INFLUENCE OF SEWAGE SLUDGE FROM IASI WATER TREATMENT STATION ON SOYBEAN YIELD QUANTITY AND QUALITY AND SOIL CHEMICAL CHARACTERISTICS

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ABSTRACT – *The fermented sewage sludge from Iaşi Municipal Treatment Station, by its chemical and biological characteristics can be used as fertilizer on most of soils, except the salted soils, due to high content of soluble salts (1.0 g/100 g dry sewage sludge) and amendment measures, necessary in these cases. The use of fermented sewage sludge in soybean crop, at a rate of 40 t/ha, resulted in getting mean yield increases of 50 % (813 kg). Heavy metals content from fermented sewage sludge at the Iaşi Municipal Treatment Station was higher at zinc (3620 ppm) and copper (53 ppm), requiring the limitation of sewage sludge rate to 20-30 t/ha. The concentration of heavy metals in seeds obtained from soybean treated with 40 t/ha sewage sludge was higher (compared to untreated control) with 5.3 ppm at Fe, 0.92 ppm at Cu and with 0.01-0.07 at Zn, Mn and Ni. The other analysed heavy metals (Cr, Pb, Cd, Co, As, Hg) were not found in soybean seeds, treated with 40 t/ha sewage sludge. The concentration of heavy metals registered in soybean seeds, fertilized with 40 t/ha sewage sludge, has shown that these values did not exceed maximum allowable concentration established by Directive of EC no. 466/2001.*

Key words: sewage sludge, soybean, soil chemical characteristics

INTRODUCTION

Sewage sludge is the most commonly studied residue; most of investigations have studied its effects on environment.

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In the guide for safe sewage sludge application on fields from Great Britain, Brian Chambers shows the minimum allowable limits for sewage sludge treatments. Applying untreated sewage sludge has been forbidden since 13 December 1999 for food crops and since 31 December 2005 for industrial crops. Applying sewage sludge on grassland and meadows is done by soil injection, but grazing is forbidden in the season of application. On arable lands, sewage sludge is applied within rotation, in crops which accumulate low amounts of heavy metals. In vegetables crops, salad may be eaten after 30 months in case of using conventionally treated sewage sludge and after 10 month in case of well-treated sewage sludge. Advanced treatment of sewage sludge consists in anaerobic fermentation accompanied by biological, chemical and thermal treatments. Enhanced treated sewage sludge will be free of *Salmonella* and will be treated so that 99.9999% pathogens should be destroyed (a 6 log reduction) (Chambers et al., 2001; Chambers, 2002).

Investigations conducted by Petra Bergkvist have shown that the use of sewage sludge on arable lands in Sweden resulted in increasing the concentration of Cd from soil by 0.01-0.1%, every year. Sewage sludge application is allowed on arable lands in cereals crops, oilseed plants and industrial crops. Maximum Cd charge, allowable on arable lands is 0.75 g/ha/ year in Sweden, 150 in EU and 1900 in USA (cumulated 39 kg ha -1). The application of sewage sludge from Uppsala, for scientific purpose, during 41 years, with a concentration of Cd between 13.2 mg Cd kg -1 (1971) and 1.7 mg Cd kg-1 (1996-1997) has determined the accumulation of a maximum allowable amount corresponding to 1900 years. The total amount of Cd, accumulated in soil layer 0-20 cm, from sewage sludge, phosphorus fertilizers and rainfall, during 1956-1977 was of 153 mg Cd m^2 on the plot treated with sewage sludge and of 13 mg Cd m^2 on control plot. Long – term application of sewage sludge on the same field has increased the organic matter content, but has not increased the adsorption capacity of Cd. The cause of this process is Fe and P (added by sewage sludge application), which diminish the binding capacity of Cd in organic stage of sewage sludge (Bergkvist, 2003). Another cause is the humus components derived from sewage sludge, which have low adsorption capacity of Cd, compared to native humus components and weak electrostatic adsorption of a Cd^{2+} by clay components. Cd content has increased in barley straw treated with sewage sludge, but the concentration from seeds was within the limits of values established for cereals used for human consumption, foreseen in the Directive of Commission no. 466/2001 (Huyard et al., 2001).

