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THE REMANENT EFFECT OF THE AGRICULTURAL USE OF URBAN SLUDGE COMPOST UPON THE SOIL PROPERTIES AND WHEAT CROP

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Abstract

The compost obtained from sludge from wastewater treatment being an important source of macro and micronutrients, can be used in agriculture, because it reduces the production costs and improves the soil quality by providing nutrients and organic matter necessary for modern, ecological agriculture, in the conditions to improve the capacity to retain moisture in the soil, also reducing the pressure on the environment generated by the storage of this waste. The compost used in the experiments is suitable for use in agriculture without risks of environmental and soil pollution, in compliance with the rules in force. The obtained results show that by applying the compost produced at SEAU Mioveni, even in the variants where the highest doses (60 t/ha) were applied, there are no significant changes in the chemical properties of the soil, especially the content of heavy metals. The values determined in the soil after applying the compost to all the experienced variants are far below the maximum allowed values for the concentrations of heavy metals in the soils. Also, analyzing the results regarding the risk of translocation of different chemical elements in the wheat grains, it can be seen that, in general, all indicators register values well below the limits from which zootoxicity phenomena can occur. No increases in heavy metal contents in the wheat grains are observed as the doses of used compost increased.

Key words: *compost, remanence effect, wheat, soil.*

INTRODUCTION

Sewage sludge is regarded as the residue produced by the wastewater treatment process, during which liquids and solids are being separated. Liquids are being discharged to aqueous environment while solids are removed for further treatment and final disposal. The constituents removed during wastewater treatment include grit, screenings and sludge (Metcalf, 1991). Sustainable sludge handling may be defined as a method that meets requirements of efficient recycling of resources without supply of harmful substances to humans or the environment (Council Directive 91/271/EEC).

The positive effect of the organic matters in general, and those from urban activity, in particular, on the physical, chemical and biological properties of the soil is also reflected in plant production, which in most cases is increasing. The organic matter is directly involved in the retention of heavy metals, as being one of the first metals studied in this regard (Kiikkila, 2002) showing that biosolid is an immobilizing agent of this heavy metal.

On the other hand (Moolenaar and Beltrami, 1998) proved that heavy metals can also be complexed by the dissolved organic matter, which influences the ion balance. One of the main factors involved in the absorption of heavy metals is the soil pH, their accessibility being very low in the reaction range of 6.5-7. The presence of competitive metal ions can affect the adsorption of heavy metals in soils. Ca^{2+} ions interfere in the adsorption processes with Zn, Cd, Cu, as a result of the fact that Zn and Cd ions are retained in the soil by cationic exchange reactions, while Cu and Pb form organic complexes with oxides of Fe, Al and Mn (Kiekens, 1983; Pirangeli et al., 2001, 2003).

The adsorption of heavy metals by iron oxides is accompanied by a protonation being dependent on pH, according to research conducted by Cornell and Schwetmann (1996).

The positive effects are due both to the high content of organic matter and nutrients in forms accessible to plants, and to the improvement of the processes of structuring the elementary soil particles in hydrostable aggregates, to the increase of water retention capacity.
The concentration of heavy metals is among the most important factors restricting the use of urban waste products on agricultural land, due to their potentially negative effects on plant biomass and their translocation into food.
The data in the literature contain different ways of interpreting the contents of heavy metals in soils, specifying limit values, but it seems that the closest model of reality is the one that takes into account the content of total forms in the soil (EPA, 1993).
The current acidity of the soil registered a tendency of reduction by biosolid fertilization in the years of application and remanence.
The potential acidity followed the same variation as the current one, so that in the conditions of applying biosolid and in the first year of remanence it had a tendency to decrease as later there was an update in the second year of remanence (Trașcă et al., 2008).
The increased interest in fertilizing the soil with sludge resulting from urban wastewater has been manifested since 1970, when it was established that it can be considered an organic fertilizer (Tomlin, 1993).
The use of sludge resulting from urban wastewater treatment in agriculture is dependent on the properties of the soil, of which pH, organic matter and nutrient content occupy a preferential place, but being restricted by the presence of heavy metals especially Cd, Pb, and Ni, whose concentration in the environment is governed by the nature of the element and the dose applied (Lopez-Mosquera, 2000).
The effect of sludge from urban wastewater treatment on the soil is investigated both in terms of pedo-improvement and in terms of environmental impact. As Beltran (1999) pointed out, knowledge of the chemical composition of sludge is of particular importance when making recommendations on application rates on the agricultural land.
Over time, soluble organic compounds tend to turn into insoluble forms, with the amount of heavy metals settling to low values when the bioavailability decreases (McBride, 1995).
Researches on the effect of sludge application on the soil have not exceeded 30 years, as demonstrated by numerous scientific papers (Kabata-Pendias, 2004).

