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PHYTOREMEDIATION OF A SLUDGE DEPOZIT PROCEEDED FROM A CITY WASTEWATER TREATMENT PLANT

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Abstract: It is presented the possibility to reduce contents of heavy metals (cadmium, zinc) in a sludge proceeded from the wastewater treatment plant of Iaşi Municipality. The sludge was deposited, for over 10 years, in a mud pond with a surface about 15 ha, placed on a calcareous and salinised alluvial soil. For this purpose, it is proposed using the spontaneous flora, which has been settled in a period of four years after closure of the deposit. The flora has been predominantly composed of *Phragmytes australis*, and also other species such as *Rumex acetosela*, *Chenopodium album, Aster panonicum, Solanum nigrum* and others. These plants accumulated in their roots and in the aerial part cadmium (Cd) quantities, which exceed up to 60, respectively 14 times the normal values. Similarly, zinc (Zn) has been concentrated in the roots and aerial parts 33 times, 18 times respectively. The transfer (TF) and bioaccumulation (BAF) factors' values highlight the plants' feature to accumulate heavy metals from the sludge. The plants can be arranged in a decreasing series of the accumulated heavy metals (cadmium, copper, lead, zinc), thus *Rumex acetosela*, *Solanum nigrum*, *Chenopodium album, Aster panonicum* and *Phragmytes australis*. Applying phytoextraction of polluting heavy metals only by annual harvesting of aerial part of the spontaneous flora now existing, will bring the sewage sludge to a normal content level of these heavy metals in a period of up to 450 years. If the harvest will include also the roots, the time necessary to decontaminate the sludge could be reduced with 50-60 %. In addition, the change of floristic composition so that *Rumex* and *Solanum* genus are becoming dominant, could lead to a significant reducing of phytoremediation period.

Keywords: zinc, cadmium, pollution, phytoremediation, spontaneous flora

1. INTRODUCTION

Phytoremediation is a useful method for *in situ* decontamination of polluted land, which is remarkable by low costs, and organic and/or inorganic pollutants absorption efficiency, but also by a longer time to achieve the desired effect. Among the inorganic pollutants, heavy metals have been stand out because of their capacity to be accumulated in the plants organs of spontaneous or cultivated flora. There are plants from spontaneous flora, often highlighted by the literature, such as: *Thlaspi caerulescens, Arabidopsis halleri, Brassica juncea, B. napus oleifera,* cultivated plants as: *Helianthus annus, Glycine max, Rye grass,* or *Hydrilla* species for the wet lands (Ernst, 2005; Simeonova & Simeonov, 2006; Kapff et al., 2006; Mc. Grath et al., 2006; Gadepalle et al., 2008; Shuhe et al., 2008; Fässler et al., 2010). *Sedum plumbizincicola* proved to be particularly useful for phytoremediation (Jiang et al., 2010). Actually, over 400 plant species with heavy metals hyper-accumulation features are known (Baker, 1995, quoted by Del Rio et al., 2002; Brooks, et al, 1998 quoted by Shuhe et al, 2008). Among these, many plants of the spontaneous flora have been distinguished such as various species of *Agrostis: Agrostis capilaris* (Watkins & Macnair, 1991), *A. castellana* and *A. deliculata* (De Koe & Jaques, 1993; De Koe T., 1994; Garcia-Sanchez et al., 1996), and other species as: *Cynodon dactilon, Amaranthus hybridus, Bidnes cynapifolia* (Bech et al., 1997;

Jonnalagadda & Nenzon, 1997), *Verbascum blattaria* (Shallari et al., 1998), *Amaranthus blitoides* (Del Rio et al., 2002), *Arundo donax* (Papazoglou et al., 2007).

Many plants belonging to the spontaneous flora, although were proved to accumulate large heavy metals quantities, up to the toxicity level, did not becoming hyper-accumulators (Papazoglu et al., 2011). It has also been noticed that a series of bio-energetic plants, such as *Canabis sativa* and different species of *Lupinus* (*albus*, *lutens*, *augustifolius*) can be used for phytoremediation of land contaminated with certain heavy metals (Egilinez-Manninen et al., 2011). To the above list could be added *Perovskia atriplicifolia* originated in Central Asia, both ornamental and medicinal plant that has certain heavy metals hyper-accumulator properties (Djenbaev et al., 2006; Zamfirache et al., 2011). Different species of fast growing trees, such as numerous species of poplar (*Populus sp.*), willow (*Salix sp.*), or birch tree (*Betula sp.*) proved to be extremely useful in phytoremediation of the heavy metals polluted soils (Rugh et al., 1998; Meers et al., 2005; Tlustoš, et al., 2006). *Lolium perene* was revealed as a useful plant to test heavy metal soil pollution (Füleky & Barna, 2008), and some vegetables (lettuce, parsley, dill, carrots, radish) grown on heavy metals polluted soils have the ability to accumulate large amounts of heavy metals (Lăcătuşu & Lăcătuşu, 2008).

