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Transfert heavy metal sewage sludge as fertilizer from soil to ray grass

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Abstract.

The land application of sewage sludge reveals a significant increase in the dray matter production of Ray Grass. In equivalent dose of liquid sludge, we registered a lower production of dry material. Besides, neither the dose nor the type of sludge seems to have an effect on the heavy metals contents in the air part plant. On the other hand, the contribution of sludge under dry or liquid forms increases significantly heavy metals contents in roots with regard to the witness without sludge.

The comparison between the beginning and the end of culture, revealed a decrease heavy metals contents in the soil in particular at the horizon 0-40 cm deep. Besides, this decrease Cd, Zn, Pb and Cu contents in the soil is not linking to transfert from soil to air part of plant, but rather is the accumulation in the roots, which play the role of a barrier.

Keywords:

Heavy metals, transfer, soil, Ray Grass, sewage sludge.

Introduction

The contamination of soil by heavy metals is a major environmental problem for two reasons. Firstly, it presents an ecotoxicology risk for food chains because of the strongly toxic properties of these elements for all the human beings. Secondly, this contamination can have very long-term effects because elements in tracks present generally a strong chemical and physical affinity for the solid matrix of soil and have a residence time in soil very long (Echevarria and More, 2006).

The assessment of risks associated to the soil pollution requires, not only knowledge of the total content in metal, but also the content in metal in the various constituent compartments of the soil (Jeans, 2007).

The heavy metals are unwanted constituents of the urban sewage sludge. As some of them are potentially toxic and present no agronomic interest, their presences generate a certain concern, perfectly understandable when it is about spread this waste on soils intended to produce food for the Man or the animals (Kiss, 2006).

The agricultural use of the residual sludge allows the recycling of precious components such as the organic matter and many nourishing elements of the plant (Logan and Harrison, 1995). It aims at arranging natural resources and at avoiding any wasting of organic matter due to the incineration or to the burying in the discharges (Lambkin *et al.*, 2004), residual sludge can replace or reduce the use of expensive fertilizers.

Sludge is a product susceptible to supply in the cultures of the nourishing elements useful for their growth and for their development. Furthermore, certain sewage sludge (composted or limed) can play the role of amendment by allowing maintaining, to improve the structure of the soil, its biological activity or still control soil its acidity. Nevertheless, from an agronomic point of view, and if the farmer respects the agronomic advice, the economy on the purchases of fertilizers can be considerable. The most popular elements are mainly the phosphor and the nitrogen. Savings are easily estimable for the elements, which are fixing by the soil

(phosphor or lime). For the nitrogen, savings are more difficult to amount because the availability depends on weather conditions, which determine the mineralization (passage of the organic shape towards the mineral shape) (Atlan, 2003).
The factors bound to the physiological behavior of plants also play an important role in the bioavailability of heavy metals. The influence of the organ of the plant (heavy metals are essentially absorbed in roots and much less in edible parts), the species, the variety (plants with fast growth are more accumulate) and the phenomena of antagonism and synergy between the various mineral elements of sludge (Juste *et al.*, 1995).

Material and methods

The soil of the try is sandy-clayey, an alkaline pH (7.50 - 8.31), an electric conductivity from 0.42 to 0.89 ms/cm what indicates a low of salinity bound to the sandy nature of the soil and a low content in total limestone (5 %) and in organic matter (0.39 % to 1.98 %). Besides, we note a better composition in organic matter, N and P in the superficial horizon (0-20 cm) compared with the other horizons (20-40) and (40-60) (Table 1).

Parameters	0-20 cm	20-40 cm	40-60 cm
pH	8,03	8,18	8,06
CE (ms/cm)	0,61	0,58	0,70
MO (%)	1,58	1,07	0,65
Total limestone (%)	1,12	2,12	2,28
N (%)	0,05	0,04	0,03
Heavy metals (mg/kg)			
Mn	136.50	125.00	107.40
Pb	34.40	29.80	28.40
Cd	2.06	1.72	1.23
Co	3.47	3.72	2.77
Cu	10.25	8.75	4.00
Fe	5337.00	7000.00	4638.00
Zn	22.50	21.70	17.90
Ni	14.07	13.10	11.20

Table 1: Characteristics of the various horizons of the soil

Parameters	Dry sludge	Liquid sludge
pH	6.46	6.30
Humidity (%)	33.30	95.40
CE (ms/cm)	6.95	6.17
MO (% MS)	40.20	94,00
N (% MS)	3.35	5.80
C/N	8.56	7.94
Heavy metals (mg/kg of dries matter)		
Mn	349	108
Pb	135	393
Cd	22	28
Cu	206	413
Fe	6954	9456
Zn	331	848
Ni	30	347

Table 2: The sewage sludge characteristic

We used sewage sludge of the KORBA water-treatment plant. The sludge stemming from this station have sudden a stabilization in aerobe followed by a drying on beds. The analysis of both chaps of sludge (liquid and dry) shows that they are very different by their chemical compositions. The pH is acid and their electric conductivities translate an important salinity.