MATERIALS AND METHODS

In order to study the remanence effect in the 2nd year from the application of a compost resulting from the sewage sludge proceeding from the treatment plant on the agricultural crops and on the soil properties, wheat was used as a test plant, the sown hybrid being Glossa.
The basic soil work was ploughing, carried out at 25 cm. Seedbed preparation was done by two passes with a disc harrow, sowing was done with SUP 29, and the seed rate was 280 kg/ha.
The experience included 5 experimental variants in 3 repetitions, the area of an experimental plot being of 105 m^2.
Fertilization was carried out with moderate doses (360 kg/ha) of complex chemical fertilizers (16-16-16) by uniform spreading and equal in all tested variants. Fertilizers were spread on the ground. Weed control was carried out using the herbicide Granstar.
The experimental variants were: V_1 - Control; V_2 - 10 t/ha; V_3 - 20 t/ha; V_4 - 40 t/ha; V_5 - 60 t/ha.
The researches were performed on a soil of luvosol, podzolite, pseudogley type, as a result of their formation under the vegetation of the quercineae forest, under the conditions of a dominant lithology of fine-textured clays and located on relatively flat-horizontal land (Trașcă et al., 2008).

The quality of the compost used in the experiments

The qualitative parameters of the analyzed compost are within acceptable values for its use in agriculture, including in terms of heavy metal content (Table 1).
The effect of applying compost from sewage sludge as a fertilizer in agriculture is currently focused on cultivated plants and soil.
The samples of compost, soil and plant (leaves, grains) were taken and analyzed according to the methodology in force (pH was determined potentiometrically in aqueous suspension; the organic matter was determined by Walkley-Black-Gogoașă method; mobile phosphorus

and potassium by Egner-Riehm-Domingo method; total nitrogen by Kjeldahl method; heavy metal content, in total forms, with dosing by atomic absorption spectrophotometry).

Table 1. The main chemical characteristics of compost

No.	Parameter	Value	Maximum values (Ord. 344/2004)
1	Volatile substances (%)	35.34	-
2	pH	7.09	-
3	$C_{organic}$ (% d.m.)	21.5	-
4	N_{total} (% d.m.)	1.52	-
5	P_2O_5 (% d.m.)	1.38	-
6	K_2O (% d.m.)	0.675	-
7	CaO (% d.m.)	0.35	-
8	Cadmium (mg/kg d.m.)	1.04	10
9	Chromium (mg/kg d.m.)	44.8	500
10	Copper (mg/kg d.m.)	74.3	500
11	Nickel (mg/kg d.m.)	26.5	100
12	Lead (mg/kg d.m.)	46.3	300
13	Zinc (mg/kg d.m.)	612	2000
14	Cobalt (mg/kg d.m.)	6.34	50
15	Arsenic (mg/kg d.m.)	4.09	10
16	Total coliform bacteria (probable no./g d.m.)	1352400	-
17	Fecal coliforms (probable no./g d.m.)	236523	-
18	Enterococci (UFC/g d.m.)	105840	-

RESULTS AND DISCUSSIONS

The influence of compost fertilization on the soil

The obtained results show that by applying the compost produced at SEAU Mioveni, on the agricultural land, even in large quantities (60 t/ha), there are no significant changes in its chemical properties, and especially in the case of potentially polluting heavy metals.

The effect of compost application (remanence in the 2^{nd} year) on the soil is presented in Table 2. The soil sampling was performed in the flowering phenophase of wheat.

