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THE EFFECT OF APPLYING ON AGRICULTURAL LAND OF THE COMPOST FROM SEWAGE SLUDGE ON THE SOIL AND THE MAIZE 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, reducing the pressure on the environment generated by the storage of this waste. The compost used in the experiments is suitable for the 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 maize 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 maize grains are observed as the doses of compost used increase.

Key words: *compost, sludge, soil, maize.*

INTRODUCTION

The changes in the soil as a result of applying these residues are registered by the agrochemical state, the agrophysical state, the agrobiological state, all competing in defining the soil fertility.

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, 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, A 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 Maizeell & 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 (Traşcă, 2008).
The soil in the location of the experiment is part of the group 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 terrain (Traşca, 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 works (Kabata-Pendias, 2004).

MATERIALS AND METHODS

In order to study the influence of the application of compost resulting from the sludge proceeding from the treatment plant on the agricultural crops and on the soil, maize was used as a test plant, the sown hybrid was F376.
The basic work of the soil was ploughing, carried out at 25 cm, the preparation of the germination bed was done by two passes with a disc harrow, the sowing was done with SPC 6, and the seed rate used was 20 kg/ha.
The experience included 5 experimental variants in 3 repetitions, the surface of an experimental plot was 105 m^2.
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 administration of the compost in the specific doses of each variant was performed by manual spreading and incorporated in the soil by ploughing.
Weed control was done by herbicidation using Dual Gold 960EC herbicide, at a dose of 1.6 l/ha, applied pre-emergently.

The quality of the compost used in the experiments
In order to determine whether the compost produced at SEAU Mioveni can be used in the experiments, its main chemical characteristics were determined (Table 1).
The qualitative parameters of the analyzed compost are within the maximum allowable values provided for use in agriculture, including in terms of heavy metal content.
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.	The quality indicator	U.M.	Value	Maximum values (Ord. 344/2004)
1	Volatile substances	%	35.34	-
2	pH	-	7.09	-
3	$C_{organic}$	% s.u.	21.5	-
4	N_{total}	% s.u.	1.52	-
5	P_2O_5	% s.u.	1.38	-
6	K_2O	%.s.u.	0.675	-
7	CaO	% s.u.	0.35	-
8	Cadmium	mg/kg s.u.	1.04	10
9	Chromium	mg/kg s.u.	44.8	500
10	Copper	mg/kg s.u.	74.3	500
11	Nickel	mg/kg s.u.	26.5	100
12	Lead	mg/kg s.u.	46.3	300
13	Zinc	mg/kg s.u.	612	2000
14	Cobalt	mg/kg s.u.	6.34	50
15	Arsenic	mg/kg s.u.	4.09	10
16	Total coliform bacteria	probable no./g s.u.	1352400	-
17	Fecal coliforms	probable no./g s.u.	236523	-
18	Enterococci	UFC/g s.u.	105840	-

RESULTS AND DISCUSSIONS

The influence of compost fertilization on the soil

The obtained results show us 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 values determined in soil after the application of compost, in all experimental variants are well below the maximum allowed values for the concentrations of heavy metals in soils (Table 2).

Table 2. The values determined in the soil after application of the compost

No.	The analyzed parameter	V_1	V_2	V_3	V_4	V_5
1	pH	5.73	5.96	5.82	5.92	6.02
2	Organic matter content (%)	4.59	4.28	4.43	4.13	4.28
3	Soluble salts (%)	0.022	0.019	0.023	0.019	0.017
4	Water storage capacity (%)	53	52	53	53	52
5	Apparent density (g/cm^3)	1.24	1.28	1.24	1.25	1.28
6	C total (% s.u.)	1.07	1.22	1.13	1.15	1.11
7	N_{total} (% s.u.)	0.126	0.122	0.128	0.125	0.128
8	P_2O_5 (% s.u.)	0.110	0.111	0.105	0.114	0.115
9	K_2O (% s.u.)	0.199	0.277	0.239	0.207	0.211
10	CaO (% s.u.)	0.153	0.155	0.157	0.143	0.128
11	Cadmium (mg/kg s.u.)	0.602	0.546	0.395	0.376	0.508
12	Chromium (mg/kg s.u.)	34.28	36.88	36.38	32.03	31.28
13	Copper (mg/kg s.u.)	17.32	16.29	16.42	15.44	15.70
14	Nickel (mg/kg.s.u.)	26.23	25.03	24.79	23.16	22.46
15	Lead (mg/kg s.u.)	13.68	12.03	13.50	11.60	14.40
16	Zinc (mg/kg s.u.)	59.99	59.92	55.58	53.79	54.31
17	Cobalt (mg/kg s.u.)	11.27	10.77	10.87	10.50	10.62
18	Arsenic (mg/kg.s.u.)	0.058	0.036	0.032	0.049	0.055
19	Total coliform bacteria (probable no./g s.u.)	173450	2855	23404	7357	5946
20	Fecal coliforms (probable no./g s.u.)	0	0	0	0	0
21	Enterococci (UFC/g s.u.)	0	72	0	300	44

