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THE REMANENT EFFECT OF THE APPLICATION OF SEWAGE SLUDGE COMPOST ON AGRICULTURAL LAND UPON THE SOIL PROPERTIES AND PEA CROP

Eusebiu SAFTA[1, 2], Leonard ILIE[2]

[1]Urban Services for Mioveni Community, 4 Carol Davila Street, Arges County, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: eustil@yahoo.com

Abstract

The compost obtained from the 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 quality of the soil through the supply of nutrients and organic matter necessary for the practice of modern, ecological agriculture, under the conditions of improving the capacity to retain moisture in the soil, also reducing the pressure on the environment generated by the storage of these wastes. The compost used in the experiments is suitable for use in agriculture without risks of environmental and soil pollution, in compliance with the norms in force. The obtained results highlight the fact that by applying compost, even in the variants where the highest doses were applied (60 t/ha), there are no significant changes in the chemical properties of the soil, especially in the content of heavy metals. The values determined in the soil after applying the compost to all the tested variants are far below the maximum values allowed for the concentrations of heavy metals in the soil. Also, analyzing the results regarding the risk of translocation of the different chemical elements in the pea grains, it can be seen that, in general, all the indicators register values far below the limits from which zootoxicity phenomena can occur. There was no increase in the content of heavy metals in the pea grains, as the doses of compost used increased.

Key words: *sewage sludge, compost, remanence effect, pea, soil properties.*

INTRODUCTION

The changes in the soil as a result of the application of these residues are recorded by the agrochemical state, the agrophysical state, the agrobiological state, all competing to define the fertility of the soil. The positive effect of organic materials in general, and of those originating from urban activity, in particular, on the physical, chemical and biological properties of the soil also affects plant production, which in most cases registers increases. The organic matter is directly involved in the retention of heavy metals, Cu being one of the first metals studied in this regard (Kiikkilia et al., 2002) showing that the biosolid is an immobilizing agent for this heavy metal. On the other hand (Moolenaar & Beltrami, 1998) demonstrated the fact that heavy metals can also be complexed by dissolved organic matter, which influences the ion balance. One of the main factors involved in the absorption of heavy metals is soil pH, their accessibility being very reduced 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 through cationic exchange reactions, while Cu and Pb form organic complexes with Fe, Al and Mn oxides (Kiekens, 1983). Adsorption of heavy metals by iron oxides is accompanied by protonation being dependent on pH, according to the research carried out by Cornell & 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 structuring processes of the elementary soil particles in hydrostable aggregates, to the increase in the water retention capacity. The concentration of heavy metals is among the most important factors that restrict the use of urban waste products on agricultural land, due to their potentially negative effects on plant biomass and their translocation into food products.

Data from literature contain different ways of interpreting the contents of heavy metals in soils, specifying limit values, but it seems that the closest model to reality is the one that takes into account the content of total forms in the soil (EPA, 1993). The current acidity of the soil recorded a tendency to decrease through fertilization with biosolids in the years of application and retention.

The potential acidity followed the same variation as the current one, so that under the conditions of biosolid application and in the first year of retention, it had a tendency to decrease, so that later in the third year of retention there was a re-actualization (Trașcă et al., 2008).

The increased interest in soil fertilization with sludge resulting from urban wastewater has been manifested since 1970, when it was established that it can be considered an organic fertilizer (Tomlin et al., 1993).

The use in agriculture of the sludge resulting from the treatment of urban wastewater is dependent on the properties of the soil among which pH, the content of organic matter and nutrients 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 et al., 2000).

The effect of sludge from urban wastewater treatment on the soil is investigated both from the point of view of soil improvement and from the point of view of the impact on the environment. As Beltran et al. (1999) pointed out, knowledge of the chemical composition of sludge is of particular importance when making recommendations on application rates to agricultural land.

Over time, soluble organic compounds tend to pass into insoluble forms, the amount of heavy metals settling at low values when bioavailability decreases (McBride, 1995).

The researches on the effect of sludge application on the soil has not exceeded 30 years, as demonstrated by numerous works (Kabata-Pendias, 2004).

MATERIALS AND METHODS

In order to study the remanence effect in the 3rd 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, pea was used as a test plant (the compost was applied in 2018).

The administration of the compost in the doses specific to each variant was carried out by manual spreading and incorporated into the soil by plowing. Basic soil work and normal plowing at a depth of 25 cm.

