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CONTENT OF COPPER, ZINC AND MANGANESE IN SOIL FERTILIZED WITH MUNICIPAL SOLID WASTE COMPOSTS

ZAWARTOŚĆ MIEDZI, CYNKU I MANGANU W GLEBIE NAWOŻONEJ KOMPOSTAMI Z ODPADÓW MIEJSKICH

Abstract: A three-year pot experiment has been conducted in order to analyze the influence of composts made from unsorted municipal solid waste and urban green waste on the total content of copper, zinc and manganese and their soluble forms in soil. The applied composts differed in maturity and the chemical composition of the matter from which they originated.

It has been found that the total content of copper, zinc and manganese in soil increased as the rates of municipal solid waste composts rose, an effect which has been observed both as a direct influence and aftereffect of fertilization. The highest increase in the total content of copper was determined in soil fertilized with six-month compost from municipal solid waste. By increasing doses of the compost, the share of the soluble form of this element was reduced versus its total content. The highest increase in total zinc appeared after soil amendment with compost which matured in a heap for three months. In respect of direct effect, the share of soluble to total zinc was the highest in the treatments fertilized with one-month compost, but as an aftereffect, six-month compost resulted in the highest percentage of soluble zinc in its total amount. As for manganese, evidently higher its total concentrations were determined in soil fertilized with three-month compost compared with one- and six-month ones. The share of the soluble form of manganese to its total content decreased when older municipal waste composts or their higher doses were applied.

In soil enriched with urban green waste, lower contents of heavy metals occurred than in soil fertilized with six-month compost. In the former soil, however, there was an increase in the share of soluble forms of the analyzed metals relative their total content.

Keywords: municipal solid waste compost, green waste compost, soil, copper, zinc, manganese

Municipal solid waste composts are used in agriculture as soil amending substances. Their chemical composition depends on a variety of factors, including the source of composted matter, the way it is composted and how long it is composted. A combination of these factors results in varied properties of produced composts [1, 2]. Among

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possible negative consequences of using composted municipal waste as a fertilizer is the risk of introducing heavy metals to the environment. This fact draws attention of many authors [3–6], who claim that the content of heavy metals in organic waste conditions the fertilizer value of many organic waste products.

Application of large doses of composts from municipal solid waste loaded with a high content of heavy metals causes a considerable increase in the total content of these elements in soil and subsequently in plants [7–8]. Thus, long-term application of municipal soil waste composts requires that the content of heavy metals in soil be regularly monitored [9].

Among some essential factors which determine the solubility of heavy metals in composts is the age of composted matter. Composting reduces soluble forms of heavy metals, which seems to suggest that the risk of heavy metals penetrating into the food chain decreases.

The content of heavy metals in composts is one of the criteria listed in the industrial standards (BN-88/9103) concerning composts. The standards establish allowable amounts of particular components in composts, which serve as a basis of assigning composts to particular quality classes [10].

The objective of this study has been to determine the direct and aftereffect of composts made from municipal solid waste and urban green waste on the total content of copper, zinc and manganese and their soluble forms in soil. The effect produced by the analyzed composts was compared with the action of a traditional organic fertilizer, such as farmyard manure.

Material and methods

The soil for the experiment originated from pot trials, which had been conducted in a greenhouse of the University of Warmia and Mazury in Olsztyn for three years. In the experiment, the direct and aftereffect of composts made from unsorted municipal solid waste according to the MUT-Dano technology on the content of total and soluble forms of copper, zinc and manganese in soil was studied. A more detailed description of the technological process for production of composts can be found in the authors' earlier paper [11].

The composts used in the experiment aged in heaps for 1, 3 or 6 months. These composts were introduced to soil in three doses: 10, 20 and 30 $g \cdot kg^{-1}$ of soil. The effect of municipal waste composts applied at the lowest rate (10 $g \cdot kg^{-1}$ of soil) was compared with the effect of an identical dose of compost made from urban green waste, which aged for six months, and that of *farmyard manure* (FYM). Rates of FYM were balanced with the lowest rate of municipal waste compost in terms of introduced *total nitrogen* (FYM_N) and *organic carbon* (FYM_C). Besides, in the treatments with the lowest doses of composts from municipal waste and FYM applied in the rate balanced with the composts with respect to the introduced nitrogen, additional mineral fertilization NPK was applied in the following quantities: 83 $mg\ N \cdot kg^{-1}$ soil, 26 $mg\ P \cdot kg^{-1}$ soil and 100 $mg\ K \cdot kg^{-1}$ soil. In the third year of the experiment, all the treatments received mineral fertilization in the rates of: 75 $mg\ N \cdot kg^{-1}$ soil, 31 $mg\ P \cdot kg^{-1}$ soil and

