THE TRANSFER FACTOR OF METALS IN SOIL-PLANT SYSTEM

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Abstract: *In sewage sludge the metals are finding in different forms, in function of chemical properties of sewage sludge and the chemistry of the metal. It was calculate the transfer factor of some metals, from soil in maize grains after sewage sludge distribution on land. The analyzed metals are: copper, iron and lead. It is known that only a part of the metals content from soil is transferred in plant, in our case being the maize grains. The analyses were made on soil samples and on maize grains. We establish the metals transfer factor using a standard formula. It was choose these three metals because their concentration in sewage sludge was higher comparative to the other metals. The experiment was done on maize hybrid: Lovrin 400 and the soil type is cambic chernozem, poorly glazed, which is characteristic for the USAMVB`s Research Station from Timisoara. The sewage sludge was distributed on land only one time, in different doses: 0, 20, 40 and 60 t ha^{-1} and we observe the remaining effect on soil and plants. The content in metals from soil was determinate in aqua regia extract and values were established to an atomic absorption spectrophotometer at different wave lengths: Fe at 510 nm, Pb at 217 nm, Cu at 470 nm).The plant samples (maize grains) were burned and after that were treated with HCl 0.1 N, and the content in metals was established as in soil case, using the same method. It was observed in soil a high content of iron, but in case of the other studied elements, their concentration is finding in normal limits. The highest values of transfer factor were determinate in case of iron, than copper and the lowest values were established for lead. After the analyses that were made, the maize grains can be used as food for animals and the fodder is not polluted with toxic metals. In the last years, in each city, after the waste waters treatment result high quantities of sludge which might be used in agriculture but it must be respected some conditions, such as the maximum dose admitted to be distribute on land in order to not produce the pollution of soil, plants, waters and food.*

Key words: *metals, soil, plant, sewage sludge*

INTRODUCTION

Generally the application of sludge on agricultural land is obtained due to production increases in nutrient rich content thereof. Some researchers consider that plant genotype can be a factor as important in controlling the translocation of metals. All research conducted so far show a trend of increasing production from sludge fertilization of most crop plants but with higher doses of sludge is a reduction of it.

Organic fertilization is mainly aimed at increasing productivity and soil fertility and is a measure of soil material supply energy.

Soil - plant system has three protective mechanisms which may limit the potential toxicity of heavy metals in plants and thus reduce the problems they might cause living beings. Barrier soil - plant includes: elements that are insoluble in the soil and does not accumulate in plants, such as Pb, Hg; elements that are absorbed in the root but are insoluble and come in limited quantities in strain as Fe; elements which, when applied in excess causes phytotoxicity, so plants are not consumed by humans or animals: Zn, Cu, Ni, Co, Mn. (CALLOT G., 1982)

Comparative data between cultivated species show broad areas of variation in their ability to absorb potentially toxic heavy metals from sewage sludge system - ground. Cereals and vegetables accumulate less Cd in leafy vegetables compared with strains such as lettuce and spinach. Tomatoes accumulate more Mo in soils treated with sewage sludge even than barley or beans. Although many experiments have been performed many questions remain about the effects it has on agricultural land application of sewage sludge. The unique composition of the sludge, and the many factors influencing the soil - plant and accumulation of these metals in the plant, has added complexity to this problem. (ALDAG R., 1991)

In sewage sludge the metals are finding in different forms, in function of chemical properties of sewage sludge and the chemistry of the metal.

MATERIAL AND METHODS

For the experiment we use sewage sludge from the Waste Water Treatment Station Timisoara. The sewage sludge was distributed on land only one time, in different doses: V1-0, V2 – 20, V3 – 40 and V4 – 60 t ha^{-1}, and we observe the remaining effect on soil and plants. We sample soil at 20 cm depth and plant samples (maize grains) from each experiment plot. The content in metals from soil was determinate in *aqua regia* extract and values were established to an atomic absorption spectrophotometer at different wave lengths: Fe at 510 nm, Pb at 217 nm, Cu at 470 nm) (RADULOV, 2011).The plant samples (maize grains) were burned and after that were treated with HCl 0.1 N, and the content in metals was established as in soil case, using the same method and apparatus. The heavy metal transfer factor from soil in plant was established using the formula (OLĂNESCU, 2007):

$$TF = \frac{Mp}{Ms}$$

Where:

TF – transfer factor,

Mp – metal content in plant (mg kg^{-1}),

Ms – metal content in soil (mg kg^{-1}).

Table 1

Fertilizing potential of sewage sludge

Indicator	*Unit measure*	*Value*	*Observations*
Organic substance	%	17	-
Total nitrogen	%	1,7	High content
P	mg kg^{-1}	28	Medium content
K	mg kg^{-1}	211	High content
Ca	mg kg^{-1}	346	High content
Mg	mg kg^{-1}	41,3	Reduce content

The sewage sludge is characterized as a potential fertilizing resource, being rich in nitrogen, potassium and calcium, as it shows in table 1. The content in phosphorus is medium and magnesium is finding in a reduced quantity.