In Germany (Rheinland-Pfalz), where farmers using sewage sludge are stimulated, from the total of used nutrients 311.5 kg/ha NPK (139.2 N; 57.1 P_2O_5; 115.2 K_2O), 152 kg are ensured by mineral fertilization, 4.4 kg/ha by biocompost, 5.9 kg/ha by sewage sludge and 149.2 kg/ha by manure. Regulations of German Government foresee limiting total nitrogen to 210 kg/ha in perennial grasses and

170 kg/ha on arable lands. In sewage sludge, maximum allowable amounts are 5 t/ha DM once in three years, or 10 t/ha well-treated sewage sludge (Jeebe, 1999).

MATERIALS AND METHODS

Investigations conducted during 2003-2006 at the Podu-Iloaiei Agricultural Research Station have studied the influence of different sewage sludge rates on yield quality and quantity and soil agrochemical characteristics. Experiments were set up in a five-year crop rotation (soybean-wheat-maize-sunflower-wheat). Sewage sludge was applied annually at rates of 20, 40 and 60 t/ha, with different mineral fertilizer rates, differentiated according to growing plant.

Determination of organic carbon content was done according to the method of Walkley-Black. Mobile forms of mineral nitrogen ($N\text{-}NO_3$ şi $N\text{-}NH_4$) have been determined spectrophotometrically and the total nitrogen content has been determined by Kjeldahl method. Determination of elements content was done by the following methods: spectrophotometrical (P), flamphotometrical (K, Ca) and Mg and heavy metals content was determined by spectrometry with atomic absorption.

The cambic chernozem used for experiments has a clayey-loam texture, a weakly acid reaction and a mean supply with mobile phosphorus and a very good one with mobile potassium.

Soil physical and chemical characteristics and concentration of polluting heavy metals from sewage sludge, soil and farming products have been studied according to the methods recommended by present standards.

RESULTS AND DISCUSSION

The climatic conditions registered during 2003-2006 have resulted in a good capitalization of mineral fertilizers and sewage sludge in main crops.

The sewage sludge from the Iaşi Station could be used on cambic chernozem-type soils from the Moldavian Plain, because it supplied significant amounts of humificated organic matter and nutrients for maize, sunflower and soybean requirements.

Fermented sewage sludge from the Iaşi Municipal Treatment Station had a neutral reaction, an organic matter content of 44.3% and an organic carbon content of 29-30%. Nitric nitrogen concentration is low, while the concentration of ammonium nitrogen reaches 276 ppm (*Table 1*). The total content of nutritive macroelements from fermented sewage sludge of metatank is high at P, K and Ca. Organo-mineral resources as sewage sludge, correctly applied, could be a substitute for a great part of expensive technological consumptions (mineral nutrients) and could contribute to the improvement of organic matter content from soil. The results have shown that the application of a rate of 40 t/ha sewage sludge determined the increase in plant supply degree with mineral elements (especially, N and P). It has also ensured a mean annual supply of 4 t/ha organic matter, highly humificated, which explained the increase in soil humus content from 2.79 to 3.92%. By using sewage sludge, plant nutrition was improved in secondary nutrients (calcium, manganese and sulphur) and in micronutrients (boron, iron, manganese and zinc). The sewage sludge from the Iaşi Station contained more zinc and copper. These elements could be used in maize and beans crops, where, on slope lands, zinc deficit was frequent. From the nine studied heavy metals (Co, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn), only zinc concentration had high values and Pb content had values below 100 ppm (maximum allowable limit for total Pb content from soil). The concentration of other heavy metals from fermented sewage sludge was similar to the normal content from soils.

Table 1

Content of heavy metals from sewage sludge at the Iaşi Station, used for experiments

Years	pH	Carbonates	Humus, %	Organic matter, %	P, ppm	K, ppm	Nt %	N- NO_3 mg/100 g	N- NH_4 ppm
2004	6.9	3.56	7.75	44.4	143	680	1.02	14.5	276
2005	6.8	6.91	8.68	44.2	160	620	1.22	23	276
Mean	6.85	5.24	8.22	44.3	151.5	650	1.12	18.75	276
Heavy metals. ppm									
Years	**Zn**	**Cu**	**Fe**	**Mn**	**Pb**	**Ni**	**Cr**	**Co**	**Cd**
2004	3126	41.6	20265	331	85	55	85	32	3,5
2005	4122	66.1	21910	323	97	61	86	30	3,7
Mean	3624	53.9	21087.5	327	91	58	85.5	31	3,6
Mean limits Directive 86/278/EEC	3250	1375	-	-	975	-	350	-	30
Content of soluble salts, aqueous extract 1:5. mg/100 g sewage sludge									
Years	**Cl^-**	**SO_4^{2-}**	**HCO_3^-**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**Total content of soluble salts**	
2004	10.5	852	41.9	73.5	10	244	37.7	1269	
2005	9.3	743	30.9	43.5	7	216	41.3	1091	
Mean	9.9	797.5	36.4	58.5	8.5	230	39.5	1180	