From the data presented in Table 2 we can observe that in the 2^{nd} year after the application of increased doses of compost from sewage sludge, the concentrations of heavy metals in the soil are below the maximum allowed values, even at high doses of compost.

Table 2. Soil chemical characteristics after remanence effect of compost

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	pH	6.37	5.93	5.98	6.08	6.32
2	Organic matter content (%)	3.95	4.25	4.41	4.35	4.06
3	Soluble salts (%)	0.016	0.013	0.015	0.013	0.015
4	Water storage capacity (%)	39	38	38	40	39
5	Bulk density (g/cm^3)	1.47	1.45	1.47	1.46	1.46
6	Total C (% d.m.)	2.45	2.37	2.41	2.48	2.50
7	N_{total} (% d.m.)	0.122	0.128	0.125	0.120	0.122
8	P_2O_5 (% d.m.)	0.121	0.131	0.123	0.127	0.130
9	K_2O (% d.m.)	0.93	1.03	0.99	1.00	1.01
10	CaO (% d.m.)	0.25	0.23	0.25	0.25	0.25
11	Cadmium (mg/kg d.m.)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
12	Chromium (mg/kg d.m.)	44.83	46.43	44.75	44.32	44.18
13	Copper (mg/kg d.m.)	17.87	18.12	16.89	17.28	18.23
14	Nickel (mg/kg d.m.)	24.98	24.22	24.38	23.19	24.33
15	Lead (mg/kg d.m.)	16.44	17.20	20.06	20.96	18.41
16	Zinc (mg/kg d.m.)	63.03	66.16	62.48	63.93	65.17
17	Cobalt (mg/kg d.m.)	12.78	11.76	12.04	12.32	12.12
18	Arsenic (mg/kg d.m.)	0.053	0.057	0.043	0.053	0.059
19	Total coliform bacteria (probable no./g d.m.)	11.482	43.952	3.484	2.780	4.102
20	Fecal coliform (probable no./g d.m.)	138	68	44	44	87
21	Enterococci (UFC/g d.m.)	25	51	0	63	236

Practically, there is already a uniformity of these concentrations, in all variants at the level of the non-fertilized variant, which shows that these very low concentrations are not related to the application in the previous year of increasing doses of compost from sewage sludge. Analyzing the data presented in Table 3, it is easy to see that in the 2nd year after the application of the compost from sewage sludge even at high doses, after wheat harvesting the soil remains "clean", the values regarding the concentrations of heavy metals, being much below the maximum allowed limits.

Table 3. Soil characteristics after wheat harvesting

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	pH	6.37	6.15	6.05	6.04	6.23
2	Organic matter content (%)	3.69	3.79	3.44	3.86	3.90
3	Soluble salts (%)	0.012	0.010	0.011	0.013	0.012
4	Water storage capacity (%)	38	35	38	33	35
5	Bulk density (g/cm^3)	1.38	1.47	1.40	1.50	1.44
6	Total C (% d.m.)	1.10	1.28	1.28	1.37	1.42
7	N_{total} (% d.m.)	0.109	0.116	0.125	0.128	0.132
8	P_2O_5 (% d.m.)	0.116	0.129	0.127	0.137	0.140
9	K_2O (% d.m.)	1.09	1.16	1.16	1.23	1.15
10	CaO (% d.m.)	0.24	0.25	0.24	0.26	0.27
11	Cadmium (mg/kg d.m.)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
12	Chromium (mg/kg d.m.)	56.94	57.33	58.63	57.60	54.52
13	Copper (mg/kg d.m.)	18.75	19.74	19.19	19.22	19.12
14	Nickel (mg/kg d.m.)	26.97	28.05	26.58	24.57	23.51
15	Lead (mg/kg d.m.)	19.01	18.81	18.13	20.39	20.29
16	Zinc (mg/kg d.m.)	59.57	61.79	61.78	63.18	60.28
17	Cobalt (mg/kg d.m.)	13.24	13.71	11.18	12.74	11.82
18	Arsenic (mg/kg d.m.)	0.051	0.049	0.049	0.052	0.053
19	Total coliform bacteria (probable no./g d.m.)	112	3519	553	2267	265
20	Fecal coliform (probable no./g d.m.)	36	1112	51	165	0
21	Enterococci (UFC/g d.m.)	0	0	0	0	0