Table 2

Content in some heavy metals of sewage sludge

Heavy metal	*Unit measure*	*Value*	*Limit value after CEE legislation*	*Observations*
Zn	mg kg^{-1}	619	2500-4000	Under limit
Cu	mg kg^{-1}	92	1000-1750	Under limit
Co	mg kg^{-1}	25.5	-	-
Pb	mg kg^{-1}	261	750-1200	Under limit
Ni	mg kg^{-1}	70	300-400	Under limit
Fe	mg kg^{-1}	20.79	-	-

Comparing with the European legislation regarding the content in heavy metals of the sewage sludge, the obtained values in those elements are under the imposed limit. (Table 2)

Soil properties (physical and chemical) where the research was made, are presented in the table below.

Table 3

Chemical and physical properties of cambic chernozem,poorly glazed

Horizon	*Ap*	*Am*	*Bv*	*B/C*	*C/CcaGo$_4$*	*CcaGr*
Depth (cm)	*0-25*	*26-51*	*52-70*	*71-80*	*81-150*	*151-220*
Coarse sand 2-0,2 mm (%)	0,5	0,4	0,3	0,3	0,6	0,4
Fine sand 0,2-0,02 mm (%)	32,1	30,6	30,8	28,5	30,0	32,0
Dust 0,02-0,002 mm(%)	26,9	28,8	28,3	30,0	27,4	26,2
Clay < 0,002 mm (%)	40,5	40,2	40,6	39,7	42,0	41,4
Texture	TT	TT	TT	TT	TT	TT
Density (D g/cm^3)	2,45	2,58	2,73	-	-	-
Apparent density (D.A. g/cm^3)	1,32	1,44	1,58	-	-	-
Total porosity (P.T. %)	47	45	43	-	-	-
Air porosity (P.A. %)	16	14	12	-	-	-
Subsidence degree (G.T. %)	13,88	4,86	0,7	-	-	-
pH	6,18	6,44	6,57	6,93	7,5	7,79
Carbonates %	-	-	-	-	11,6	12,5
Humus %	3,28	2,97	2,1	-	-	-
Nitrogen indicator	2,76	2,58	1,85	-	-	-
Mobile Phosphorus (P ppm)	13,0	8,5	2,6	3,7	-	-
Mobile potassium (K ppm)	128	120	128	134	-	-
Hydrogen sum (SH me/100g soil)	4,75	4,21	2,62	2,43	-	-
Bases sum (SB me/100g soil)	25,6	26,06	26,98	27,52	-	-
Total cation exchange capacity (Tme/100g soil)	30,35	30,27	29,60	29,95	-	-
Degree of base saturation (V %)	84,34	86,09	91,14	91,88	-	-

The composition of the soil granules fractions indicate that the soil texture is clay loam/clay loam ant the soil is formed on middle fine loess deposits. Soil density is high and the subsidence degree indicates that the soil is medium pressed.

Regarding the chemical properties of soil, as they are presented in table 3, it can be observed that the soil reaction is weak acid in the superior horizons and weak alkaline in the inferior horizons. The content in humus demonstrate a good content in organic matter of the soil, such as the nitrogen indicator, which is related to the degree in base saturation (V %). Content in mobile phosphorus is reduced and the content in mobile potassium is medium. The bases sum is reduced in the superior horizons and the value is increasing on the depth. The total exchange cation capacity is specific to the soils which has a normal content in humus and clay. The degree in base saturation is high especially in the inferior horizons, where we observe a concentration of the carbonates.

RESULTS AND DISCUSSIONS

Metals transfer from soil in plant depends on elements chemistry, on plant bio-disponibility and on analyzed part of plant. Leafs, scions and organs with photosynthetic activity accumulates higher quantities of metals than grains. Most plants act as a barrier to accumulation of pollutants in the food chain.

A particular problem is the translocation of heavy metals in soil in different tissues of plants. Most research has shown that the concentration of metal grains is rarely due to significant use in animal feed ban. The highest accumulation of heavy metals was found in the leaves of lettuce, sugar beet and clover, concentrations frequently exceed phytotoxic levels.

In soil the copper content might be between 4 and 49 mg kg^{-1} total forms and 0.5 -5 mg kg^{-1} available copper. (RADULOV, 2011) But copper remains in the area where it was distributed because it forms compounds to the organic matter of the soil.

In plants the normal content in copper is 3-15 mg kg^{-1} in the dry substance, but higher quantities might be finding in grains. If the content exceeds 20 mg kg^{-1}, the effect of copper upon the plant is toxic.

