the one determined for the farmyard manure.

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Magnesium content in the examined materials did not differ significantly from the contents determined for the farmyard manure (0.39% Mg), except for the chemical sludge (0.06% Mg), for which the value was six times lower.

In all examined fertilising materials the level of sodium was lower than found in the farmyard manure (0.95% Na) and ranged between 0.23 and 0.44% Na in dry matter.

Copper content in the sludge ranged from 4.53 to 64.51 mg Cu $\cdot$ kg^{-1} of dry matter and did not exceed the boundary values [12].

Chromium content ranged widely from 127 up to 9584 mg Cr $\cdot$ kg^{-1} of dry mass; its maximum value was 9 times higher than the boundary value (1000 mg Cr $\cdot$ kg^{-1}) suggested by Kabata-Pendias and Piotrowska [12].

Both lead and cadmium contents (12.80 to 28.83 mg Pb $\cdot$ kg^{-1} and 0.07 to 0.78 mg Cd $\cdot$ kg^{-1} of dry mass, respectively) in the analysed materials were well below the boundary values.

In the first year of investigations the yield forming effect of organic materials was estimated for fodder beets experiment (tab. 2).

Organic fertilisation caused the yield of dry mass leaves to increase for all the treatments in comparison to the control one; the increase was statistically significant (tab. 2).

When compared to the plot fertilised with the farmyard manure, statistically detectable increase of dry mass of fodder beet leaves was found both for plots that had received mineral treatment with NPK and untreated biological sludge. The respective yields were higher by 12% and 13%. The increase in yields of dry mass leaves at the other plots was statistically insignificant. Neither the plots fertilised with the farmyard manure, untreated biological sludge nor the ones receiving NPK mineral fertilisation showed higher yield of dry mass beet root than the plot fertilised with the untreated chemical sludge for which the yield reached the highest, statistically significant value of 11.19 t $\cdot$ ha^{-1} (see tab. 2).

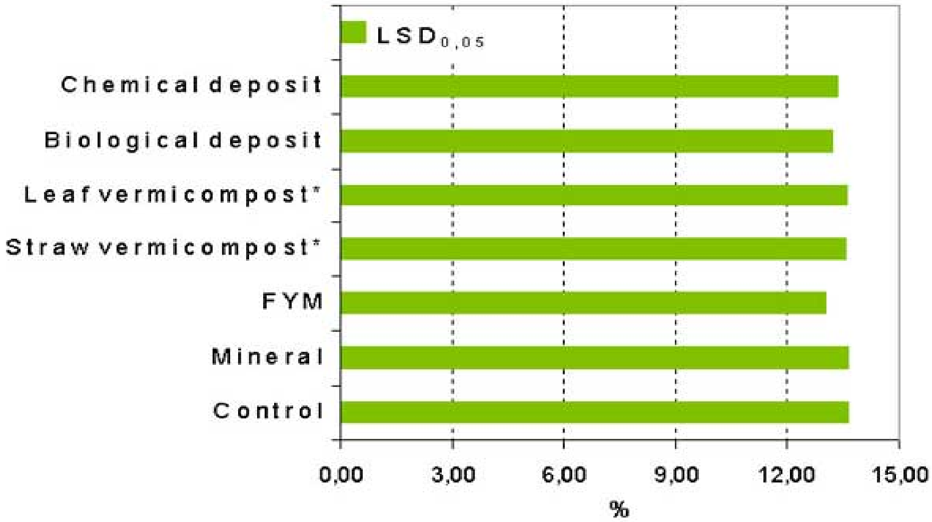
In relation to the plots treated with the farmyard manure, vermicomposts to which straw and leaves were added, caused insignificant (6 and 8%) increase in the yields for fodder beet root dry mass; similarly untreated chemical sludge led to a 16% rise.

Total dry mass yield for leaves and roots of fodder beets was the highest for the plot fertilised with the untreated chemical sludge and reached 15.47 t $\cdot$ ha^{-1}.

In the first year of the consecutive fertilising effect of the organic materials (1997) their influence on potato crop was investigated in relation to plot exposed to the uniform mineral fertilisation.