109 mg K · kg^{-1} soil. The characteristics of the soil used for the experiment were given in the authors' earlier paper [12]. Polyethylene Kick-Brauckamn pots were used for the experiment. They were filled with 10 kg of typical brown soil of the grain-size distribution of light loamy sand, and the pH KCl = 5.5, which was sampled from the humus layer Ap. Soil in the pots was maintained at a moisture level of 60 % field water capacity.

During the first year of the experiment, maize and sunflower were grown. Maize was harvested after 84 days of vegetative growth, in the panicle initiation phase and sunflower was collected after 61 days of growing, in the early inflorescence phase. In the second year, the crops included spring barley, harvested 57 days after sowing, in the stem elongation phase, and white mustard was gathered after 32 days of growing, in the full inflorescence phase. In the third year, lacy phacelia was grown, which was cut in the full inflorescence phase, corresponding to 61 days of vegetation.

The total content of heavy metals in the composts, farmyard manure and soil was determined with *the atomic emission spectrophotometric method with inductively activated plasma*, using an ICP-AES apparatus, model PS 950, manufactured by Labs, having first eluted samples of composts with a mixture of spectrally pure acids HNO_3 and $HClO_4$, mixed at a 5 : 4 ratio, in a VAL heat block. Soluble forms of heavy metals in soil were extracted with aqueous solution of HCl in the concentration of 1 mol · dm^{-3}.

Results and discussion

The quality of composts can be evaluated with an aid of a variety of methods, including analysis of their chemical composition, or their influence on the growth and development of plants or soil properties [13]. In the municipal waste composts analyzed in our tests, the total content of heavy metals in the original material was variable. It contained less than ten-fold more zinc and less than a hundred-fold more manganese than copper (Table 1). The references cite that the content of these elements in composts is changeable, a conclusion which is confirmed, for example, by the results reported by Sanchez et al [14], who demonstrated that municipal waste composts contained much more zinc than manganese or copper, whereas Gautman et al [15] proved that composts had more manganese than zinc or copper.

Table 1

Content of copper, zinc and manganese in composts, farmyard manure and soil prior to the experiment [mg · kg^{-1} d.m.]

Metal	Ageing of composts			Municipal solid waste compost	Farmyard manure (FYM)	Soil
	1 month	3 months	6 months			
Cu	161.10	177.45	187.70	67.90	30.10	6.62
Zn	1041.20	1340.60	1031.35	649.55	198.90	31.92
Mn	618.60	796.60	580.70	447.10	443.10	268.10

The length of time during which composts aged in heaps evidently had some influence on the content of each of the tested elements. The highest concentrations of zinc and manganese were found in three-month compost. Further maturation of compost in a heap resulted in a decrease in the content of the elements down to the levels determined in one-month composts. In general, composting causes an increase in the content of heavy metals in the final product. This relationship, however, has not been confirmed in the authors' own study, which may be explained by the fact that the composts used for our analyses were sampled on the same day but they aged in heaps for different periods of time. Thus, the initial material from which the composts were made was characterized by similar albeit not identical properties.

In respect of copper, the concentrations of this metal increased gradually until the sixth month of ageing. The fact that concentrations of heavy metals increasing during the composting process has been demonstrated by other authors [16–17]. Niedzwiecki et al [18] found that composts made from a selected fraction of municipal waste contained more zinc and copper but less manganese compared with the results obtained in our study. Urban green waste contained nearly three-fold less copper than municipal waste composts, and two-fold more versus farmyard manure. Similar relations were discovered for zinc. The content of manganese in this compost was 30 to 78 % lower than in municipal waste composts and close to the content determined in FYM.

The content of heavy metals in soil fertilized with composts depended on the type of applied composts, doses and the time which elapsed from their application.