Besides phytoextraction, other phenomena take place such as phytostabilization, rhizofiltration or phytovolatilization (Raskin & Ensley, 2000).

Some researchers have highlighted the role of enzymatic metabolism processes even of transgenic plants in the absorption of pollutants by plants (Salt et al., 1995, Rugh et al., 1998, Dietz & Schnoor, 2001, Bennett et al., 2003). Also, were been highlighted limiting factors of absorption and the relations between plant extraction and agricultural technologies (Wei et al., 2008).

The present paper presents the absorption of heavy metals by some plants of the spontaneous flora grown on a mud pond with sludge proceeded from a wastewater treatment plant.

2. MATERIAL AND METHODS

The sludge proceeded from the Iaşi Municipality wastewater treatment plant has been stored, for ten years, between 1995 and 2006, in mud pond arranged on a calcareous salinised alluvial soil, within a 15 ha area (Figure 1).

After four years of mud pond closure, a study concerning the possibility of using spontaneous flora developed on the surface of sludge after evaporation of the liquid phase part was performed. This wild flora consisted mainly of *Phragmytes* species, predominantly *Phragmytes australis,* but also from other plant species such as *Rumex acetosela, Chenopodium album, Aster pannonicum, Solanum nigrum* etc.

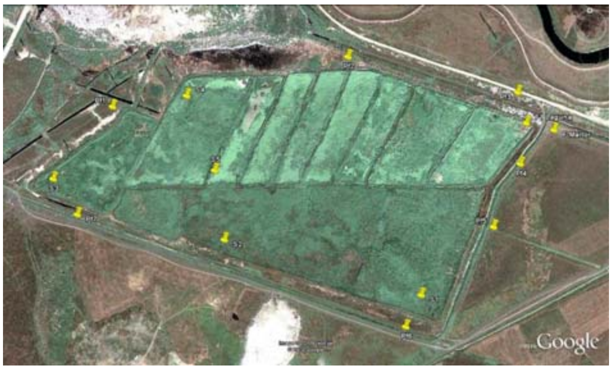

Figure 1. The localization of the mud pond of the Iaşi wastewater treatment plant and of the sampling points of sludge and vegetal material

From the mud pond precinct, sludge samples on geometric depths of 20 to 20 cm up to 40 cm depth and from a certain point up to 160 cm depth were collected.

Around each of sludge sampling point plant samples consisting of roots and aerial part were collected. Figure 1 shows the location of sampling points. Control samples were taken from a soil profile outside the mud pond.

General properties and the heavy metals contents of the samples were been analyzed in the laboratory. To assess the general characteristics following determinations were carried out: soil reaction by potentiometer measurement with a combined glass-calomel electrode; organic carbon content by Walkley-Black method modified by Gogoaşă; total nitrogen content by Kjeldahl method; total soluble salts contents by conductometric determination. Mobile forms of nitrogen (nitrates, NO_3^-), phosphorus and potassium (soluble in the ammonium-acetate-lactate solution at pH 3.7) were analyzed: potentiometer with ion selective electrode (nitrate) and by UVIS spectrometer (phosphorous) and flamphotometer (potassium).

The total content of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn) contents were measured by atomic absorption spectrometer in a hydrochloric solution resulted by digestion of samples in mineral acids (perchloric acid – $HClO_4$, nitric acid – HNO_3) mixture.

The heavy metals content in plants was carried out in hydrochloric solution resulted by solubilization of plant ash (obtained after several hours calcination at 450°C), using also the atomic absorption spectrometry.

Analytical methods are in accordance with national (STAS) and international (ISO) standards.

Analytical data were statistically calculated as spreading parameters (x_{min}, x_{max}, the coefficient of variation – cv%, the standard deviation – σ) and grouping parameters (arithmetic mean – $\overline{x}$, geometric mean – x_g). Correlations analysis was used to highlight the causal link between certain chemical compounds.