Concerning heavy metals, the Fe and Zn are the most represented. The average contents found in dry sludge are organizing according to the following sequence:

Fe >>Mn> Zn > Cu >Pb> Ni > Cd > Co.

The average contents of heavy metals brought by sludge are representing on the Table 2. Provide sufficient detail to allow the work to be reproducing, with details of supplier and catalogue number when appropriate. Methods already published should be indicate by a reference: only relevant modifications should be described.
The plant material used in our experiment is the English Ray Grass (*Lolium perenne*). In this study, we made five successive cuttings at the bolting stage, at 3 cm of the surface of the soil, at the interval of one month.
Five treatments are realizing for this experiment. Besides the treatment control soil, four treatments including two types of sludge, a dry sludge and a liquid sludge (thickened sludge) brought each there two doses (5 and 10t/ha) were applied in four repetitions:

Treatment T: Control soil without contributions of sludge.
Treatment 5 BS: Contribution of dry sludge 5 t/ha, equivalent of 0.5kg/m².
Treatment 10 BS: Contribution of dry sludge 10 t/ha, equivalent of 1 kg/m².
Treatment 10 BL: Contribution of liquid sludge 10 t/ha, equivalent of 1 l/m².
Treatment 5 BL: Contribution of liquid sludge 5 t/ha, equivalent of 0.5 l/m².

Results and discussion

For the same applied dose, dry matter production was higher with dry mud (Figure 1). Slurries with a leaching loss of an amount of nitrogen provided by the sludge are likely. The contribution of 5t/ha liquid sludge's had no significant effect on the production of dry material, while the dose 10 t/ha is accompanied by a significant increase of the production of the dry material compared with the control soil without contribution of sludge.
This increase of the production of material dry registered with treatments sludge is probably the result of the contribution by sludge of essential nourishing elements for the growth of the plant, such as the nitrogen and the phosphor. For the same applied dose, the production of dry material is more raising with the dry sludge. With liquid sludge, a loss by lixiviation of a quantity of nitrogen brought by sludge is probable. The comparison between both types of sludge shows that the contribution of 10t/ha liquid sludge is equivalent to the contribution of 5t/ha dry sludge from point of view effect on dry matter production.
The contribution of liquid sludge has not positive effect on the production of roots (Table 3). However, the weight of roots is increase with dry sludge. We also note a significant effect of the dose of dry sludge on the weight roots. The concentration of diverse heavy metals measured in the air parts of the Ray Grass expressed this evolution.
We note absence of effect measures of sludge on the content in Zn of the plant (Figure 2). Besides, the comparison between cuttings shows a significant increase of the content in Zn obtained with cuttings four and five as well for the dry sludge as the liquid sludge. This increase is linking to a competition between Zn and Cd.

Treatments	MS (g/m²)
Control soil	19 680
5t/ha BL	24 000
10 t/ha BS	51 540
5t/ha BS	33 700
10 t/ha BL	32 120

Table 3: Effect of liquid (BL) and dry (BS) sludge on the production of root.