The experience included 5 experimental variants in 3 repetitions, the area of an experimental plot being of 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 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 (Traşcă 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) (Safta & Ilie, 2022).

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).

RESULTS AND DISCUSSIONS

The effect of compost application (remanence effect in the 3rd year) on pea plants

It can be noted that, in general, for all the analyzed indicators, there are no values that are phytotoxic for the field pea plants as a result of the remanence effect, the 3rd year of fertilization with sewage sludge compost in increasing doses.

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	-

Only for copper and lead, slight increases are observed, at high doses of compost, compared to the unfertilized variant, but without affecting the normal growth, development and fruiting of field pea plants, these being well below the concentration limits at which phenomena of toxicity occur (Table 2).

We will proceed to follow how the translocation of different chemical elements took place in the field pea grains, by analyzing their content, after harvesting and interpreting these values in correlation with the contents determined in the leaves.

Table 2. Influence of the remanence effect of compost application on the chemical composition of pea leaves - at flowering

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	Humidity (%)	67.8	84.6	85.0	75.9	87.43
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.)	7.67	7.49	7.14	6.81	7.98
5	Nickel (mg/kg d.m.)	4.47	2.76	4.64	2.65	2.31
6	Lead (mg/kg d.m.)	2.97	5.03	3.41	5.62	7.14
7	Zinc (mg/kg d.m.)	32.79	28.21	31.58	26.11	30.27
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

It can be noted that, in general, for all the analyzed indicators, no toxic values are recorded for the field pea grains as a result of the remanence effect, the 3rd year of fertilization with sewage sludge compost in increasing doses (Table 3).

The concentrations in the pea grains, resulting from the variants that received increasing doses of compost from sewage sludge, are normal and similar to those in the control variant.

The influence of compost fertilization (remanence effect in the 3rd year) on the soil

The very high values for the physical indicator, bulk density, for all variants, including the control without compost (2.39 g/cm^3), mean an exaggerated settlement of the soil, by performing mechanical works at high humidity (Table 4). It is necessary to follow this indicator, when analyzing the soil samples taken after harvesting the field pea crop.

Table 3. Influence of the remanence effect of compost application
on the chemical composition of pea grains - at harvest

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	Humidity (%)	9.35	10.49	11.16	10.45	11.33
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.)	4.26	5.04	4.38	5.14	4.86
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.)	41.65	25.68	31.58	33.25	47.07
8	Cobalt (mg/kg d.m.)	<1.5	<1.5	<1.5	<1.5	<1.5
9	Arsenic (mg/kg d.m.)	<0.03	<03	<0.03	<0.03	<0.03

It can be seen from the data presented in Table 4, that in the 3rd year after the application of increasing doses of compost from sewage sludge, concentrations of heavy metals above the maximum allowed values are not found in the soil, not even with high doses of compost (Table 5). Practically, there is already a uniformity of these concentrations, in all variants, close to the level of the non-fertilized variant, which shows that these otherwise very low concentrations are not related to the application of increasing doses of compost from sewage sludge.

Table 4. The influence of the remanence effect of compost application on the chemical characteristics
of the soil before pea sowing

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	pH	6.31	6.23	6.21	6.24	6.34
2	Organic matter content (%)	3.91	3.65	3.70	4.10	3.70
3	Soluble salts (%)	0.012	0.013	0.011	0.011	0.013
4	Water storage capacity (%)	34.8	34.8	34.9	36.2	33.5
5	Bulk density (g/cm^3)	2.39	2.19	2.36	2.23	2.23
6	Total C (% d.m.)	1.06	1.05	1.02	1.02	1.10
7	N_{total} (% d.m.)	0.113	0.115	0.114	0.118	0.115
8	P_2O_5 (% d.m.)	0.114	0.129	0.112	0.115	0.135
9	K_2O (% d.m.)	0.90	0.86	0.90	0.60	0.90
10	CaO (% d.m.)	0.25	0.28	0.27	0.25	0.27
11	Cadmium (mg/kg d.m.)	<0.3	0.4	<0.3	0.32	<0.3
12	Chromium (mg/kg d.m.)	41.63	41.29	42.36	35.62	42.34
13	Copper (mg/kg d.m.)	18.12	17.07	16.99	16.17	16.99
14	Nickel (mg/kg d.m.)	25.77	24.28	24.78	23.39	24.41
15	Lead (mg/kg d.m.)	17.71	15.90	15.15	13.84	15.36
16	Zinc (mg/kg d.m.)	61.82	66.11	62.27	60.75	66.54
17	Cobalt (mg/kg d.m.)	12.95	13.06	12.50	11.66	13.98
18	Arsenic (mg/kg d.m.)	0.055	0.052	0.041	0.051	0.057
19	Total coliform bacteria (probable no./g d.m.)	21 386	659340	113988	13563	66474
20	Fecal coliform (probable no./g d.m.)	4403	142450	98	863	0
21	Enterococci (UFC/g d.m.)	13	0	0	12	0