Transfer and bioaccumulation factors (TF and BAF) were computed in order to establish the transfer intensity of the heavy metals from soil to plants. The first represents the ratio between the chemical element's concentration in the roots and in sludge, and the second signifies the ratio between the chemical element's concentration in the whole plant (roots and aerial part) and in sludge.

The ratio of the chemical element content in the root and aerial part of plant was calculated and expressed as a root aerial part index (RAPI).

3. RESULTS AND DISCUSSIONS

3.1. General chemical characteristics of soil on that the mud pond was placed and of stored sludge

The sludge deposit has been located on a calcareous alluvial soil with a slightly alkaline reaction, a medium content of calcium carbonate, a small humus content, medium content of total nitrogen but low of nitrates, low content of mobile phosphorus, and high of mobile potassium. The soil is strongly naturally salinised, predominantly being the sulphates and bicarbonates (Table 1 and 2).

The sludge proceeded from the wastewater treatment plant also has an alkaline reaction, a medium content of calcium carbonate, high contents of organic carbon and total nitrogen, as well as mobile phosphorus and potassium contents.

Sulphates, both in soil samples and in sludge, namely, high, dominate the total content of soluble salts in descending order sulphates of calcium, magnesium and sodium (Table 2).

Therefore, the general chemical characteristics of the sludge and of the alluvial soil upon that was deposited sludge are close in terms of quality, but contrasting in terms of quantity.

3.2. The heavy metals content of the sludge and of the soil on that the mud pond has been placed

The statistical parameters of the total heavy metals contents of the alluvial soil on that the mud pond is placed reveal normal average values for cadmium (Cd), chrome (Cr), lead (Pb), slightly higher for cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), but very high for zinc (Zn). The high zinc values in soil are brought about by the sludge influence and the ground became polluted with zinc through vertical and horizontal diffusion. (Table 3).

The sludge is strongly polluted with cadmium, up to the maximum content 7.21 mg•kg^{-1} being by 24 times higher than the normal concentration of this chemical element in soil, by 1.4 times higher than the alarm threshold, value for a less sensitive land use, and then the intervention threshold for a sensitive land use. It is also by 2.4 times higher than the alarm threshold for a sensitive land use.

Table 1. General chemical features average values of the soil on which the mud pond is placed and of the sludge

Material	pH_{H_2O}	$CaCO_3$	$C_{org.}$	N_t*	U**	C/N	$N\text{-}NO_3$	P_{AL}***	K_{AL}
		%					mg·kg^{-1}		
Soil 0-100 cm	8.26 ± 0.21	6.6 ± 2.3	1.68 ± 0.68	0.141 ± 0.048	25.8 ± 7.12	13.4 ± 1.14	3 ± 1	13 ± 6	339 ± 94
Sludge 0-100 cm	7.38 ± 0.28	7.2 ± 2.4	13.0 ± 1.1	0.840 ± 0.145	128 ± 68	18.4 ± 2.3	66 ± 83	174 ± 88	404 ± 87

*) Total nitrogen
**) Moisture content dry basis (105ºC)
***) Recalculated values depending on soil reaction

Table 2. The average total content and percentage composition of soluble salts

Material	Total content	$Ca(HCO_3)_2$	$Mg(HCO_3)_2$	$NaHCO_3$	$CaSO_4$	$MgSO_4$	Na_2SO_4	NaCl	KCl
	mg·100g^{-1}								
Soil 0-100 cm	705 ± 700	26 ± 23	10	12	12.5	23	36	14	3
Sludge 0-100 cm	909 ± 130	4	-	-	38	35	16	5	2

Table 3. Statistic parameters of the total heavy metals content ($mg \cdot kg^{-1}$) of the soil on which the mud pond is placed and of the sludge, as compared to the normal values (NV) and to the values of the alarm threshold (AT) and intervention threshold (IT) for a less sensitive land use