In the first year after the application of composts, their significant influence on an increase in the total and soluble form of copper content appeared. It was found out that the total content of copper in soil rose as more mature composts had been applied, which was a consequence of the initial composition of composts (Table 2).

Soil fertilized with urban green waste compost contained significantly less copper compared with soil fertilized with an identical dose of municipal waste composts. In the FYM fertilized treatments, much lower concentrations of copper were determined than in soil fertilized with municipal waste composts, but close to the amounts determined in soil amended with urban green waste compost. The highest increase in the soluble form of copper was determined in soil fertilized with one-month compost. Additional mineral fertilization applied alongside the composts created a tendency towards increasing the content of soluble copper in comparison with the treatments enriched with composts alone, applied in identical doses. In the treatments receiving urban green waste compost and FYM, the content of soluble copper in soil was much lower than in the treatments which were fertilized with municipal waste composts.

The direct effect of composts caused an increase in the total and soluble form of zinc in soil. This dependence appeared in all the treatments, which were amended with composts of different age. The content of both forms of zinc was the highest in the soil fertilized with three-month compost. In the soil enriched with urban waste compost and FYM, the respective values were much lower, and within the doses of FYM they were approximately the same.

Table 2

Total contents of copper, zinc and manganese and their soluble forms in the first year after application of composts

No.	Dose [g · kg^{-1} soil]	Cu		Zn		Mn	
		Metal content [mg · kg^{-1} d.m.]					
		total	soluble form	total	soluble form	total	soluble form
1	0	6.58	4.09	31.56	15.81	267.3	168.3
Municipal solid waste compost heap-stored for 1 month							
2	10	8.19	4.50	41.72	22.13	274.0	167.1
3	20	9.80	4.90	51.91	26.52	280.1	168.1
4	30	11.40	5.44	62.31	31.30	286.4	166.1
5	10 + NPK	8.19	4.53	41.50	22.01	273.9	175.0
6	FYM_N*	6.86	3.77	33.33	16.71	271.8	167.7
7	FYM_N* + NPK	6.85	3.79	33.16	16.40	271.7	174.7
8	FYM_C*	7.04	3.94	34.47	16.92	274.5	167.4
Municipal solid waste compost heap-stored for 3 months							
9	10	8.35	4.12	44.79	22.73	275.7	160.7
10	20	10.13	4.42	58.08	28.59	283.7	164.5
11	30	11.88	5.06	71.35	33.64	291.7	160.7
12	10 + NPK	8.34	4.25	44.52	22.73	275.6	168.1
13	FYM_N*	6.96	3.83	33.96	17.35	273.3	169.7
14	FYM_N* + NPK	6.95	3.85	33.80	17.23	273.2	173.5
15	FYM_C*	7.01	3.87	34.28	17.84	274.0	164.4
Municipal solid waste compost heap-stored for 6 months							
16	10	8.46	4.01	41.77	20.59	273.6	156.5
17	20	10.32	4.51	52.00	24.54	279.4	156.7
18	30	12.19	5.07	62.26	28.68	285.2	148.6
19	10 + NPK	8.44	4.14	41.77	21.30	273.4	160.5
20	FYM_N*	7.00	3.85	34.23	17.20	273.8	167.0
21	FYM_N* + NPK	6.99	3.87	34.01	17.67	273.7	172.9
22	FYM_C*	6.98	3.83	34.10	17.87	273.6	164.9
Green waste compost							
23	10	7.25	3.77	37.92	19.34	272.2	158.7
$LSD_{0.05}$							
Dose (d)		1.08	0.69	4.12	4.08	6.57	7.1
Ageing of compost (a)		1.11	0.49	3.98	2.78	4.17	3.2
Interaction: d · a		2.15	0.37	7.29	8.11	13.12	4.2

* Explanation in section Material and methods.

Fertilization with rising doses of municipal waste composts contributed to a gradual increase in the content of manganese in soil. Among the three analyzed metals, manganese was the dominant element in soil. A higher total content of manganese in soil was observed in the treatments with three-month compost than in the ones amended with one- or six-month ones. No significant differences were found between the total content of this element in soil fertilized with composts made from municipal waste versus the ones receiving urban green waste composts and FYM.