The highest amount of starch (13.68%) was detected in potato tubers cultivated on the mineral treatment, straw vermicompost (13.60%) and leaf vermicompost (13.62%). A similar starch content was found also in the tuber yield for the untreated control plot (fig. 2). Comparison with the contents registered for the farmyard manure treatment proved that the determined increments in starch content were not statistically significant.

Fig.2. Content of starch in potatoes
*** prepared from biological deposit**



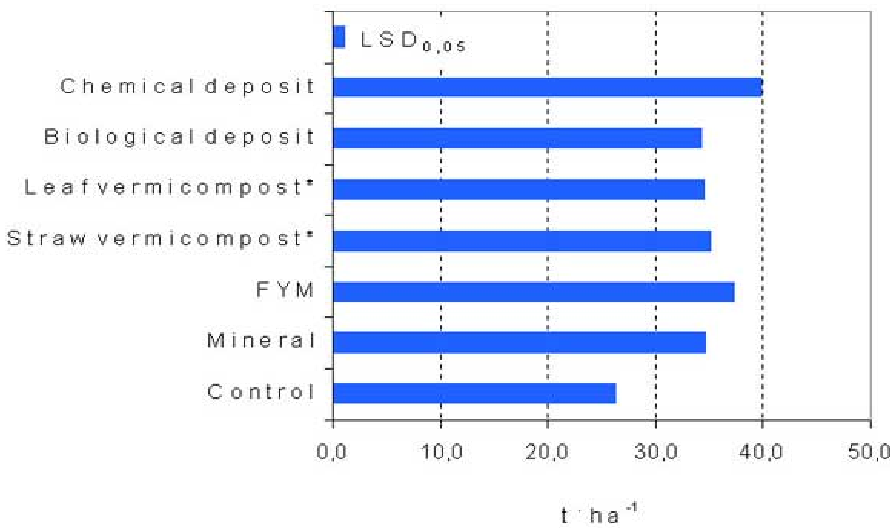
Fertilisation with organic materials slightly diversified the yield of dry mass tuber. Yet again, the differences were not statistically significant, except for the straw vermicompost treatment for which the yield was the highest (tab. 2). In the second year (1998) of consecutive effect of organic treatment a silage maize was cultivated. Great diversification in the yields of dry mass maize was observed for different plots (tab. 2). The consecutive effect of each of the applied fertilisers was reflected in significant increases in dry mass maize yields when compared with the control plot.

The biggest yield of dry mass was harvested at the plot to which untreated chemical sludge treatment was applied. The yield here was higher by 24% than the one for the plot exposed to NPK mineral treatment and by 6% where the farmyard manure was applied. The increase in both cases gain statistical importance.

The consecutive effect of untreated biological sludge and its vermicomposts affected the yield of dry mass maize in a similar degree as the mineral treatment, whereas the farmyard manure treatment appeared to be more effective.

Total dry mass yields for plants cultivated in the three-year field experiment are shown in figure 3.

Fig. 3. Total yields of plants (tops and roots) in experiment
*** prepared from biological deposit**



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Plants responded to fertilisation with organic materials showed great diversity. A significant increase of total yields was observed for all the plots; it ranged from 30 to 51%. Total yields for plants fertilised with vermicompost were comparable with the yield for NPK mineral treatment, though they were significantly lower than for the farmyard manure. For the plots fertilised with the untreated chemical sludge a statistically significant increase in the total yield of dry mass of plant in relation to both NPK mineral fertilisation and farmyard manure (of 15% and 7%, respectively) was found.

The effect of fertilisation with tannery materials on the level of plant nitrogen is shown by a weighted mean content of this element in the yield of 3 plants (tab. 3). The content of nitrogen for plants from plots fertilised with vermicomposts and the farmyard manure were at the similar level. For plants grown on the untreated biological sludge and NPK mineral treatment the content of this element was higher. Relatively high content of nitrogen and other elements in plants from the control plot resulted from nitrogen concentration in a relatively low yield.

For all the fertilised plots phosphorus concentration was similar and did not reveal any diversification (tab. 3).