Statistic parameter	Cd	Co	Cr	Cu	Mn	Ni	Pb	Zn
soil								
x_{min}	0.145	12.6	16.2	28.0	423	41.9	13	201
x_{max}	0.401	24.2	26.6	52.6	1398	74.4	22	510
$\overline{x}$	0.24	17.9	20.5	39	782	53	18	275
σ	0.08	3.4	3.7	7	310	8	2	107
cv (%)	33	19	18	18	39	16	41	39
x_g	0.23	15.8	19.3	36	776	50	17	269
sludge								
x_{min}	3.56	12.6	15.2	101	361	29.5	42.3	1057
x_{max}	7.21	18.3	38.4	152	1025	51.4	75.2	5455
$\overline{x}$	4.90	16.4	22.5	123	471	39.2	61.2	1905
σ	1.10	2.3	6.3	17	153	9.8	11.5	1425
cv (%)	22	14	28	14	32	25.0	19	75
x_g	4.87	15.3	22.0	121	470	37.8	60.5	1875
NC	0.30	5	30	20	500	20	15	50
AT	5.0	100	300	250	2000	200	250	700
IT	10.0	250	600	500	4000	500	1000	1500

The total zinc content in the sludge reaches 5455 $mg \cdot kg^{-1}$, 109 times higher than the normal soil content. The average value exceeds by 38 times the normal content, by 2.7 times the alarm threshold for a less sensitive land use, and by 1.3 times the intervention threshold for the same kind of use. For a sensitive land use, the average value would be by 6.4 times higher than the alarm threshold and by 3.2 times higher than the intervention threshold. It results that the sludge is heavily polluted with zinc and cadmium, thus its contents must be significantly reduced for an efficient use as source of nutritive elements.

The contents of the others heavy metals (cobalt, chromium, copper, manganese, nickel, lead, zinc) in sludge are, on an average, at higher concentration levels than the normal contents (3.2 times for cobalt; 6 times for copper; 1.9 times for nickel; and 4.1 times for lead). In some cases, slightly exceeding of the alert threshold for the sensitive land use, 1.2 times for copper and lead, were recorded. However, only Cd and Zn can be considered as highly polluting chemical elements, and as such, the sludge should be subject to a technology that could lead to reduce the quantities, particularly, of these elements.

3.3. The possibility to reduce heavy metals contents of sludge by phytoremediation

3.3.1. Heavy metals accumulation in Phragmytes australis **plants**

Although *Phragmytes australis* is not recognized as heavy metals hyper-accumulator plant, however, in an environment with significant abundance in such chemical elements, particularly by rhizomes, but also through the aerial part, it can absorb heavy metals at levels content much higher than normal. On the polluted land areas where *Phragmytes australis* prevails, this plant can be a storage media for heavy metals, and a way for the ground decontamination.

Table 4. The average contents ($mg \cdot kg^{-1}$) of heavy metals in roots and aerial parts of *Phragmytes australis* plants grown on the sludge from the mud pond as compared with the same species plants sampled from a nearest unpolluted area

Localization	Analyzed organ	Cd	Co	Cr	Cu	Mn	Ni	Pb	Zn
Mud pond	aerial part	7.5	5.4	5.5	9	73	2.1	9	473
	roots	31.0	6.3	3.9	20	97	5.1	3	869
Unpolluted area	aerial part	0.08	0.6	4.7	4	26	1	7	16
	roots	0.02	0.4	0.3	0.6	37	2	7	19
E.I.*	aerial part	*94*	*9.0*	*1.2*	*2.2*	*2.8*	*2.1*	*1.3*	*30*
	roots	*1550*	*16*	*19.5*	*33*	*2.6*	*2.5*	*3.2*	*45*

* The enrichment index of a plant grown on sludge as compared to other grown in an unpolluted area

Analytical data of heavy metal content of *Phragmytes australis* plants harvested from the mud pond with sludge from the municipal wastewater treatment plant, and the plants of the same species collected from an unpolluted area, considered as a control, clearly highlights this aspect. Thus, strongly polluting chemical elements Cd and Zn have been accumulated in the aerial part of *Phragmytes australis* up to concentrations of 94, respectively 30 times higher than normal, and in roots up to 1,550 times, and 45 times respectively (Table 4). Regarding the accumulation of other metallic elements, a slight tendency to increase, not significant, is observed, especially for copper, mainly in roots. The values of the transfer (TF) and bioaccumulation factors (BAF) are higher than one for cadmium and subunit for zinc (Table 5).