Soil chemical analysis

It is found that by applying the compost produced at SEAU Mioveni, on the agricultural land, even in the fertilized variants with the highest doses (60 t/ha), there are no significant changes in its chemical properties and with special reference to the potentially polluting heavy metals. The values determined in the soil after the maize harvest, in all the experimented variants, are far below the maximum allowed values for the concentrations of heavy metals in the soils (Table 3).

Table 3. Soil chemical characteristics after maize harvesting

No.	The analyzed parameter	V_1	V_2	V_3	V_4	V_5
1	pH	6.16	6.10	6.04	6.07	6.16
2	Organic matter content (%)	4.36	3.77	3.76	3.96	4.06
3	Soluble salts (%)	0.021	0.018	0.015	0.022	0.019
4	Water storage capacity (%)	40.7	41.1	40.5	40.9	41.3
5	Apparent density (g/cm^3)	1.28	1.28	1.30	1.29	1.28
6	C total (% s.u.)	1.27	1.08	1.17	1.18	1.20
7	N_{total} (% s.u.)	0.105	0.097	0.098	0.097	0.102
8	P_2O_5 (% s.u.)	0.126	0.123	0.119	0.112	0.121
9	K_2O (% s.u.)	0.59	0.58	0.58	0.57	0.60
10	CaO (% s.u.)	0.26	0.24	0.25	0.26	0.26
11	Cadmium (mg/kg s.u.)	0.766	0.747	0.554	0.364	0.589
12	Chromium (mg/kg s.u.)	55.96	53.18	54.39	53.32	50.65
13	Copper (mg/kg s.u.)	18.58	17.87	17.62	16.24	17.13
14	Nickel (mg/kg s.u.)	26.26	22.49	24.80	23.21	21.66
15	Lead (mg/kg s.u.)	17.90	16.67	19.42	16.83	18.27
16	Zinc (mg/kg s.u.)	67.36	60.99	66.68	65.42	62.48
17	Cobalt (mg/kg s.u.)	12.78	11.83	12.03	11.99	11.65
18	Arsenic (mg/kg s.u.)	0.046	0.039	0.035	0.041	0.051
19	Total coliform bacteria (probable no./g s.u.)	17876	38.454	178438	1.025	101108
20	Fecal coliforms (probable no./g s.u.)	39	100	7.763	241	5957
21	Enterococci (UFC/g s.u.)	0	0	278	0	0

In Romania, the technical norms regarding the protection of the environment, and especially of the soils, when sewage sludge are used in agriculture (even composted) were provided in the Order 344/2004, published in the Official Gazette no. 959/October 19th, 2004.

The technical norms of the Order 344/2004 have as main provision the content of heavy metals, both from the soils on which the sewage sludge is applied, and the content of these metals in the sludge.

These norms aim at capitalizing on 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) trophic chain. The references are for the following heavy metals: *cadmium copper, nickel, lead, zinc, mercury and chromium*, focused on 3 directions:

a) the maximum permissible values of heavy metals in the soils on which the sewage sludge is applied (Table 4);

b) the maximum allowed values of heavy metals from the sewage sludge to be applied on the soils (Table 5);

c) the limit values for the annual quantities of heavy metals accumulated in the soils (Table 6).