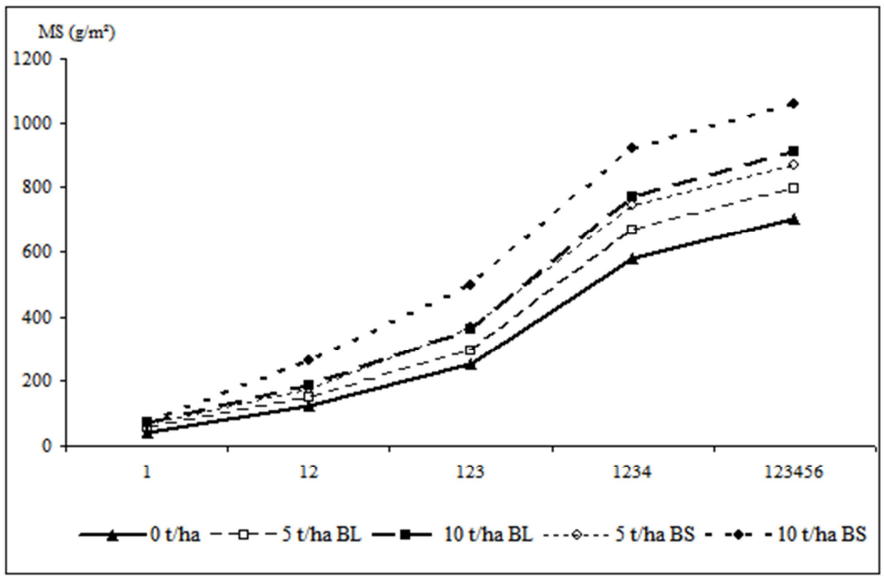

Figure 1: Evolution of the production accumulated by dry material (MS) of the air part according to the various doses of (BL) liquid and (BS) dry sludge.

The Cd contents of the dose of sludge have not any effect of the air part of the Ray Grass. For dry sludge, the contents tend to increase with the contribution of sludge 10 t/ha dose for the first three cuttings. We observed no effect of the dose or the type of sludge on the content in Cu of the air part of the Ray Grass and of the dose or the type of sludge on the content in Cu of the air part of the Ray Grass.

The average Pb contents oscillate around 8 µg/g. These values situated below threshold of toxicity of vegetables (30 µg/g). The sampling of roots realized further to the last cutting of the ray fat. The contribution of sludge increases significantly the content in Zn, Cd and Pb in roots (Table 4) compared with the control soil sample without any contribution. However, the Pb and Cd a significant effect of the dose indicated in roots as well for liquid sludge as for dry sludge.

Accumulation of heavy metals in the soil: The analysis of the soil realized after the last cutting of the Ray Grass (Figure 3), shows a significant decrease of the content of the Zn in the superficial horizon of the soil (0-20 cm) for both doses and both types of brought sludge.

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As for the deeper horizon (20-40 and 40-60 cm), no significant effect of the dose of dry sludge was noticed on the content of Zn in the soil between the beginning of the try and after the last cutting.

Treatments	Zn	Pb	Cu	Cd
Control soil	68,6	13,9	19,8	1,3
5t/ha BL	101,4	14,1	22,6	2,1
10 t/ha BS	113,1	15,7	24,3	2,5
5t/ha BS	99,6	15,9	25,7	2,1
10 t/ha BL	103,7	17,5	25,7	2,7

Table 4: The variation of Pb, Cd, Cu and Zn Fe and Mn contents (mg/kg) in the roots linked with different dose of liquid (BL) and dry (BS) sludge treatment.