In Romania, the technical norms regarding the protection of the environment, and especially of the soils, when sewage sludge is used in agriculture (even composted) were provided in Order 344/2004, published in the Official Gazette no. 959/October 19th, 2004, an order that is in the process of modification and completion, including through the contribution of the partners of this project. These norms aim at capitalizing the agrochemical potential of the sludge from the treatment plants, preventing all harmful effects on the soils, considered the basic link in the soil - plant - animal (human) food chain. The technical norms of Order 344/2004 have as main provision the content of heavy metals, both from the soils on which the sewage sludge is applied, as well as the content of these metals in the sludge. The references are for the following 7 heavy metals: cadmium, copper, nickel, lead, zinc, mercury and chromium, focused on 3 directions: the maximum allowed values of heavy metals in the soils on which the sewage sludge is applied (Table 4), the maximum allowed values of heavy metals from sewage sludge to be applied to soils (Table 5), limit values for annual quantities of heavy metals accumulated in soils (Table 6).

The new regulations regarding the protection of the environment, and especially of the soils, when sewage sludge is used in agriculture, (even composted), will have in our opinion to distinguish between the application in agriculture of dehydrated and anaerobically stabilized sewage sludge and application in agriculture of compost from sewage sludge. We believe that a special law is required for composts, which regulates the specific rules for their use as fertilizers in agriculture and which also refers to the accepted limits in terms of their microbiological load.

Table 4. The maximum permissible values for the concentrations of heavy metals in soils

The analyzed parameter	The limit value (mg/kg d.m.)
Cadmium	3
Copper	100
Nickel	50
Lead	50
Zinc	300
Mercury	1
Chromium	100

(Source: Order 344/2004)

Table 5. The maximum permissible concentrations of heavy metals in the sewage sludge for use in agriculture

The analyzed parameter	The limit value (mg/kg d.m.)
Cadmium	10
Copper	500
Nickel	100
Lead	300
Zinc	2000
Mercury	5
Chromium	500
Cobalt	50
Arsenic	10

(Source: Order 344/2004)

Table 6. The limit values for the annual quantities of heavy metals that can be introduced into agricultural land based on a 10 year average for use in agriculture

The analyzed parameter	The limit value (kg/ha/year)
Cadmium	0.15
Copper	12
Nickel	3
Lead	15
Zinc	30
Mercury	0.1
Chromium	12

(Source: Order 344/2004)

Analyzing the values of the analyzed indicators (Tables 7 and 8) it can be observed that none of the tested variants show potentially toxic values, these being well below the maximum values allowed and otherwise relatively similar to the values of these indicators in the non-fertilized control with compost from sewage sludge.

Following the translocation of the different chemical elements in the wheat grains and leaves resulting from their analyzes, no potentially dangerous translocations can be found in any experimental variant.

It can therefore be concluded the aspect that in the case of wheat crop cultivated on fertilized land in the previous year, with compost from sewage sludge (remanence effect in the 2nd year), even in large doses, there is no accumulation of potentially hazardous chemicals; the quality of wheat grains was within normal limits and relatively similar to the unfertilized control.

More directly, in the concrete case of using compost from sewage sludge with the specified quality parameters, in the 2nd year of application, wheat can be grown without any restrictions. It can be seen that in general, all the analyzed indicators do not register values that are considered phytotoxic for wheat plants as a result of fertilization in the previous year in the preceding crop (maize) with compost from sewage sludge, in increasing doses.

It is recommended to follow the way in which the translocation of the different chemical elements in the wheat grains took place, by analyzing their content, after harvesting and interpreting these values in correlation with the contents determined in the leaves.