Table 5. 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)

It is noted that the very high values of the physical indicator, bulk density, are maintained in all variants, including the control variant without compost (2.53 g/cm^3), it means an exaggerated settlement of the soil, by performing mechanical works at high humidity (Table 6).
It is also found from the data presented, that in the third year after the application of increasing doses of compost from sewage sludge, concentrations of heavy metals above the maximum allowed values are not found in the soil, not even with high doses of compost (Table 5).
Practically, there is already a uniformity of these concentrations, in all variants, close to the level of the non-fertilized variant, which shows that these otherwise very low concentrations are not related to the application of increasing doses of compost from sewage sludge.

Table 6. The influence of the remanence effect of compost application on the chemical characteristics of the soil after pea harvesting

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	pH	6.38	6.38	6.24	6.17	6.32
2	Organic matter content (%)	3.54	3.56	3.38	4.95	3.61
3	Soluble salts (%)	0.014	0.011	0.009	0.013	0.014
4	Water storage capacity (%)	34.7	35.4	33.3	34.7	34.7
5	Bulk density (g/cm^3)	2.53	2.28	2.31	2.40	2.18
6	Total C (% d.m.)	1.30	0.89	1.16	1.14	1.16
7	N_{total} (% d.m.)	0.109	0.104	0.108	0.120	0.121
8	P_2O_5 (% d.m.)	0.119	0.124	0.118	0.121	0.148
9	K_2O (% d.m.)	1.22	1.07	1.18	0.85	1.22
10	CaO (% d.m.)	0.23	0.31	0.29	0.27	0.32
11	Cadmium (mg/kg d.m.)	<0.3	0.35	<0.3	<0.3	<0.3
12	Chromium (mg/kg d.m.)	58.71	55.23	55.18	51.47	52.76
13	Copper (mg/kg d.m.)	19.08	18.16	20.04	17.96	18.05
14	Nickel (mg/kg d.m.)	26.25	27.19	25.37	23.85	22.57
15	Lead (mg/kg d.m.)	20.13	16.17	14.03	14.03	17.11
16	Zinc (mg/kg d.m.)	60.41	63.34	64.73	64.13	63.58
17	Cobalt (mg/kg d.m.)	13.51	14.62	10.90	12.07	11.46
18	Arsenic (mg/kg d.m.)	0.049	0.050	0.038	0.047	0.052
19	Total coliform bacteria (probable no./g d.m.)	512	241	5772	5746	5707
20	Fecal coliform (probable no./g d.m.)	0	0	0	0	0
21	Enterococci (UFC/g d.m.)	0	0	0	1	0

CONCLUSIONS

The studied compost lends itself to use in agriculture without the risk of environmental and soil pollution with the rigorous observance of the entire set of specific technical measures.
For the field pea crop (3rd year), it can be noted that in general, for all the analyzed indicators, no toxic values are recorded for the field pea grains as a result of the remanence effect, 3rd year of fertilization with sewage sludge compost in increasing doses.
The concentrations in the pea grains, resulting from the variants that received increasing doses of compost from sewage sludge, are normal and similar to those in the control variant.
It is also found from the data presented, that in the third year after the application of increasing doses of compost from sewage sludge, concentrations of heavy metals above the maximum allowed values are not found in the soil, not even with high doses of compost.
Practically, there is already a uniformity of these concentrations, in all variants, close to the level of the non-fertilized variant, which shows that these otherwise very low concentrations are not related to the application of increasing doses of compost from sewage sludge.
It should be mentioned that in order to comply with the strict rules known in agricultural research, for the accuracy of the obtained experimental results, it is recommended to carry out another three-year rotation cycle, with

a second application of the compost, only in this way can the combined effect of the directly applied compost be verified, with its remanence effect, especially on the soil, but also indirectly on the plants.

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