With respect to the soluble form of manganese, it was demonstrated that its content increased up to the second dose of municipal waste composts. In the treatments fertilized with FYM, higher quantities of soluble manganese in soil were determined than in soil fertilized with municipal waste and urban green waste composts.

Once the experiment was terminated, that is three years after using the composts, the content of total copper, zinc and manganese slightly decreased, which was caused by the removal of these elements with the yields of the test crops (Table 3). The effect of the type of applied composts as well as their doses was similar to their direct effect. However, these relationships were shaped differently for the soluble forms of the analyzed heavy metals. The content of the soluble form of copper in soil fertilized with one-month compost was higher than in the first year, whereas in soil amended with three- and six-month composts, it decreased.

In respect of the soluble form of copper, such a tendency may have been caused by a larger drop in the soil reaction value in the treatments with one-month compost compared with the ones fertilized with more mature composts. Concerning zinc, higher concentrations of the soluble form of this element were found in soil fertilized with composts which aged for 3 and 6 months than in soil receiving one-month compost. The tendency for an increase in the soluble form of zinc was also noticed in soil fertilized with FYM. The content of soluble manganese in soil enriched with three- and six-month composts decreased in comparison with the first year of the experiment but rose in soil fertilized with one-month compost, especially with its higher doses.

The results of our experiment coincide with the reports presented by other authors. Gigliotti et al [19] demonstrated that as a result of soil fertilization with municipal waste composts, a significant increase in the content of copper and zinc in soil was observed. Similar conclusions were drawn by Jordao et al [20], who claim that application of composts made from municipal waste raise the amounts of available forms of heavy metals in soil. In respect of copper, this increase was proportional to the introduced dose of compost, whereas the content of manganese declined. Petruzzelli et al [21] concluded that the content of heavy metals in soil depended on the applied extractant and changed in time. The highest amounts of soluble forms of copper and zinc were found after soil extraction with *diethylene triamine pentaacetic acid* (DTPA). In their experiment, Bowszys et al [22] demonstrated that application of composts from sewage sludge, in comparison with soil fertilized with farmyard manure, raised the pool of available forms of copper and zinc in soil, a result that occurred in the fourth year after the application of these soil-amending substances. It was also proven that soil analyzed after the termination of the experiment, ie after four years, contained more soluble forms of metals than the soil analyzed at the beginning of the tests.

Table 3

Total content of copper, zinc and manganese and their soluble form in the third year after application of composts

No.	Dose [g · kg^{-1} soil]	Cu		Zn		Mn	
		Metal content [mg · kg^{-1} d.m.]					
		total	soluble form	total	soluble form	total	soluble form
1	0	6.42	4.05	31.22	16.88	265.2	160.5
Municipal solid waste compost heap-stored for 1 month							
2	10	8.01	4.59	41.40	20.42	270.2	157.3
3	20	9.65	5.03	51.41	24.22	274.3	170.4
4	30	11.22	5.83	61.94	28.56	281.7	171.2
5	10 + NPK	8.01	4.67	41.08	19.50	265.3	163.8
6	FYM_N*	6.64	3.66	32.71	17.03	268.4	166.9
7	FYM_N* + NPK	6.66	3.69	32.67	17.74	268.1	172.0
8	FYM_C*	6.89	3.86	34.01	17.53	270.8	163.1
Municipal solid waste compost heap-stored for 3 months							
9	10	8.22	3.86	44.41	23.42	273.2	154.2
10	20	9.89	4.09	57.64	30.07	280.1	156.9
11	30	11.56	4.68	70.82	34.71	287.2	155.4
12	10 + NPK	8.20	3.96	43.19	23.37	273.1	158.7
13	FYM_N*	6.78	3.67	33.41	17.78	271.9	167.0
14	FYM_N* + NPK	6.71	3.77	33.25	18.01	272.1	171.7
15	FYM_C*	6.74	3.58	33.30	17.37	272.5	165.6
Municipal solid waste compost heap-stored for 6 months							
16	10	8.34	3.76	41.35	22.81	272.3	147.4
17	20	10.04	4.43	51.38	26.82	278.7	144.1
18	30	12.00	4.81	61.76	32.30	281.1	142.6
19	10 + NPK	8.29	3.58	41.09	23.12	268.1	153.4
20	FYM_N*	6.71	3.64	33.61	17.11	269.3	162.0
21	FYM_N* + NPK	6.76	3.79	33.53	17.83	268.7	167.7
22	FYM_C*	6.72	3.56	33.54	17.60	270.2	165.1
Green waste compost							
23	10	7.01	3.53	37.38	19.87	269.3	148.5
$LSD_{0.05}$							
Dose (d)		0.92	0.47	3.92	3.12	4.29	4.11
Ageing of compost (a)		1.11	0.63	3.12	3.07	2.19	3.07
Interaction: d · a		2.31	0.67	6.33	7.42	10.05	3.23

* Explanation in section Material and methods.