Table 5. The values of the transfer (TF) and Bioaccumulation (BAF) factors of cadmium and zinc

Plant nature		Cd	Zn
Aster panonicum	TF	4.49	0.69
	TF	5.00	0.57
Rumex acetosela	TF	20.8	1.95
	BAF	15.2	1.51
Chenopodium album	TF	13.4	1.13
	BAF	7.9	0.77
Solanum nigrum	TF	9.8	1.06
	BAF	9.6	0.81
Phragmytes australis	TF	6.3	0.45
	BAF	3.9	0.35

This means easily accumulation of cadmium in the rhizomes and the aerial part of plants, where Cd contents have become superior to those of sludge. Unlike cadmium, zinc has a much lower mobility, which leads to its concentration in sludge. Moreover, it can see the superiority of zinc accumulation in rhizomes as compared to the aerial part of plants. The statements above are reinforced by RAPI values specific to Cd and Zn for *Phragmytes australis* (Table 6).

The analyze of the ratio between the concentration of the main heavy metals in plants, and the sum of each element in the five genera and species of plants investigated, reveals that *Phragmytes australis* is stands in last place, in order of decreasing in the plant (Fig. 2). However, if we take into consideration that *Phragmytes australis* occupies approximately 90% of the mud pond surface, it means that this plant has a major role in absorbing heavy metals from sludge. Moreover, a botanically related plant, *Arundo donax*, proved to be able to accumulate high cadmium and nickel quantities without undergoing morphological and physiological changes (Papazoglou et al., 2007).

3.3.2. Heavy metals accumulation in other plant species grown on the mud pond

Apart from *Phragmytes australis,* on the edge of mud pond, also is found a consortium of grassy plants consisting of dominant species such as *Aster pannonicum, Rumex acetosela*, *Chenopodium album* and *Solanum nigrum.* These plants proved to be, in its turn, heavy metals accumulators, especially for cadmium and zinc. As seen from the data in table 7, the average contents of cadmium in the aerial part of these plant species range between 12 and 47 $mg \cdot kg^{-1}$, and in the roots between 22 and 102 $mg \cdot kg^{-1}$. Of the four plant species analyzed, is detached *Rumex acetosela* that accumulated large amounts of Cd both in the aerial part and in roots. In fact, we can see that this plant has accumulated, also, the biggest amount of zinc, both in the aerial part (2023 $mg \cdot kg^{-1}$) and in roots (3732 $mg \cdot kg^{-1}$). *Solanum nigrum* also stands out for the absorption of cadmium and zinc as well as *Chenopodium album* and *Aster pannonicum* for the absorption of high quantities of cadmium and zinc in their roots. Comparable data or even lower regarding accumulation of cadmium and zinc in other plants of the spontaneous flora can be found in papers of Del Rio et al. (2002), Papazoglou et al. (2007). All these plant species installed on the mud pond stand out by an enlarged capacity of iron accumulation in roots.

The other analyzed chemical elements (cobalt, chrome, copper, manganese, nickel, and lead) were found at normal levels of content. The phenomenon is mostly due to lower content of these chemical elements in the substrate consists of sludge proceeded from wastewater treatment plant. Another cause may be related to the weakly alkaline reaction of the sludge, which does not allow strong mobilization of these chemicals in the liquid phase of the substrate.

Table 6. The values of the root-aerial part index (RAPI) of the heavy metals

Plant nature	Cd	Co	Cr	Cu	Mn	Ni	Pb	Zn
Aster panonicum	1.23	1.05	5.10	0.63	0.76	0.35	0.67	0.65
Rumex acetosela	0.46	0.38	1.47	0.44	2.04	0.14	0.38	0.54
Chenopodium album	0.18	1.41	2.20	0.11	1.35	0.34	0.35	0.37
Solanum nigrum	0.96	0.55	0.70	1.22	2.76	0.58	0.47	0.52
Phragmytes australis	0.06	0.86	1.41	0.45	0.75	0.41	3.00	0.54