The transfer factor of copper from soil in plant has values between 0.05 and 0.28, after RUSU, 2005)

Table 4

Copper content in soil, in plant and transfer factor

Experiment plot	*Soil content in copper (mg kg^{-1}Cu)*	*Plant content in copper (mg kg^{-1}Cu)*	*TF*
V1	17,419	5,79	0,332
V2	32,663	7,80	0,238
V3	32,951	11,24	0,341
V4	34,567	12,26	0,354

The higher content copper in soil was 34.567 mg kg $^{-1}$ determinate in V4 experiment plot, where was applied 60 t ha $^{-1}$ sewage sludge. The plant content in copper is related to the content in soil, 12.26 mg kg $^{-1}$, was found in the V4 experiment plot. In the case of plant the values are in the normal limits established for copper content, but in the case of soil it was observed an overtaking of the accepted concentration. The higher transfer factor was calculated in V4 experiment plot: 0.354 and it exceed the limit, but also in V1 and V3 experiment plot.

If the content in copper exceeds the normal limits in plants it might be produced phytotoxicity and it might be transferred in food.

Literature data indicate that more than 17% of total Cu, Zn, Pb and Cd and about 22% of Ni, are absorbed and changeable in form, this form is available to plants. Remaining quantities are present in forms that require conversion to water-soluble form, change or absorbed, before being taken over by plants.

Copper has an important role in metabolism, involved in transforming tyrosine. Along the iron is present in cytochrome oxidase, which participates to the respiration process. Almost all of the copper in the leaves is located in chloroplasts. Copper influences carbohydrate and protein balance of plant growth-enhancing content of carbohydrates, lipids, and vitamins. Prevents physiological aging process and promote the vital activity of leaf extension. Copper is absorbed by plants as Cu 2 + ions or chelated form. Enters the plant by foliar and root.

The normal content in iron of chernozems from our country is 1.6 to 2.4 mg kg^{-1} and it might be influenced by the degree in base saturation, by the presence of carbonates and the soil reaction. (RUSU, 2005)

The green of the plant contain 20-300 mg kg $^{-1}$ Fe. Seeds and fruits have lower iron content. It enter the root only Fe2 +. Biochemical functions of iron in plants are explained by its assimilation to form complex compounds and to undergo reversible valence changes. It is directly involved in all physiological processes. Iron participates in chlorophyll synthesis and photosynthesis. Directly or indirectly is involved in trans-ammination processes, in protein synthesis.

Table 5

Iron content in soil, in plant and transfer factor

Experiment plot	*Soil content in iron (mg kg -1Fe)*	*Plant content in iron (mg kg -1Fe)*	*TF*
V1	1,003	0,36	0,358
V2	2,797	1,10	0,393
V3	5,419	2,77	0,511
V4	5,578	3,01	0,539

The soil content in iron is between 1.003 mg kg $^{-1}$ and 5.578 mg kg $^{-1}$, the higher value was determinate in V4 experiment plot. We observe a higher concentration than normal in V2, V3 and V4 experiment plot, caused by the content of sewage sludge on iron and by the quantity of sewage sludge that was distributed (40 t ha $^{-1}$ and 60 t ha $^{-1}$).The content of iron in plant is low (maximum 3.01 mg kg $^{-1}$ which was established in the plot where we distribute 60 t ha $^{-1}$ sewage sludge), because the analyzed part of plant are grains and they aren't photosynthetic parts. The higher transfer factor 0.539 was established in V4 experiment plot.

In case of iron the phenomenon of phytotoxicity is not present, because of the reduced quantity in grains.

Table 6

Lead content in soil, in plant and transfer factor

Experiment plot	*Soil content in lead (mg kg -1Pb)*	*Plant content in lead (mg kg -1Pb)*	*TF*
V1	2,870	0,50	0,174
V2	18,054	1,96	0,108
V3	23,806	4,27	0,179
V4	23,567	4,82	0,204

The normal lead content in soil is 18-36 mg kg^{-1} as it is specified in the European legislation.

Plants accumulate lead while the soil is polluted with this element, but essential matter plant specificity in absorption and translocation of this element, the tolerance to high concentrations of this heavy metal. Lead is considered a heavy metal toxic to animals consuming forage high in this element, as well as humans.

The transfer factor of lead from soil in plant has values between 0.15 and 0.87 according to the study case made by RUSU, 2005.

Soil content in lead is in normal limits, because the sewage sludge has not a very high concentration in this element. The highest value (23.806 mg kg $^{-1}$) was established in V3 experiment plot, where was distribute 40 t ha^{-1} sewage sludge. The content in lead from the maize grains is low (maximum 4.82 mg kg $^{-1}$ in V4 experiment plot), such as the transfer factor from soil in plant.

CONCLUSIONS

1. We observe in soil a high content of iron, but in case of the other elements, their concentration is finding in normal limits.
2. The highest values of transfer factor were determinate in case of iron, than copper and the lowest values were established for lead.
3. We can conclude that the maize grains can be used as food for animals and the fodder is not polluted with metals.
4. We recommend distributing sewage sludge on land on moderate doses, not higher than 40-60 t/ha, in order to avoid the accumulation of heavy metals in plants and the apparition of phytotoxicity phenomenon.

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