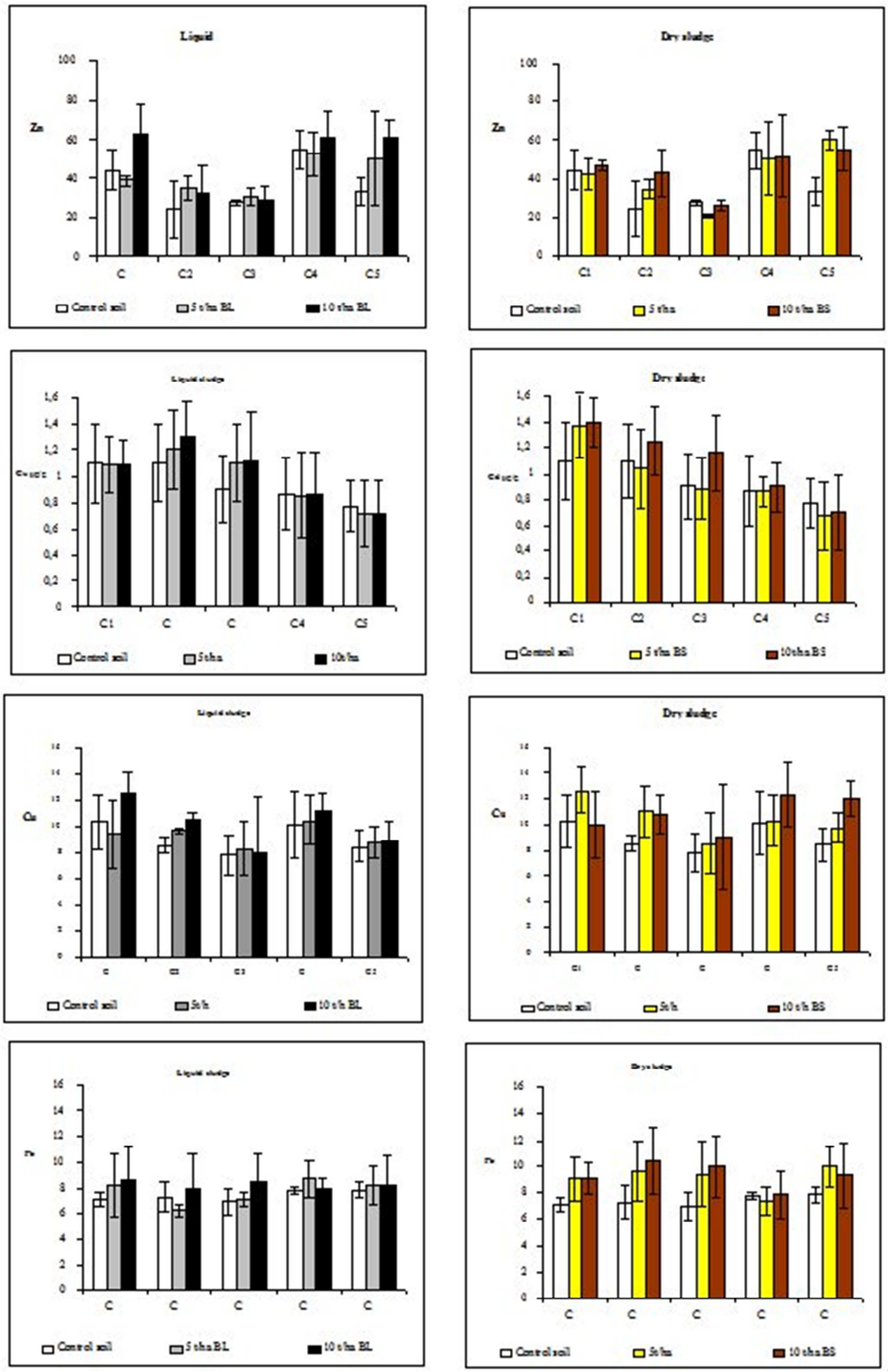

Figure 2: Variation according to the time of the accumulation of Cd, Zn, Cu and Pb (mg/kg) to the plants of Ray Grass cultivated in the presence of the increasing doses of liquid and dry sludge.

However, for the liquid sludge in particular for the dose 10t/ha the content of Zn tends to decrease between the beginning and the end of the try. For the Pb, we note a significant

decrease of the content in Pb of the soil between the beginning and the end of the try in the superficial horizon. This decrease noticed also in the deeper soil horizon (20-40 and 40-60 cm).

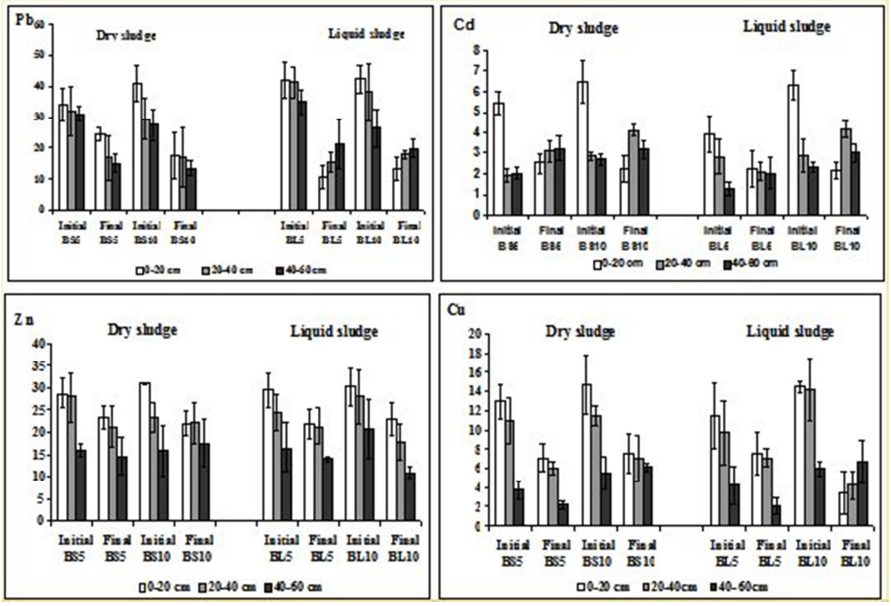

Figure 3: Comparison of Pb, Cd, Zn and Cu contents (mg/kg) in the soil before and after the last cutting of the Ray Grass.