In the present research, the percentage of soluble forms of copper, zinc and manganese to the total concentrations of these elements was variable and largely dependent on the factors which shaped their content in soil (Fig. 1).

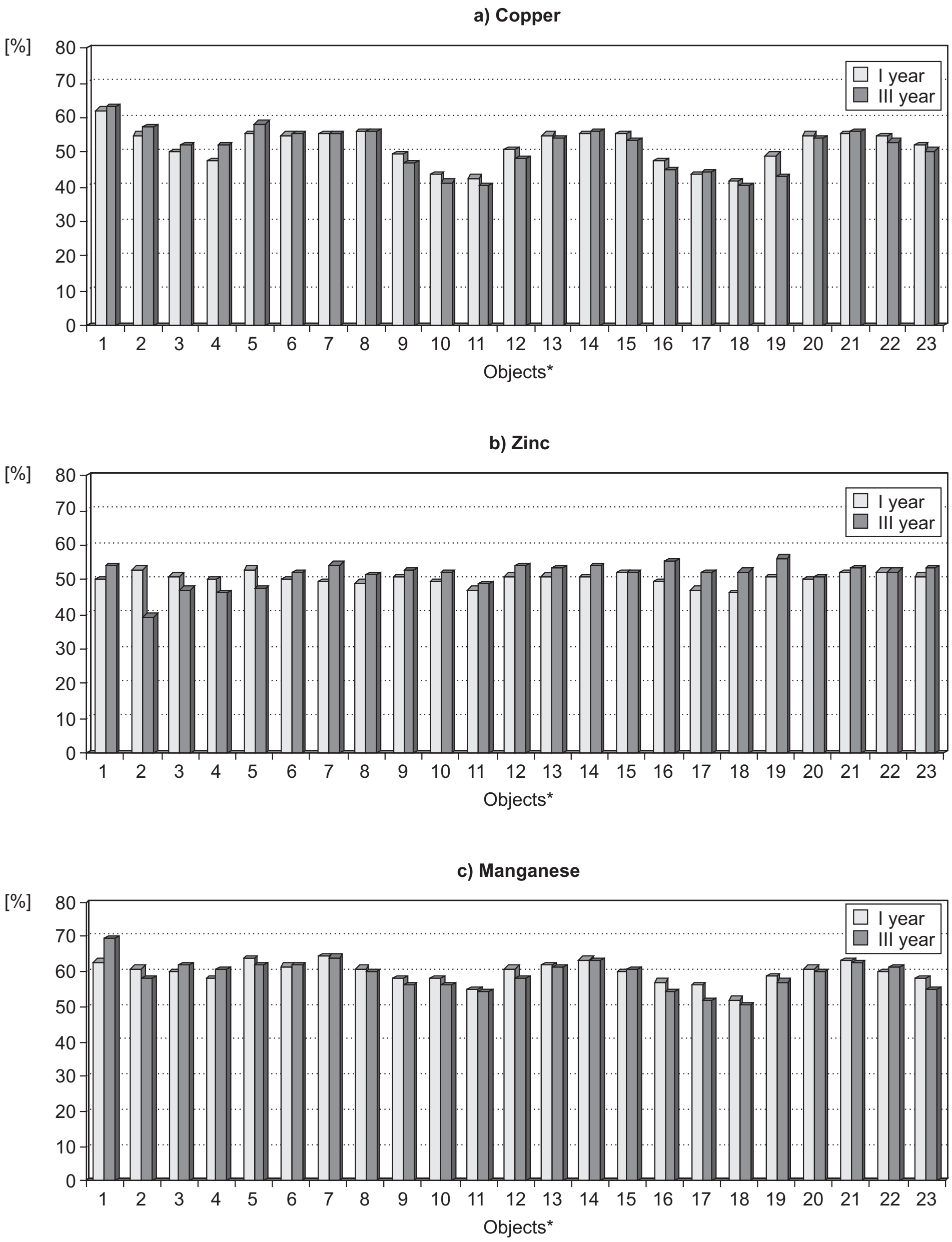

Fig. 1. Share of soluble forms of copper, zinc and manganese in their total concentrations; *1–23 explanations see Table 2