Table 3. Average weighted content of macroelements in dry mass of plants (% in dry mass)

Fertilizer objects	N	P	K	Ca	Mg	Na
A. Control	1.45	0.30	1.86	0.12	0.24	0.18
• Mineral fertilization	1.45	0.27	1.60	0.10	0.24	0.18
• FYM	1.31	0.25	1.39	0.11	0.20	0.18
• Straw vermicompost*	1.29	0.25	1.57	0.13	0.25	0.21
• Leaf vermicompost*	1.33	0.27	1.62	0.12	0.24	0.21
• Biological deposit	1.46	0.27	1.73	0.13	0.26	0.21
• Chemical deposit	1.31	0.24	1.44	0.13	0.28	0.20

*** prepared from a biological deposit**

The effect of applied materials was more pronounced for potassium content, which proved to reach the highest value for the plots fertilised both with biological tannery materials and mineral components (tab.3).

The lowest content of potassium (1.39% K) was found for plants fertilised with the farmyard manure and untreated chemical sludge (1.44% K), whereas it was the highest for plants fertilised with tannery materials. Such high contents, however, could have resulted from introducing a relatively big amounts of mineral potassium in order to balance its deficiency in the materials of tannery origin.

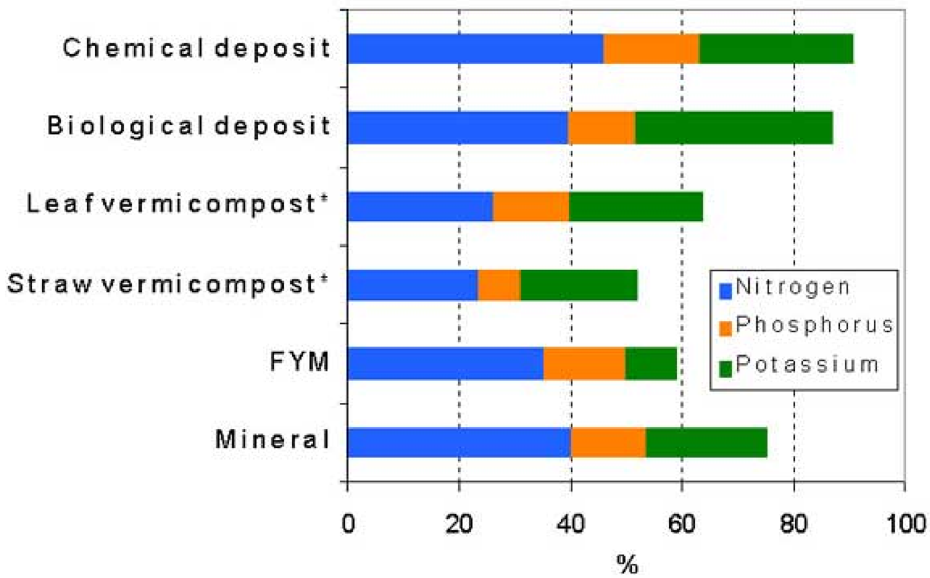
Considerable amount of calcium introduced into the soil with vermicomposts and untreated sludge did not significantly affect calcium concentrations in plants grown on vermicomposts (tab. 3). Higher Ca level in the yields of plants for the plots fertilised with tannery materials varied from 9 to 18% in relation to farmyard manure treatment.

Organic treatment influenced powerfully the contents of magnesium in plants (tab. 3). With the plot that had received the farmyard manure treatment set as the standard (0.20% Mg), an increase in the concentration of that element varied between 20% and 40% for plots fertilised with a leaf vermicompost and untreated chemical sludge, respectively. A minor increase was found when related to the mineral treatment.

Average weighted contents of sodium in plants differed for the plots fertilised with tannery materials and traditionally i.e. with NPK minerals and farmyard manure (tab. 3). The average sodium contents in plats originating from plots fertilised with vermicompost and sewage sludge was higher by 15% than from the other ones.

Approximate data on utilisation of three nutrients (N, P and K) from the fertilisers were calculated as a difference in the amount of the respective elements in yields for fertilised plots and for the untreated control. The amounts of nitrogen, phosphorus and potassium used throughout the three-year experiment were presented in the chapter describing methods. The results concerning N, P and K utilisation are shown in figure 4.

Fig. 4. Approximate utilization of N, P and K components after three years of
*** prepared from biological deposit**



Nitrogen was the most easily utilised element; its amount utilised from fertilisers ranged from 23 to 46%. The highest nitrogen utilisation was observed for the plots fertilised with untreated sludge where utilisation was comparable with the one observed for the plot receiving NPK mineral treatment. Quantities of nitrogen utilised at the plots treated with vermicompost were lower in relation to the value determined for the plot receiving farmyard manure (35%).