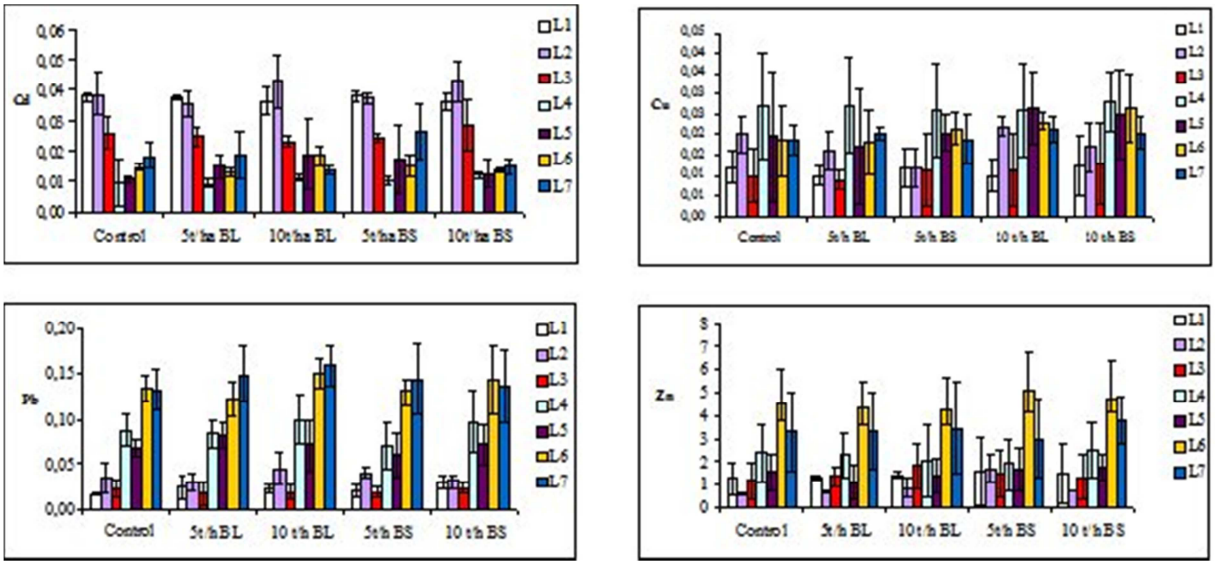

Figure 4: Cd, Zn, Pb and Cu contents (mg/kg) in waters of drainage during the growth of the Ray Grass.

Accumulation of heavy metals in the water of drainage – In this part, we use the analysis of the water leaving the lysimeter boxes for the different treatments in order to explore the possibility of migration of tracks elements to the water. The analysis of drainage water showed for various sludge treatments (Table 4) that the levels are not significantly different from control soil treatment. This suggests that the Cd, Zn, Cu and Pb retained rather in the soil.

The spreading of liquid and dry sludge resulted in an increase in the production of biomass Ray Grass. This increase is a function of increasing sludge doses applied. This the positive effect of sludge on yield found in other cultures. Indeed, many authors [MOREL and GUCKERT, 1979; LARRY, 1981; REJEB and BAHRI, 1995; REJEB *et al.*, 2003] reported a