The share of the soluble form of copper to its total content in the first year of the experiment, as shaped under the influence of composts, decreased relative to the control. This value, however, was lower when more mature composts were used. The effect of growing doses of composts on the above parameter was reversely proportional. When higher doses of composts were applied, the ratio of soluble copper to its total content decreased. In the treatments fertilized with farmyard manure, the percentage of soluble copper was higher than in compost-treated soil. In the aftereffect, ie in the third year of the experiment, the effect of higher doses of composts was analogous to their effect in the first year. However, it was noted that the percentage of soluble copper in the total content of this element relative to the first year increased in soil from the treatments fertilized with one-month compost but decreased in soil treated with three- and six-month composts. The same relationship was observed in soil from the pots fertilized with FYM.

The influence of rising doses of composts on the soluble form of zinc relative to its total content was similar to that observed for copper. Nonetheless, such relationships were recorded only as a result of the direct effect produced by composts. The aftereffect was completely opposite. A decrease in soluble zinc in soil in response to the increasing rates of a fertilizer was recorded in the treatments receiving three-month compost. In soil amended with one-month compost, the lowest ratio of this form of zinc to its total content was found when the rate of 20 $g \cdot kg^{-1}$ of soil had been applied, but in soil enriched with six-month compost, the same result was caused by the lowest dose of the fertilizer. The aftereffect of the age of composts became most visible in the case of soil fertilized with the youngest compost, where the ratio of soluble zinc to its total content was much more depressed compared with the results obtained two years earlier.

The application of composts which aged for 3 and 6 months raised the share of soluble zinc in its total content. Such relationships were also demonstrated for the treatments fertilized with FYM, dosed according to the amount of organic carbon as well as total nitrogen. In addition, fertilization with municipal waste and urban green waste composts had some influence on changes in the ratio of soluble manganese to its total soil content. In the direct effect, soil from the treatments fertilized with one-month compost had the highest percentage of soluble manganese. More mature composts, ie three- and six-month old ones, caused a decrease in this parameter. Moreover, as higher doses of these composts were introduced to soil, the ratio of soluble manganese to total manganese decreased. In the treatments fertilized with FYM, solubility of manganese was higher than in the treatments amended with municipal waste or urban green waste composts. In the aftereffect, composts and FYM tended to depress the solubility of manganese in soil.

Some researchers [23] claim that application of municipal waste composts causes a rise in the reaction of soil, but this effect is short-lasting. Such a tendency appeared in our study, as well (Table 4).

In the first year after the application of municipal solid waste and urban green waste composts, the value of pH was much higher than the soil reaction noted as an aftereffect of the fertilizers, that is three years after the application of composts. This change in the

Table 4

Soil reaction value after first and third year of experiment

No.	Dose [g · kg^{-1} soil]	First year		Third year	
		pH (H_2O)	pH (1 mol KCl · dm^{-3})	pH (H_2O)	pH (1 mol KCl · dm^{-3})
1	0	6.96	6.69	6.05	5.43
Municipal solid waste compost heap-stored for 1 month					
2	10	7.40	7.21	6.38	5.69
3	20	7.44	7.19	6.42	5.73
4	30	7.27	7.31	6.47	5.89
5	10 + NPK	7.35	7.17	6.19	5.55
6	FYM_N*	7.35	7.16	6.22	5.44
7	FYM_N* + NPK	7.31	7.14	6.12	5.40
8	FYM_C*	7.23	7.02	6.20	5.59
Municipal solid waste compost heap-stored for 3 months					
9	10	7.29	7.07	6.43	5.97
10	20	7.46	7.18	6.55	6.13
11	30	7.47	7.43	6.60	6.41
12	10 + NPK	7.25	7.02	6.33	5.96
13	FYM_N*	7.39	7.18	6.20	5.37
14	FYM_N* + NPK	7.20	7.15	6.18	5.33
15	FYM_C*	7.42	7.09	6.30	5.41
Municipal solid waste compost heap-stored for 6 months					
16	10	7.00	6.95	6.28	5.61
17	20	7.33	7.15	6.31	5.69
18	30	7.35	7.23	6.39	5.80
19	10 + NPK	6.96	6.90	6.20	5.55
20	FYM_N*	7.37	7.02	6.18	5.32
21	FYM_N* + NPK	7.30	7.00	6.17	5.30
22	FYM_C*	7.38	7.13	6.22	5.43
Green waste compost					
23	10	7.31	7.11	6.33	6.01