The total content of soluble salts from fermented sewage sludge was 1.18 g/100 g air dried sewage sludge, where calcium sulphate was prevalent, small amounts of calcium, manganese and sodium or potassium chlorides being added (*Table 1*).

Investigations conducted on the influence of sewage sludge treatment on heavy metals content from soil have shown that continuous application for three years of sewage sludge on the same field resulted in the accumulation of heavy metals in soil (*Figure 1, 2*). These results have also shown that the only criterion limiting the rate of fermented sewage sludge at 10-20 t/ha DM was zinc content.

Cd and Ni concentration from soil, achieved by applying for 3 years rates of 60 t/ha sewage sludge, was lower compared to the mean allowable limit established by Directive 86/278/EEC (*Figure 1*).

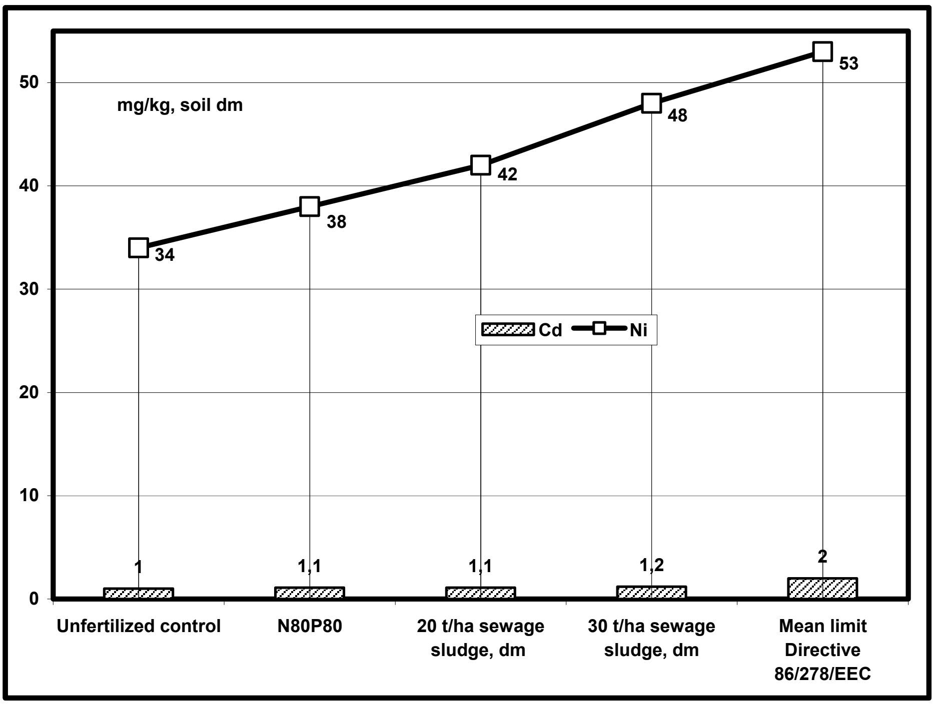

Figure 1 - Cd and Ni content from soil at different fertilizer rates, in comparison with the mean allowable limit, established by Directive 86/278/EEC

By comparing the concentration of heavy metals from soil with maximum allowable limits established by EU countries, we found that sewage sludge from Iaşi Municipal Treatment Station was within these limits and by applying rates of

20 t/ha sewage sludge dry matter, the limits foreseen by the Directive 86/278/EEC were not exceeded (*Figure 2*). At the rate of 60 t/ha raw sewage sludge (30 DM), the limit foreseen by the Directive 86/278/EEC was exceeded only at zinc (440 mg/kg soil DM).