Table 7. Analysis of wheat leaves at the flowering phenophase

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	Humidity (%)	10.1	9.2	9.8	10.3	10.7
2	Cadmium (mg/kg d.m.)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
3	Chromium (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
4	Copper (mg/kg d.m.)	6.63	7.68	7.09	6.89	6.81
5	Nickel (mg/kg d.m.)	< 1.5	< 1,5	< 1.5	< 1.5	< 1.5
6	Lead (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
7	Zinc (mg/kg d.m.)	11.98	13.39	15.21	16.21	16.42
8	Cobalt (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
9	Arsenic (mg/kg d.m.)	<0.03	<0.03	<0.03	<0.03	<0.03

Table 8. Characteristics of wheat grains at harvest

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	Humidity (%)	9.80	9.51	9.73	9.69	9.82
2	Cadmium (mg/kg d.m.)	< 0.3	< 0.3	<0.3	< 0.3	<0.3
3	Chromium (mg/kg d.m.)	< 1.5	< 1.5	<1.5	< 1.5	< 1.5
4	Copper (mg/kg d.m.)	6.24	6.30	5.78	6.24	5.75
5	Nickel (mg/kg d.m.)	< 1.5	<1.5	<1.5	<1.5	<1.5
6	Lead (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
7	Zinc (mg/kg d.m.)	34.88	32.50	30.62	34.29	34.04
8	Cobalt (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
9	Arsenic (mg/kg d.m.)	<0.03	<0.03	<0.03	<0.03	<0.03

Also, in the wheat crop, determinations were made regarding the influence of compost fertilization on: weeding degree, plant height, grain production, the thousand grain weight, hectoliter mass (Table 9).

Table 9. The influence of remanent effect of compost on wheat crop

The experimental variant	The degree of weeding (pl/m^2)	Plant height (cm)	Production (kg/ha)	The thousand grain weight (g)	Hectoliter mass (kg)
V_1	167	70	4333	44	63.3
V_2	185	72	4670	45	57.1
V_3	192	72	4800	49	64.7
V_4	243	76	6930	45	59.5
V_5	250	78	7200	47	61.4

Determining the degree of weeding is important to see how it is influenced by the compost doses.

For each variant, three determinations were made, for each repetition, the data representing average values. It can be seen that the degree of weeding was influenced by the remanence effect of compost and the size of the doses used according to the experimental variants. Thus, the degree of weeding increased by 11-49% in the variants fertilized with compost compared to the control variant (V_1), which did not received compost, in the preceding crop. The highest increase in weeding, of 49%, is recorded in V_5 (60 t/ha compost). This is explained by the fact that in the process of composting due to the high temperatures achieved in certain phases of composting, although most of the weed seeds are destroyed, weed seeds also get into compost, which germination capacity is maintained in the 2nd year after the application of the compost. It is necessary to carefully direct the humidity and the air inside the compost pile so as to achieve the conditions of raising and maintaining high temperatures, corresponding to the destruction of pathogen agents but also of weed seeds.

The size of the plants was higher by 3 to 11% in the fertilized versions with compost, compared to unfertilized variant (V_1-control), the evolution of the wheat plants height registering the same increasing trend with the size of the compost doses used; thus, the highest size of the wheat plants (78 cm) is in V_5 (60 t compost/ ha). The remanence beneficial effect of compost application on the vegetative growth of wheat plants is very clear.

The use of remanence effect of compost has resulted in extremely high production increases, which reached 66% at V_5 (60 t/ha).

The value of TGW is in all variants within biological limits specific to the cultivated soil (Glossa). There are no significant differences in TGW of wheat grains between the tested variants.

The average values of HLM registered in all variants, relatively low values and which do not correlate with the rather high values of TGW. We mention the fact that the specific value of HLM for the studied wheat variety is over 75. This is explained by the less favorable climatic conditions in the "grain filling" period. There are no systematic differences in HLM of wheat grains between the tested variants.

CONCLUSIONS

For the wheat crop cultivated in fertilized land in the previous year, with compost from sewage sludge (remanence effect in the 2nd year), even in large doses there is no accumulation of potentially dangerous chemical elements, wheat being within normal limits and relatively similar to the unfertilized variant (control).

In the 2nd year after the application of the compost from the sewage sludge even at high doses, after the wheat harvest, the soil remains "clean", the values referring to the concentrations of heavy metals being well below the maximum allowed limits.

It can be said that in the concrete case of using compost from sewage sludge with quality parameters in the 2nd year of application, the wheat crop can be cultivated without any restrictions, both in terms of quality production but also soil quality.

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