* Explanation in section Material and methods.

soil pH may have had some influence on an increase in the amount of soluble forms of the metals in the third year after the application of composts.

Conclusions

1. Fertilization with municipal solid waste composts raised the total content of copper, zinc and manganese in soil. It also affected contents of soluble forms of these

metals. The total content of the metals three years after the application of composts was depressed due to their uptake by the test crops, but the concentration of their soluble forms increased, which may have been caused by a decrease in the soil reaction.

2. The total content of copper in soil fertilized with composts tended to increase as higher rates of the fertilizers were used, a tendency which appeared both as a direct and aftereffect. Among the analyzed composts, the highest increase in the total content of copper was caused by the application of six-month compost. Higher rates of composts led to a depressed share of soluble form of this element in its total content.

3. The highest increase in the total form of zinc in soil occurred after the application of compost which aged in a heap for three months. In the direct effect of composts, the ratio of soluble zinc to its total content was the highest in the treatments fertilized with one-month compost, but in the aftereffect, six-month compost produced an analogous result.

4. Much higher total contents of manganese were found in soil fertilized with three-month compost compared with soil amended with one- and six-month composts. The ratio of soluble form of this element to its total content decreased as more mature composts were used and when higher doses of composts were applied.

5. In soil enriched with urban green waste compost, lower levels of heavy metals were determined compared with soil fertilized with six-month compost made from municipal solid waste. However, in this soil an increase in the share of soluble forms of the analyzed metals versus their total content appeared.

References

[1] Rutkowska B., Ożarowski G., Łabętowicz J. and Szulc W.: Zesz. Probl. Post. Nauk Roln. 2003, **494**, 383–390.

[2] Weber J., Karczewska A., Drozd J., Licznar M., Licznar S., Jamroz E. and Kocowicz A.: Soil Biol. Biochem. 2007, **39**, 1294–1302.

[3] Paré T., Dinel H. and Schnitzer M.: Biol. Fertil. Soils 1999, **29**, 31–37.

[4] Hargreaves J.C., Adl M.S. and Warman P.R.: Agr. Ecosyst. Environ. 2008, **123**, 1–14.

[5] Achiba W.B., Gabteni N., Lakhdar A., Laing G.D. Verloo M., Jedidi N. and Gallali T.: Agr. Ecosyst. Environ. 2009, **130**, 156–163.

[6] Szulc W., Rutkowska B. and Łabętowicz J.: Zesz. Probl. Post. Nauk Roln. 2009, **535**, 415–421.

[7] Rutkowska B., Ożarowski G., Łabętowicz J. and Szulc W.: Zesz. Probl. Post. Nauk Roln. 2003, **493**, 839–845.

[8] Warman P.R., Rodd A.V. and Hicklenton P.: Agr. Ecosyst. Environ. 2009, **133**, 98–102.

[9] Bhattacharyya P., Chakraborty A., Chakrabarti K., Tripathy S. and Powell M.A: Environ. Geol. 2006, **49**, 1064–1070.

[10] Rosik-Dulewska Cz.: Zesz. Probl. Post. Nauk Roln. 2001, **477**, 467–477.

[11] Sądej W. and Namiotko A.: Polish J. Environ. Stud. 2010, **19**(5), 999–1005.

[12] Sądej W., Namiotko A. and Bowszys T.: Zesz. Probl. Post. Nauk Roln. 2003, **493**(III), 847–852.