significant increase in yields of various crops such as sorghum, corn, chili, potato. Our tests also showed a better performance with dry and liquid sludge with the year of application.
This could also be the result of a share of a probable loss of nitrate made in slurries and other wealth of the sludge brought dry matter. In fact, the dry matter content from the sludge is variable about 5% and 67% in the slurry and dry sludge respectively.
Moreover, the contribution of sludge caused heavy metals enrichment soil and more particularly to the horizon (0-20 cm). However, this increase is not significant except for Cd content, which has indeed increased, significantly in the presence of sludge. In the lower horizon soil (20-40 and 40-60 cm), the Pb, Zn, and Cu contents remained equivalent to the control soil. Regarding the accumulation of heavy metals in the plant, our results showed that the contents of Cd, Pb, Zn, and Cu in the aerial part of the plant does not vary with the addition of 5 and 10 t/ha of dry or liquid sludge. These results are in agreement with those of [BERTHET *et al.*, 1983] who studied the evolution of the levels of Pb in tissues of Ray Grass, subject to three types of treatment (control soil without mineral fertilizer and sludge amendment).
They showed that there is no significant difference between the mean levels of Pb in different crops Ray Grass, from different treatments of the same culture series, performed on the same date. They found the same effect for Zn [BERTHET *et al.*, 1984]. By cons, other studies have shown that Zn absorbed easily by plants [JUSTE and SOLDA, 1977; CHANG *et al.*, 1983; REJEB, 1999] and that this absorption could Pb to a significant increase in the content in the seed [JUSTE and SOLDA, 1977, CHANG *et al.*, 1983].
For Cu, no dose sludge effects observed in the Ray Grass. According to our experiments, the concentrations of Cu ranged between 4 and 15 mg/kg in the leaves of Ray Grass. These contents are by [REUTER and ROBINSON, 1997] for optimal growth. According to the same authors, the toxicity threshold reached in Cu from a Cu concentration of 15 to 30 mg/kg DM in the leaves of crops. However, the Cu content in the plant can reach a critical concentration variable, depending on the plant species from which appear symptoms of phytotoxicity [MARSCHNER, 1995]. A slight accumulation of Zn in the roots of Ray Grass observed for both types of sludge. The Pb content is increasing with 10t/ha doses of liquid and dry sludge. The Cd increased in roots with the addition of sludge and function of the applied dose. Various studies have shown an accumulation of Cd into the roots of certain plants [CARLSON, 1991], or in the leaves of other species [KIM *et al.*, 1988].
The flow heavy metals made by urban sludge are very low on the scale of a year and their accumulation does not represent a risk to the environment if the prescribed conditions are met [MAISONNAVE *et al.*, 2003]. However, the accumulation of heavy metals depends on the plant species. In addition, the response of plants to metals in sludge also varies depending on the elements. In early try, Pb testing shows that there is no significant difference in the surface horizon soil (0-20 cm) compared to control soil any dose given 5t/ha or 10 t/ha for both types of sludge. Yet at the end of the trial, the Pb contents are a significant decrease for all treatments with a more pronounced decrease Pb contents in horizon soil (20-40 cm) receiving liquid or dry sludge.
From application of sludge containing heavy metals results a very significant increase heavy metals contents in surface horizon soil [LEGRET, 1988] and in particular the horizon (0-20 cm). The displacement of Pb in soil stopped at horizon (20-40cm). The Pb is associated with acid phases–soluble and reducible; it not moved into horizon soil 20-40 cm. In case of application of dry sludge and slurry, the Cu contents in the horizons (0-20 cm) and (20-40 cm) show a significant decrease in the soil at the end of Culture.
However, the horizon soil (40-60 cm) has not the chemical effect. The mobility of Cu in soil is defining as the ability of this element to transfer to the horizon soil where it is less strongly retaining. The deep horizon soil is representing by the solution into the soil, which the Cu is immediately available to plants [JUSTE *et al.*, 1995]. The Cu added distributed in two forms, a liquid phase and a liquid phase. The Cu contents in the solution into the soil are generally very low.
At the end of culture, with both types of sludge tested, we observed a significant decrease in the content of Cd in the surface layer (0-20 cm), increased levels of Cd in the layer (20-40 cm) and a slight increase in levels of the layer (40-60 cm).

In this work, analysis of drainage showed that the addition of increasing doses (5t/ha and 10t/ha) liquid and dry sludge has no significant effect on the levels of Zn, Cd, Pb and Cu in lixivia; these levels are negligible and similar to the witness.

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References

Atlan M. Guy., Les boues d'épuration et leurs perspectives de gestion en île de France. In : agriculture, environnement, ruralité (CESR), 2003, pp. 14

Baize Denis., Christian Courbe., Olivier Suc., Christophe Schwartz., Martine Tercé., Antonio Bispo., Thibault Sterckman., Henri Ciesielski, Épandages de boues d'épuration urbaines sur des terres agricoles : impacts sur la composition en éléments en tracesdes sols et des grains de blé tendre. In : Courrier de l'environnement de l'INRA n°53. 2006, pp. 29.