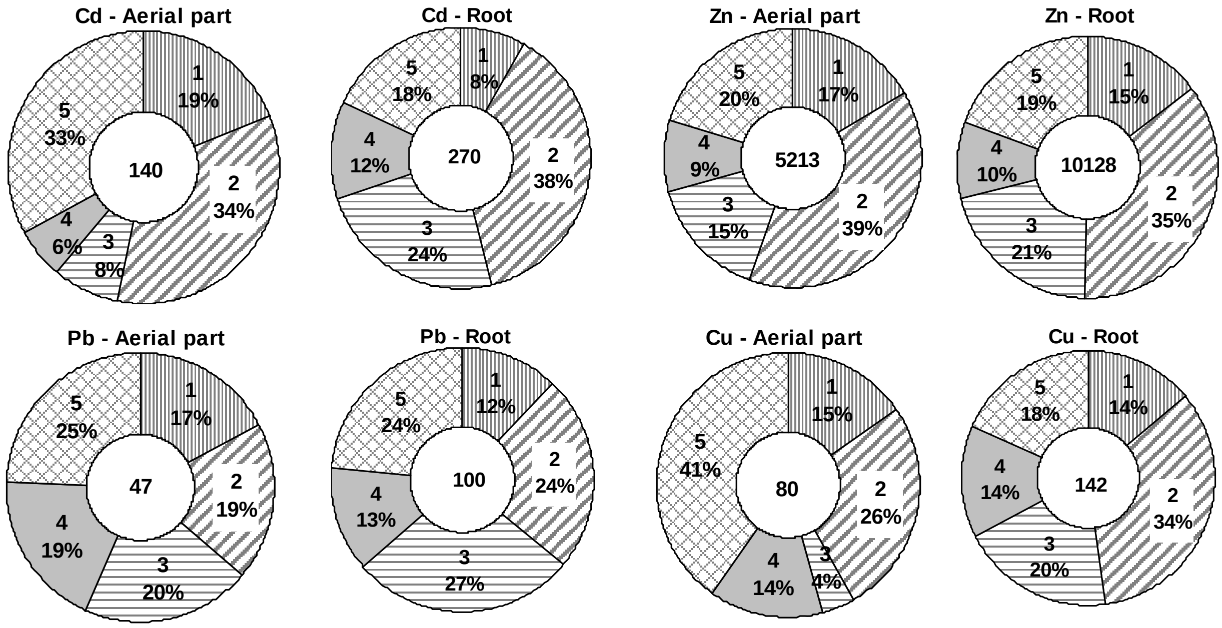

Figure 2. Percentage distribution of the heavy metals contents of the plants grown on the sewage sludge pond from the wastewater treatment plant of Iaşi, related to total heavy metal total ($mg \cdot kg^{-1}$) accumulated in plants: **1.** *Aster panonicum*, **2.** *Rumex acetosela*, **3.** *Chenopodium album*, **4.** *Phragmytes australis*, **5.** *Solanum nigrum*

Table 7. The average heavy metals content ($mg \cdot kg^{-1}$) in the aerial part and in the roots of different plant species of the spontaneous flora developed on the sludge proceeded from the Iaşi wastewater treatment plant

Plant species	Analyzed organ	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Aster panonicum	aerial part	27 ± 65	6,2 ± 0,4	4,1 ± 0,8	12 ± 5,8	372 ± 125	127 ± 11	2,9 ± 0,7	8 ± 0,3	860 ± 534
	root	22 ± 18	5,9 ± 2,4	0,8 ± 0,1	19 ± 1,6	4140 ± 567	166 ± 118	8,3 ± 3,1	12 ± 4,0	1318 ± 356
Rumex acetosela	aerial part	47 ± 22	2,9 ± 1,4	5,3 ± 3,1	21 ± 8,7	524 ± 86	290 ± 72	2,2 ± 0,7	9,1 ± 1,2	2023 ± 615
	root	102 ± 47	7,6 ± 2,1	3,6 ± 1,4	48 ± 9,4	7026 ± 2006	142 ± 67	15,3 ± 4,8	24 ± 4,2	3732 ± 3000
Chenopodium album	aerial part	12 ± 8	4,8 ± 0,1	1,1 ± 0,2	3,2 ± 1,5	389 ± 206	111 ± 126	2,8 ± 1,7	9,6 ± 1,4	794 ± 167
	root	66 ± 27	3,4 ± 2,5	0,5 ± 0,3	28 ± 19	4471 ± 3471	82 ± 50	8,2 ± 6,6	27 ± 3,9	2148 ± 1785
Solanum nigrum	aerial part	46	3,9	9,97	32,1	1262	384	4,33	11,3	1063
	root	48	7,1	14,2	26,1	4094	139	7,35	23,7	2026

The values of the transfer (TF) and bioaccumulation factors (BAF) of cadmium and zinc (Table 5) are entirely higher than one for cadmium and in minority for zinc. Among the investigated plants, are detached *Rumex acetosela, Chenopodium album* and *Solanum nigrum* with values for cadmium higher than one, but large, for both factors, and lower values, but predominantly higher than one for Zn. These values show that the analyzed plants have capacity to transfer this two polluting elements from sludge into roots and in the entire plant. *Aster pannonicum* accumulates more cadmium from the sludge than zinc (Table 5).