[13] Iwegbue C.M.A., Egun A.C., Emuh F.N. and Isirimah N.O.: Pakistan J. Biol. Sci. 2006, **9**(15), 2933–2944.

[14] Sánchez L., Diez J.A., Polo A. and Román R.: Biol. Fertil. Soils 1997, **25**, 163–141.

[15] Gautam S.P., Bundela P.S., Pandey A.K., Awasthi M.K. and Sarsaiya S.: J. Appl. Sci. in Environ. Sanit. 2010, **V**(N), 372–377.

[16] Garcia C., Hernández T., Costa F. and Ayuso M.: Suelo Planta 1991, **1**, 1–13.

[17] Farrell M. and Jones D.L.: Bioresource Technol. 2009, **100**, 4423–4432.

[18] Niedźwiecki E., Wojcieszczuk T., Meller E., Nędzusiał J. and Adamczewska M.: Folia Univ. Agric. Stetin. 242, Agricultura 2004, **98**, 109–114.
[19] Gigliotti G., Businelli D. and Giusquiani P.L.: Agr. Ecosyst. Environ. 1996, **58**, 199–206.
[20] Jordão C.P., Nascentes C.C., Cecon P.R., Fontes R.L.F. and Pereira J.L.: Environ. Monit. Assess. 2006, **112**, 309–326.
[21] Petruzzelli G., Lubrano L. and Guidi G.: Plant Soil 1989, **116**, 23–27.
[22] Bowszys T., Wierzbowska J., Bowszys J. and Bieniek A.: J. Elementol. 2009, **14**(1), 33–42.
[23] Gondek K. and Filipek-Mazur K.: Acta Agrophys. 2006, **8**(3), 579–590.

ZAWARTOŚĆ MIEDZI, CYNKU I MANGANU W GLEBIE NAWOŻONEJ KOMPOSTAMI Z ODPADÓW MIEJSKICH

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Abstrakt: W 3-letnim doświadczeniu wazonowym analizowano wpływ kompostów wytworzonych z niesegregowanych odpadów komunalnych i zieleni miejskiej na zawartość całkowitych i rozpuszczalnych form miedzi, cynku i manganu w glebie. Wykorzystane komposty różniły się między sobą stopniem dojrzałości oraz składem chemicznym materiału wyjściowego.

Stwierdzono, że całkowita zawartość miedzi, cynku i manganu w glebie zwiększała się wraz ze wzrostem dawek kompostów wytworzonych z odpadów komunalnych, co zaobserwowano zarówno w działaniu bezpośrednim, jak i następczym. Największy wzrost całkowitej zawartości miedzi uzyskano w glebie nawożonej kompostem z odpadów komunalnych dojrzewającym 6 miesięcy. Wzrost dawki kompostu powodował obniżenie udziału rozpuszczalnej formy tego pierwiastka w stosunku do jego całkowitej zawartości. Największy wzrost zawartości całkowitej formy cynku w glebie nastąpił po zastosowaniu kompostu dojrzewającego w pryzmie przez okres 3 miesięcy. W bezpośrednim działaniu kompostów udział rozpuszczalnego cynku w stosunku do formy całkowitej był największy na obiektach z kompostem miesięcznym, natomiast w działaniu następczym taki efekt miał miejsce na obiektach z kompostem dojrzewającym 6 miesięcy. W przypadku manganu wyraźnie większe zawartości całkowitej formy tego pierwiastka notowano w glebie nawożonej kompostem dojrzewającym 3 miesiące w porównaniu z glebą nawożoną kompostami po 1 i 6 miesiącach dojrzewania. Udział rozpuszczalnej formy manganu w stosunku do jego zawartości całkowitej zmniejszał się wraz z wiekiem zastosowanych kompostów z odpadów komunalnych, jak też i wskutek zwiększania ich dawek.

W glebie nawożonej kompostem z odpadów zieleni miejskiej odnotowano mniejsze zawartości metali ciężkich w porównaniu z glebą nawożoną kompostem z odpadów komunalnych dojrzewającym 6 miesięcy. W glebie tej nastąpił jednak wzrost udziału rozpuszczalnych form analizowanych metali w stosunku do całkowitej ich zawartości.

Słowa kluczowe: kompost z odpadów komunalnych, kompost z zieleni miejskiej, gleba, miedź, cynk, mangan