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

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

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 s.u.)
Cadmium	10
Copper	500
Nickel	100
Lead	300
Zinc	2000
Mercury	5
Chromium	500
Cobalt	50
Arsenic	10

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/an)
Cadmium	0.15
Copper	12
Nickel	3
Lead	15
Zinc	30
Mercury	0.1
Chromium	12

The influence of compost fertilization on maize crop

The analyzes performed on the maize leaves show that all the analyzed indicators do not register values in general which are phytotoxic for the maize plants fertilized with compost from sewage sludge.

There are there slight increases only in copper and zinc, at high doses of compost, compared to the unfertilized witness, but without affecting the normal growth, development and fruiting of maize plants (Table 7).

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

Table 7. The influence of compost fertilization on maize cultivation

No.	The analyzed parameter	V_1	V_2	V_3	V_4	V_5
1	Humidity (%)	78.4	76.1	75.63	76.1	78.2
2	Cadmium (mg/kg s.u.)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
3	Chromium (mg/kg s.u.)	< 1.5	< 1.5	< 1.5	<1.5	<1.5
4	Copper (mg/kg s.u.)	6.44	4.70	11.71	9.02	8.40
5	Nickel (mg/kg s.u.)	< 1.5	< 1.5	< 1.5	<1.5	< 1.5
6	Lead (mg/kg s.u.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
7	Zinc (mg/kg s.u.)	17.22	13.60	50.54	48.57	44.0
8	Cobalt (mg/kg s.u.)	< 1.5	< 1.5	<1.5	<1.5	< 1.5
9	Arsenic (mg/kg s.u.)	0.043	0.030	0.030	0.037	0.039
10	Total coliform bacteria (probable no./g s.u.)	32	2381	880	1627	2607
11	Fecal coliforms (probable no./g s.u.)	0	23	18	8	8
12	Enterococci (UFC/g s.u.)	0	3	26	3	2

Analysis of maize grains

The normal lead content of cereals is considered to be between 0.2-0.5 ppm, and the maximum in fodder is 40 ppm (Order MSF/MAAP-358/248 of 2003).

The normal copper content in the maize grains is 1.8 ppm and a maximum of 10 ppm in fodder (Table 8).

The fodders become toxic to animals when their cadmium content is 40-100 ppm.

Regarding zinc, the maximum content of fodder in this microelement is considered to be at 200 ppm.
Nickel is sometimes present in fodder, the normal value is below 5 ppm and the maximum accepted being situated at 12 ppm.
It can be seen that, in general, all the analyzed indicators register values well below the limits from which zootoxicity phenomena can occur.
Also, there is no increase in heavy metal content in maize grains, as the doses of compost used to fertilize maize increase.
It follows that from the point of view of the fodder quality of maize grains, it is not affected even in the case of the use of high doses of compost in the fertilization of the crop by the quality of the experienced one.

Table 8. Analysis of maize grains

No.	The analyzed parameter	V_1	V_2	V_3	V_4	V_5
1	Humidity (%)	24.03	23.79	22.45	20.95	23.51
2	Cadmium (mg/kg s.u.)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
3	Chromium (mg/kg s.u.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
4	Copper (mg/kg s.u.)	1.19	1.19	1.18	1.25	1.09
5	Nickel (mg/kg s.u.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
6	Lead (mg/kg s.u.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
7	Zinc (mg/kg s.u.)	25.78	13.60	23.76	21.26	24.83
8	Cobalt (mg/kg s.u.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
9	Arsenic (mg/kg s.u.)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
10	Total coliform bacteria (probable no./g s.u.)	227	115	45	16	1052
11	Fecal coliforms (probable no./g s.u.)	0	0	0	0	0
12	Enterococci (UFC/g s.u.)	0	0	0	0	0