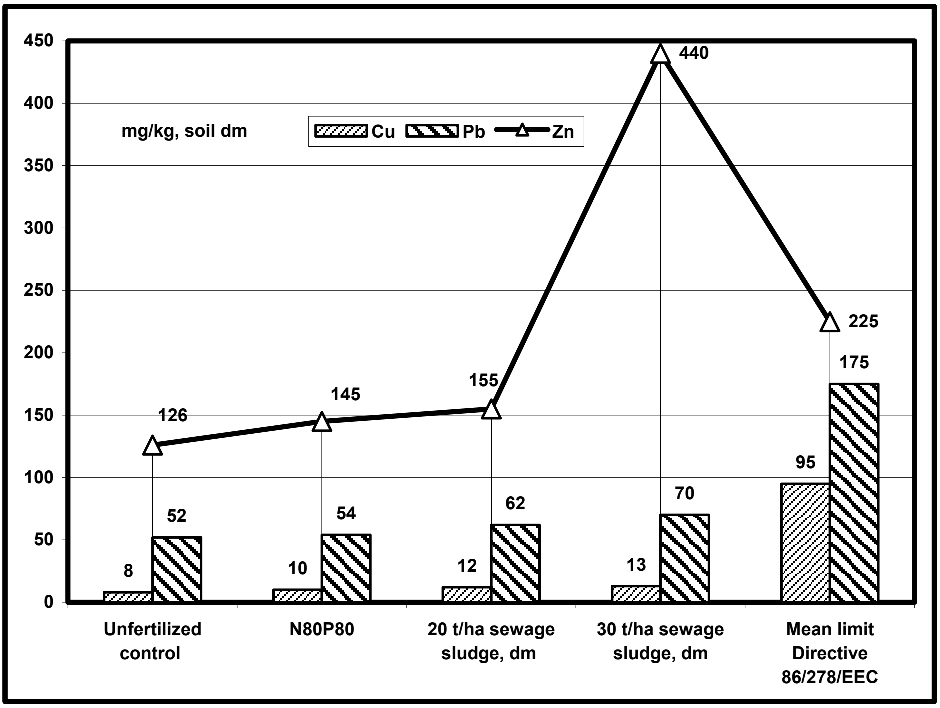

Figure 2 - Copper, lead and zinc content from soil at different fertilizer rates, in comparison with the mean allowable limit established by Directive 86/278/EEC

These rates should be increased on soils lacking zinc in plants. The rates of sewage sludge should be applied on soils with neuter or weakly acid reaction or should not be applied on soils with lower than 5.5 pH, where the mobility of certain heavy metals increased in soil.

Long-term experiments on the impact of applying sewage sludge on soil and plants, conducted in nine localities from Great Britain, during 1984-2002, allowed us to establish relationships between the concentration of heavy metals from sewage sludge and the content of heavy metals from soil and plants. We found out the presence of a positive correlation between extractable copper from soil and Fe_2O_3 content from soil (Johnsson, 2002).

The mean yield obtained in soybean crop, grown in 5 year rotation , during 2003-2006 was of 1621 kg/ha in unfertilized control and 3253 kg/ha at the rate of 40 t/ha sewage sludge + $N_{60}P_{60}$ (*Table 2*). The mean yield increases obtained in the last 4 years in soybean crop, by applying rates of 40 t/ha sewage sludge, were of 813 kg/ha (50%), compared to untreated control. Mean yield increase obtained in the last 4 years in soybean crop, for each tone of sewage sludge, was of 20 kg/t. Nitrogen and phosphorus fertilizers resulted in average yield increases of 987 kg/ha (61%) and sewage sludge applied at rates of 40 and 60 t/ha resulted in yield increases of 813 (50%) and, respectively, 1096 kg/ha (68%).

Table 2

Influence of sewage sludge and mineral element fertilization on soybean yield

Treatment	Yield (kg/ha) obtained in the year				Average yield		Difference kg/ha
	2003	2004	2005	2006	Kg/ha	%	
Unfertilized control	1430	1960	1633	1460	**1621**	100	
$N_{60}P_{60}$	2240	2957	2593	2640	**2608**	161	987
20 t/ha sewage sludge	1660	2233	2053	2240	**2047**	126	426
20 t/ha sewage sludge +$N_{60}P_{60}$	2380	3457	2680	3120	**2909**	179	1288
40 t/ha sewage sludge	2020	2863	2243	2610	**2434**	150	813
40 t/ha sewage sludge +$N_{60}P_{60}$	2590	3950	2930	3540	**3253**	201	1632
60 t/ha sewage sludge	2410	3140	2427	2890	**2717**	168	1096
60 t/ha sewage sludge +$N_{60}P_{60}$	2970	4467	3240	3680	**3589**	221	1968
LSD 5% = 230 kg/ha, LSD 1% = 320 kg/ha, LSD 0.1% = 540 kg/ha							