The plants used much small amounts of phosphorus (fig. 4). The worst utilisation was observed for the straw vermicompost plot (7.5%), which could have resulted from a lower decomposition rate of the material. Phosphorus from chemical sludge (17%) was utilised in the most effective way. Its utilisation was even higher than for the mineral treatment (13%). Definitely lower indices for phosphorous utilisation from the applied fertilisers might be explained by a very high phosphorus abundance in the soil prior to the application of treatment.

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A similar tendency was observed for potassium utilisation by plants (fig. 4). The element was most easily utilised from the untreated biological (35%) and chemical sludge (28%), which in turn might have developed from of easy uptake of potassium mineral form in order to supplement its deficiency. The level of potassium utilisation from farmyard manure was the least impressive (9%), though its utilisation from vermicompost was comparable to the values determined for NPK mineral treatment (22%).

Heavy metal contents are illustrated by average weighted content of copper, cadmium, chromium and lead (tab. 4).

Table 4. Average weighted content of heavy metals in dry mass of plants ($mg \cdot kg^{-1}$ dry mass)

Fertilizer objects	Cu	Cd	Cr	Pb
A. Control	5.75	0.21	1.06	3.22
• Mineral fertilization	5.57	0.21	1.06	3.38
• FYM	4.90	0.19	1.22	2.99
• Straw vermicompost*	5.68	0.22	1.27	3.32
• Leaf vermicompost*	5.78	0.25	1.34	3.31
• Biological deposit	6.10	0.26	1.45	3.50
• Chemical deposit	5.61	0.24	1.27	3.28

*** prepared from a biological deposit**

For copper, the approximate quantities were found in plants for mineral NPK treatments and for the plots receiving vermicompost and untreated chemical sludge (tab. 4). The plants fertilised with farmyard manure contained the smallest amount of copper (4.90 $mg \cdot kg^{-1}$d.m.). Copper contents determined for fodder plant yields remained at the deficiency levels [11].

The content of cadmium ranged from 0.19 $mg \cdot kg^{-1}$ in plants fertilised with farmyard manure to 0.26 $mg\ Cd \cdot kg^{-1}$ d.m. on the plot receiving untreated biological sludge (tab.4). Slightly higher Cu contents found in the plants fertilised with tannery materials did not, according to Anke [1], exceed the respective boundary values for fodder.

In comparison with farmyard manure, high concentrations of chromium in the tannery materials used for treatment did not have any greater effect on Cr contents in plants that were pronounced as lack of diversification (tab. 4). Chromium contents determined for the plant yields remained at the level of physiological values [4].

The content of lead was similar to chromium. It did not reveal any diversification among the experimental plots; in plants receiving vermicompost and untreated sludge its level reached the level determined for plants fertilised with mineral components (tab. 4).

DISCUSSION

According to Siuta [17] sludge from sewage treatment plants is abundant in organic and mineral fertiliser components. Therefore, the components should return to soil environment as naturally as plant mass returns to soil. In a traditional agriculture it is returned as farmyard manure. Not returned soil forming mass both impoverishes the biological activity of the environment and pollutes the soil in the areas burdened with such substances in form of either liquid or solid waste. Specific methods of the utilisation of sewage sludge have been suggested by many authors [5, 7, 15]. For the same reason in the experiment discussed hereby, we used untreated sludge from a biological and chemical treatment plant of tannery waste together with vermicompost prepared from biological sludge.

The investigation has revealed that the composition of the initial material i.e. biological sludge, differed from the composition of vermicomposts of tannery sludge origin obtained by employing *Eisenia fetida.* The contents of essential nutrients, particularly nitrogen, phosphorus, calcium and magnesium suggest considerable fertilising worth of the analysed material, which does not deviate much from the amounts of the components determined by Gąsior et al. [10] in vermicomposts based on cattle, sheep and pig manure.

Tested samples of vermicompost contained definitely smaller quantities of potassium in comparison to a standard organic fertiliser, i.e. farmyard manure. Such a feature, however, is determined by a small amount of potassium, which is being removed from the sludge in the treatment procedure with waste waters [7, 13].