Also, in the maize crop, determinations were made regarding the influence of compost fertilization on: weeding degree, plant height, grain production, mass of one thousand grains, hectoliter mass (Table 9).
Determining the degree of weeding is important to see how it is influenced by the compost doses.
For each variant, three determinations were made, on each repetition, the presented data representing the average values.
It can be seen that the degree of weeding was influenced by the application of compost and the size of the doses used according to the experimental variants.
Thus, the degree of weeding increased by 19-70% in the variants fertilized with compost compared to the witness variant (V1), which was not fertilized with compost. The highest increase in the degree of weeding, of 70%, is recorded in V4 (40 t/ha compost).
This aspect is explained by the fact that in the composting process due to the high temperatures achieved in certain phases of composting, although most of the weed seeds are destroyed, there are still weed seeds with germination capacity.
As a result, a more careful management of humidity and air inside the compost pile is required so as to achieve the conditions for raising and maintaining temperatures corresponding to the destruction of pathogens and weed seeds.

Table 9. The influence of compost application on maize crop

The experimental variant	The degree of weeding (pl/m^2)	Plant height (cm)	Production (kg/ha)	The mass of a thousand grains (g)	Hectoliter mass (kg)
V_1	87	170	9125	348	73.8
V_2	104	175	9675	352	70.4
V_3	145	185	10147	348	71.9
V_4	148	188	10285	336	72.3
V_5	135	222	11814	370	88.0

The size of the plants had higher values by 3 to 30% for the variants fertilized with compost, compared to the unfertilized witness variant, the evolution of the height of maize plants registering the same increasing trend with the size of the compost doses used; thus the highest size of the maize plants (222 cm) was recorded in the fertilized version with the maximum dose of compost (V5 = 60 t/ha).

The beneficial effect of compost on the vegetative growth of maize plants is very clear.

The maize grain production (average values, recalculated at STAS humidity, U = 14%)

There is generally a fairly high level of production due to climatic conditions in the experimental year, very favorable for maize crop.

The use of compost has determined very important increases in production, which reach 29% at V_5 (60 t/ha).

We mention the fact that the production increases obtained by using compost, although very important, are not very large, this due to the good natural fertility of the soil on which the experiments were located, as well as the fact that for reasons of economic efficiency and the witness without compost was fertilized with moderate doses of chemical fertilizers.

The mass of one thousand grains is in all variants within biological limits specific to the cultivated hybrid (F376), quite high, as a result of the achievement of favorable cultural and natural conditions for the witness variant as well.

There are no significant differences in the MMB of maize grains between the experimental variants.

The average values of the hectoliter mass registers relatively good values for the variants: V_1, V_2, V_3 and V_4 (MH = 70.4-73.8), but only at V_5 the MH value is higher (MH = 88). There are no significant differences in MH of maize grains between the experimental variants.

CONCLUSIONS

The studied compost is suitable for use in agriculture without risks of environmental and soil pollution with strict compliance with the entire set of specific technical measures.

The application of compost produced on agricultural land, even at the maximum dose (60 t/ha), did not cause significant changes on the chemical properties of the soil and with special reference to potentially polluting heavy metals.

The content of heavy metals determined in the soil when applying the compost and after harvesting the maize, in all the experienced variants is well below the maximum allowed values for the concentrations of heavy metals in the soils.

In general, all the analyzed indicators do not record values that are phytotoxic for maize plants fertilized with sewage sludge compost, regardless of doses.

There are slight increases only in copper and zinc, at high doses of compost, compared to the unfertilized witness, but without affecting the normal growth, development and fruiting of maize plants.

The results regarding the translocation of the different chemical elements in the maize grains highlight that in general, all the analyzed indicators register values well below the limits from which zootoxicity phenomena can occur.

Also, there is no increase in heavy metal content in maize grains, as the doses of compost used to fertilize maize increase.

From the point of view of the quality of maize grains, this is not affected even in the case of using high doses of compost to fertilize the crop by the quality of the experienced one.

The degree of weeding was influenced by the application of compost and the size of the doses used, as a result it requires a more careful management of moisture and air inside the compost pile so as to achieve the conditions of raising and maintaining temperatures for the total destruction of pathogens, but also weed seeds.

The analysis of the results on the influence of compost application on maize crop clearly highlights the beneficial effect of compost on maize plants.

The use of compost has determined very important increases in production, which reach 29% at V_5, fertilized with 60 t/ha.

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