Analyses conducted on the content of elements in soybean seeds, obtained from crops treated with 40 t/ha sewage sludge, have shown that the nitrogen accumulated in seeds were higher at the rate of 40 t/ha sewage sludge, compared to untreated control (*Figure 3*). Watching phosphorus and potassium content from seeds at harvesting, a higher consumption was found in case of applying sewage sludge. Differences between treated and untreated plants were within normal limits, which were found in case of mineral or organic fertilization.

Investigations conducted on the influence of sewage sludge treatment on heavy metals content in seeds have shown that continuous application for three years of sewage sludge on the same field resulted in the accumulation of heavy metals in eatable parts of plants.

Cu content from soybean seeds obtained from fertilized crops with 40 t/ha sewage sludge was of 0.4-1.48 ppm. The highest Cu concentration was registered in soybean and sunflower seeds, followed by maize cobs. These values did not exceed maximum allowable concentrations established by Directive of European Commission no. 466/2001. The other studied heavy metals (Cr, Co, Pb) were not present (no traces were found) in seeds of soybean; this proved that the products had a good quality and were within the EU standards stipulated by Directive 2000/EC. Zinc content from seeds and plants treated with high sewage sludge rates was higher in maize and sunflower and differences to untreated control were lower in soybean. Utilization of sewage sludge in agriculture has a major interest, due to nitrogen and phosphorus and microelements supply (Zn, Cu). For slope lands degraded by erosion, sewage sludge together with other organic resources can contribute to the improvement in soil characteristics. The application of rates of 24.6 t/ha sewage sludge DM has resulted in the accumulation of mobile phosphates in soil of 42 ppm, and the content of microelements, mobile forms from soil, was of 12.1 ppm at Cu , 0.35-0.48 ppm at B, 155 ppm at Zn and 386 ppm at manganese.

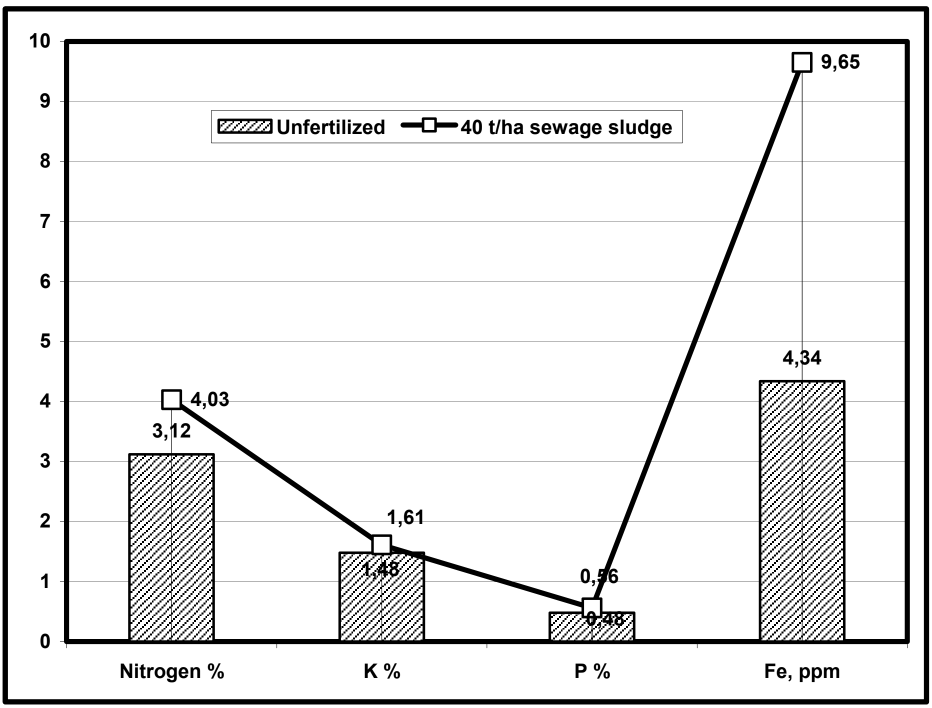

Figure 3 - Mineral elements content from soybean seeds obtained from plants treated with sewage sludge