Berthet. B., Amiard-triquet C., Metayer C., et Amiard J. C., Etude des voles de transfert du plomb del'environnement aux végétaux cultivées;application a l'utilisation agricole de boues desstations d'épuration.water, air, and soil pollution 21, 1983, pp. 447-460.

Berthet B., Amiard J. C, Amiard-triquet C. et Metayer C., Etude expérimentale de la relation entrela forme physicochimique du Zn et sa disponibilité à l'égard de végétaux cultivés. Application à l'utilisation agricole de boues de stations d'épuration. Hant and Soil 82, 1984, pp. 231.

Carlson A.R., Phipps G.L., Mattson V.R., Kosian P.A. and Cotter A.M., The role of AVS in determining Cd bioavailability and toxicity in freshwater sediments.Environ ToxicolChem, 10, 1991, pp. 109-131.

Chang A. C., Page A. L., Warneke J. E., Resketo M. R. ., Jones T. E., Accumulation of Cd and Zn in barley grown on sludge-treated soils: a longterm field study.J. Environments Quality. 12, 1983, pp. 391-397.

Echevarria Guillaume., Morel Jean-Louis., Caractérisation de la biodisponibilité des éléments en traces dans les sols et validation de mesures fiables. Sols et environnement. Vandœuvre-lès-Nancy., 2006, pp 57.

Gukert A., Morel J L., Billon de cinq années d'utilisation de boues résiduaires urbaines sur plantes de grande culture dans les conditions agro-climatiques lorraines.Frist European symposium of traitemant and use of sewage sludge Ed Alexendre Detott H, 1979, pp. 269-282.

Jean Liliane., Mobilisation du chrome et du Ni à partir de sols contaminés, en présence de complexant : Transfert et accumulation de ces métaux chez Datura innoxia. Thèse de doctorat, Université de limoge. 2007, p. 187.

Juste C., Les micro-polluants métalliques dans les boues résiduaires des stations d'épuration urbaines. Convention ADEME-INRA, ADEME éd., 1995, pp. 209.

Juste C. et Solda P., Effets d'applications massives de boues de stations d'épuration urbaines en monoculture de maïs : actions sur le rendement et la composition des plantes et sur quelques caractéristiques du sol. Sciences du sol. Bull. A.F.E.S 3, 1977, pp. 147-155.

Kim S.J., Chang A.C., Page A.L. and Warneke J.E., Relative concentrations of Cd and Zn in tissue selected food plants grown on sludge-treated soils. J Environ Quality, 17, 2, 1988, pp. 239-246.

Lambkin, D., Nortcliff, S., White, T., The importance of precision in sampling sludges, biowastes and treated soils. In a regulatory framework Trends in Analytical Chemistry, 23, 2004, pp. 10-11.

Larry D K., Interaction chimique pour l'élévation de la biodisponibilité des métaux en traces du sol. Agronomie, 16, 1981, pp. 201-215.

Legret., M, Divet. L ., Juste.C . Migration et spéciation des métaux lourds dans un sol soumis à des épandages de boues de station d'épuration à très forte charge en Cd et Ni .War. Res. Vol. 22, No. 8. 1988, pp. 953-959.

Logan, T.J., Harrison, B.J., Physical characteristics of alkaline stabilized sewage sludge (N-vitro soil) and their effects on soil properties. J. Environ. Quality. 24, 1995, pp. 153-164.
Maisonnave V. ; Bonnin Ch. ; Vignoles M. ; Revel J. C. ; Patria L., Impact des épandages de boues sur la teneur en éléments traces métalliques dans un sol et un végétal .In Techniques sciences méthodes, génie urbain génie rural, 4, 2003, pp. 41-49.
Marschner H., Mineral Nutrition of Higher Plants. In: Academicpress, London. 1995, pp. 69-75.
Rejeb. S ,Effet des eaux usées et des boues résiduaires sur la croissance et la composition chimique de quelques espèces végétales .Thèse de doctorat, Faculté des sciences de Tunis, 1990, p. 230.
Rejeb S et Bahri A , Incidence de l'apport de boues résiduaires urbaines sur la composition minérales et la productivité de quelques espèces cultivées en Tunisie. Les Cahiers de CRGR. 24, 1995, p. 13-32.
Rejeb. S ; Khelil M.N ; Gharbi .F Ghorbal M. H., Effet des boues urbaines sur la production dela pomme de terre, FRANCE, vol. 12, no1, 2003, p. 39-42.