The C to N ratio is an important criteria to determine the worth of the obtained vermicompost. In the presented types of vermicompost the ratio was of lower value than determined for farmyard manure. It resulted on the one hand from insufficient amount of organic carbon supplied as a component for composting and from high concentration of nitrogen in the sludge, on the other. Such a low C:N ratio might also reflect the process of organic matter utilisation from the mass composted by *Eisenia fetida*.

The observed content of chromium restricts the possibilities of agricultural utilisation of tannery sludge and vermicomposts originating from them [8, 13]. It is conditioned by the technological process of leather tanning and subsequent accumulation of chromium in the sewage sludge. We feel oblige to remind here that toxicity of chromium and therefore the detrimental effect it may have on plants is highly dependable on its form and the applied dose [9]; moreover, according to Koc et al. [13] small doses of chromium affect the plants positively.

The results presented in this paper confirm that treatment with tannery sewage sludge and vermicompost based on it can be beneficial with respect to plant yields. Yields obtained in the field experiment were diversified with respect to the cultivated crop and treatment, but in general remained at the levels comparable with yields obtained for mineral and farmyard manure treatments. Filipek-Mazur [6] on the basis of crop yields for fodder beet, potato and grass obtained in two 3-year field experiments, found also a favourable yield forming effect of both untreated and composted with straw or sawdust tannery sludge, comparable to farmyard manure effect.

In relation to the plot receiving farmyard manure, fertilisation with tannery sludge and vermicompost applied in the concerned experiment, beneficently influenced contents of calcium, magnesium and sodium mainly at the untreated sludge treatment. Moreover, the content of potassium in yields was higher than for the plot treated with the farmyard manure and NPK.

Studies conducted by Mazur and Koc [16] show that treatment with tannery sludge has diversified contents of nitrogen and sodium in plants, but the levels of phosphorus, calcium and magnesium remained unchanged, whereas for potassium a declining tendency was observed. Inconsistent results for magnesium, potassium and calcium contents obtained by Mazur and Koc [16] may be explained by the fact that in the 1st year of the experiment a supplementary phosphorus and potassium treatment was applied in order to balance all the components at all fertilised plots.

Diverging results for contents of potassium, magnesium, phosphorus and calcium in plants may, however, be of more complex origin than only the kind of material used for treatment. The mineral uptake is dependable on physico-chemical characteristics of soil, its type, date of fertilisation, atmospheric conditions and plant species. Such factors might have not only significantly influenced all the mineralisation processes of the introduced organic materials but also determine the availability of nutrients.

Organic materials applied in the field experiment did not diversify plant contents of chromium at the respective treatments, despite their quite significant amount introduced into the soil. According to Czekała [3] 0.21 mg Cr $\cdot$ kg^{-1} contents for potato tubers and 0.48 mg Cr $\cdot$ kg^{-1} for beet roots are considered to be natural values. In the discussed experiment chromium contents were higher. In his later extensive studies on chromium, Czekała [4] reported that chromium contents varied for fodder crops not only from species to species but also among cultivars. On the basis of the obtained results he classified plants according to their average contents of chromium. Beet roots, potatoes and maize belonged to the same group containing between 0.11 and 0.50 mg Cr $\cdot$ kg^{-1}. Czekała [4] also found differences in chromium contents that depended on the plant organ, cultivar and in particular on fertilisation. Similar results were obtained in the presented studies.

Almost uniform contents of heavy metals in plants was observed most likely due to low concentrations of heavy metals in the fertilisers applied; such a supposition was confirmed in studies by Filipek-Mazur [8].

CONCLUSIONS

1. Untreated tannery sludge from chemical and biological-and-mechanical treatment plants as well as the ones composted by *Eisenia fetida* were more abundant in organic matter, nitrogen, calcium and sodium than farmyard manure but potassium deficient, whereas similar contents of phosphorus and magnesium were found.
2. Apart from chromium the contents of heavy metals in the applied organic materials were within the acceptable limits.
3. The yield forming effect for both untreated biological sludge and vermicompost were equivalent to the effect caused by mineral treatment; chemical sludge gave results similar to farmyard manure.
4. Organic materials affected the contents of potassium, calcium, magnesium and sodium in the obtained yields of plants more effectively than farmyard manure.
5. The applied treatment did not diversify the contents of heavy metals in obtained yields of plants.

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