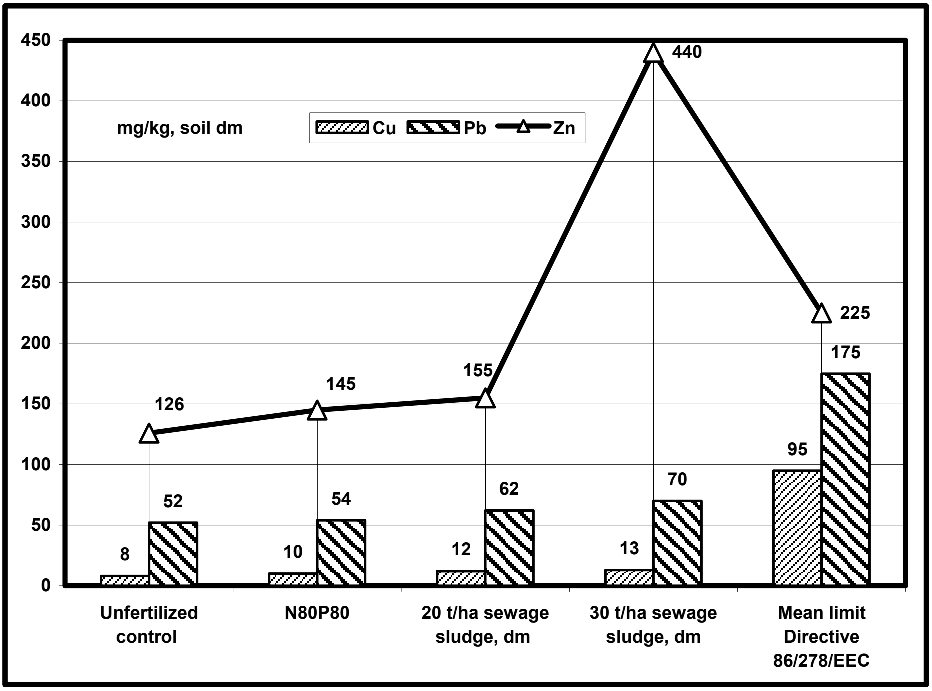

Figure 4 - Concentration of heavy metals from soybean seeds obtained from plants fertilized with sewage sludge

CONCLUSIONS

The fermented sewage sludge from Iaşi Station, by its chemical and biological characteristics can be used as fertilizer on most of soils, except the salted soils, due to high content of soluble salts (1.0 g/100 g dry sewage sludge) and amendment measures, necessary in these cases.

The use of fermented sewage sludge in soybean crop, at a rate of 40 t/ha, resulted in getting mean yield increases of 50% (813 kg).

Heavy metals content from fermented sewage sludge at the Iaşi Municipal Treatment Station is higher at zinc (3620 ppm) and copper (53 ppm), requiring the limitation of sewage sludge rate to 20-30 t/ha.

Maximum sewage sludge rate, which may be applied on fields, without exceeding the maximum charge rates of 30 kg/ha/year for zinc and 12 kg/ha/year for copper, foreseen by Directive 86/278/EEC and Order of Romanian Government no. 49 from 14 January 2004, is of 30 t/ha.

The content of heavy metals from soil at the treated variant for 4 years with 20 t/ha sewage sludge has increased (compared to control) with 29 ppm at zinc, 5 ppm at copper, with 10-14 ppm at Cr, Ni and Pb and with 0.10 ppm at Cd. The four year application of 20 t/ha fermented sewage sludge resulted in the increase of mobile phosphorus content from soil (compared to untreated control) from 40 to 82 ppm and the increase of humus content from soil from 2.79 to 3.73%.

The concentration of heavy metals in seeds obtained from soybean treated with 40 t/ha sewage sludge was higher (compared to untreated control) with 5.3 ppm at Fe, 0.92 ppm at Cu and with 0.01-0.07 at Zn, Mn and Ni. The other analysed heavy metals (Cr, Pb, Cd, Co, As, Hg) were not found in soybean seeds, treated with 40 t/ha sewage sludge.

The concentration of heavy metals registered in soybean seeds, fertilized with 40 t/ha sewage sludge, has shown that these values did not exceed maximum allowable concentration established by Directive of EC no. 466/2001.

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