The transfer of heavy metals from roots into the aerial part is done with increased speed especially in the case of chromium and manganese. *Aster panonicum* and *Chenopodium album* stand out for chromium, *Solanum nigrum* and *Rumex acetosela* for manganese and, however surprising, *Phragmytes australis* for lead (Table 7)

3.3.3. Correlations between the heavy metals contents in sludge and flora grown on the mud pond surface

Direct proportionality relations statistically ensured between the cadmium and zinc total contents of the sludge and of the flora grown on the sludge mud pond were established (Fig. 3). The lowest values of the two chemical elements in sludge and plants are belonging to *Phragmytes australis* and *Chenopodium album* species, the highest ones to *Rumex acetosela* and *Solanum nigrum*, while the *Aster panonicum* values have a median position in the soil-plant system correlations.

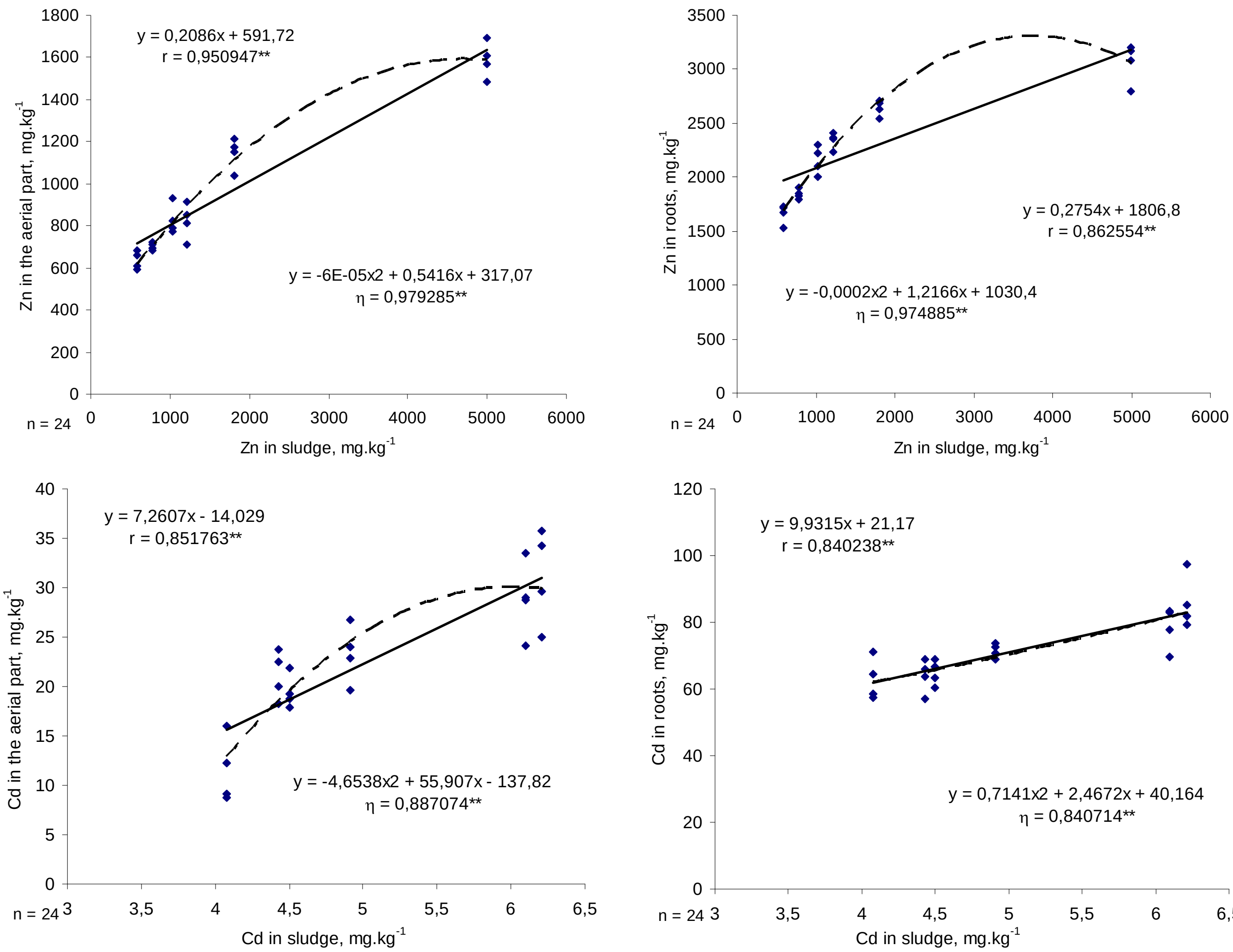

Figure 3. Correlations between heavy metals contents in the sludge and in the flora grown on the mud pond

When comparing the start values of correlations for Cd, it could find that the minimum values recorded in sludge are 13.3 times higher, and those maximum 22 times higher than normal. In the roots of plants from spontaneous flora analyzed by us were recorded minimum contents of Cd, but that exceeding about 60 times the normal content and in the aerial part about 14 times.

By contrast, maximum values, outlined by lines and regression curves are 21 times higher in sludge, 70 times in roots and 28 times in the aerial parts of plants.

Similarly, the values recorded for Zn in the sludge are 5.9 times higher than, those usual in soil, while those of roots and the aerial part is 15 times, respectively 6.7 times higher than in equivalent organs of the same plants grown under normal conditions.

Unlike these, the maximum zinc values registered in the framework of the correlations between sludge and plant (roots and aerial part) are 50, 33, respectively 18 times higher than the normal values.

The higher cadmium mobility as compared to the zinc's is also revealed by the fact that higher cadmium quantities, as reported to the normal values, are accumulate in plants than in the sludge they grow on, while for Zn the phenomenon is reversed.

Taking into account: the quantities of significant polluting heavy metals (cadmium and zinc) accumulated in the aerial part of the spontaneous flora developed on the mud pond, the surface covered by each of different plant species, contrasting as heavy metals - accumulators potential, the annual harvesting, we could assess that almost 450 years would be necessary to reach a normal polluting heavy metals level in the sludge.

If the plants' roots, also, would be extracted this period could be reduced by 50-60%. The needed time for sludge phytoremediation could, also, be reduced by changing the composition of flora so that the heavy metals accumulators (*Rumex* or *Solanum* species) becoming dominant. Comparable values of period necessary for Cd and Zn phytoextraction have been obtained Felix (1997), Knight et al., (1997), Robinson et al., (1998).

Over the years, through the mineralization of plant debris and native content of mineral elements, sludge could turn into a fertile material with a high potential for various other plants, including the cultivated ones.

4. CONCLUSIONS

The sludge proceeded from the Iași Municipality wastewater treatment plant has polluting contents of cadmium and zinc, with values up to 7.21 mg·kg^{-1}, respectively 5455 mg·kg^{-1}.

The sludge storage in a mud pond without impermeable bed has contributed to the pollution of soil on that is placed, both vertically and horizontally.

On the mud pond, a spontaneous flora has been installed, that is consisting predominantly of *Phragmytes australis*, representing the dominant species, *Aster pannonicum, Rumex acetosela, Chenopodium album, Solanum nigrum*, and others.

In the aerial part of these plants developed on the mud pond have been accumulated amounts of 140 mg kg^{-1} Cu and of 5213 mg·kg^{-1} Zn, and 270 mg ·kg^{-1} Cd and 10128 mg kg^{-1} Zn in roots.

The values of the transfer (TF) and bioaccumulation (BAF) factors highlight the studied plants properties to accumulate heavy metals from sludge.

The translocation of heavy metals from roots toward the aerial part of the plants is done with increased speed for chromium in *Aster pannonicum* and *Chenopodium album* and in the case of manganese in *Solanum nigrum* and *Rumex acetosela*.

Depending on the amount of heavy metals accumulated in plants and the total quantity of these chemicals elements accumulated in dominant species, plants can be in series, in descending order as follows: *Rumex acetosela, Solanum nigrum, Chenopodium album*, *Aster pannonicum* and *Phragmytes australis.*

Applying the phytoextraction of pollutant heavy metals using plants from spontaneous flora installed on mud pond, using only aerial part of the plant would lead to a time required to achieve normal heavy metal content in sludge for nearly 450 years. If the plants' roots would be also extracted this period could be reduced by 50-60%. The needed time for sludge phytoremediation also, could be significantly reduced by changing the composition of flora, so that the heavy metals accumulators belong to *Rumex* or *Solanum* should become dominants.

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