Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 6, No. 6, p. 115-124, 2015
http://www.innspub.net

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RESEARCH PAPER

OPEN ACCESS

Effect of urban treated sewage sludge on concentration of lead and cadmium in parsley and its soil

E. Nikzad[1], M. Kalbasi[1], M. Hoodaji[1], J. Fallahzade[2]

[1]*Department of Soil science, Faculty of Agriculture, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran*

[4]*Young Researchers and Elite Club, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran*

Article published on June 08, 2015

Key words: Sewage sludge, Lead, Cadmium, Parsley.

Abstract

Using sewage sludge, as fertilizer, in farmlands has been very prevalent. It is rich in plants nutrients but its heavy metals high concentration leads to contamination of soil, plants and food chain jeopardizing the human and animals' health. This study aimed to examine the effect of using urban sewage sludge on concentration of lead and cadmium in parsley and its soil. It was done in the form of a completely randomized factorial experiment with six levels of sewage sludge and three replications in a greenhouse. The amounts of 0, 1, 2, 4, 8, and 16 percent of the soil dry weight of the sewage sludge were added to the pots having soil of three areas namely Baharan, Najvan and Shakrekord. Next, the parsley transplants were planted in the vases. Having reached to the 4-5 leaf-stages, the plants were harvested and each vases soil and plant was analyzed. Application of sewage sludge decreased soil pH and at the same time increased and electrical conductivity in soils. Generally decrease and increase was proportional to the sewage sludge application rates. Sewage sludge application of increased the soil total and available lead and cadmium concentration significantly. In most cases, the amount of increase was proportional in with the sludge amount. Using the sewage sludge had a significant effect on concentration of lead and cadmium, and increased their concentration in parsley and enhanced its yield.

***Corresponding Author:** E. Nikzad ✉ e_n200060@yahoo.com

Introduction

One of the most essential principles of sustainable agriculture is keeping the optimum amount of the soil organic matters Afyuni *et al.* (1998). Therefore, they should always be added to soil areas with low organic matter. Organic matters are considered as soil supplementary components and as important factors of soil fertility because of their constructive effects on its physical, chemical and biological characteristics. However, more than 60 percent of Iran soil enjoys less than one percent of organic matter Hosseinpour and Ghajar Sepanlou (2013). Mohsenpour *et al.* (2015) showed that the amounts of plant biochemistry properties were decreased in all polluted samples with heavy metals. According to the Iranian per capita vegetable consumption in their diet and the high cultivation level of vegetables, management of the organic fertilizers consumption, e.g. sewage sludge, in planting the vegetables is of great importance. High amounts of heavy metals in sewage sludge, it can be problematic and leads to excessive accumulation of heavy metals in soil and plant. Contamination of soil to lead and cadmium transfers them to food chain and makes toxicity Chang *et al.* (1998). Cadmium is one of the heavy metals whose lowest absorption by human is hazardous. Its negative effects on soil biological activities, plant metabolism and human and animal caused that its behavior is studied by several researches Stoeppler (1991). Some believe that significant increase of weaken-transplanted and exchangeable cadmium in soils received sludge has an effect on the plan availability (Kabata-Pendias and Pendias, 2000). Lead is a non-dynamic element and its transfer to soil and plant organs are very trivial. Although lead has been known as one of the low-movement elements, if having the in-environment solution forms, the plants roots can absorb a high rate of water .Some factors including low pH, the soil low phosphor concentration and abundant of organic ligands have been known as the factor of increasing the absorption of lead by plants and transferring it to the plants aerial organs. Its entrance to food cycle is mostly under the effect of human activities. In addition, using sludge and sewages having lead in agricultural products causes that they are contaminated to lead. The research presented by researchers revealed the lead intense connection with clay mineral, iron and manganese oxides, aluminum hydroxides and organic matters, although lead may connect to articles of calcium carbonate or phosphate in some soils. According to American environment report, using sewage sludge can result in increase of concentration of lead, nickel, cadmium and copper 100 fold of these elements field concentration in soil (Chang, 1982).

In a research, Chang (1982) observed that application of sludge increased the concentration of cadmium, lead and chrome was 4 fold, 2 fold and 2.5 fold, respectively. A study showed that increasing the addition of sludge to soil increased the concentration of lead, cadmium and nickel in the soil surface level from 0 to 15 cm and just few of them penetrated to the soil deep (Bradford, 1975). Addition of sewage sludge to soil has a direct effect on solvability and absorbability of heavy metals (Ortiz and Alkaniz, 2006). The maximum concentration of the heavy metals forms is different from each other. For example, nickel has the most concentration in exchange part while cadmium, lead, chrome and copper have more concentration in connection with organic matters (Singh and Lag, 1976).

Evaluation of the heavy metals concentration of the sewage sludge and examination of the possibility of their absorption by agricultural productions cultivated on soils treated by sewage sludge is importance. Therefore, examination of the concentration of the heavy metals in sludge and their comparison with global standards and study of their absorption by plants, especially the plants in human food chain, are of great importance.

Heavy metal contaminated crops could be detrimental to human and livestock health, especially in the edible parts of the plants, bringing about the uptake and accumulation of the metals (Lim *et al.*,

2008). The sewage sludge usage in Iran farmlands and vegetables lands has been prevalent from decades ago but unfortunately, research about quality of sludge and its application is not enough. It had been supposed that there may be some heavy metal contamination in the agricultural crops with the application of sludge. There is requirement for studying heavy metal concentration levels in these crop samples. Thus, the main objective of this study was to analyse the effects of using urban sewage sludge on concentration of lead and cadmium in parsley and its soil as well as its yield.

Materials and methods

This study was done in research greenhouse of agriculture faculty in Islamic Azad University, Isfahan (Khorasgan) branch in 2012.

Soil sampling and characterization

The soils collected from vegetable cultivation areas of Najvan, Baharan Isfahan and Kiar located in Isfahan and Chaharmahal va Bakhtiari provinces. The soil samples were selected from the depth of 0-30 centimeters and transferred to the laboratory. Some soil characteristics were shown in Tables 1 and 2.

Table 1. Selected physical and chemical properties of three soils.

Soil characterizes	Sampling region		
	Najvan	Baharan	Shahrekord
Clay (%)	28	46	50
Silt (%)	66.5	16	45
Sand (%)	5.5	38	5
Texture	Clay	Silty Clay Loam	Silty Clay
$CaCO_3$ (%)	38.5	37.5	44
Organic matter (%)	0.63	0.46	1.03
CEC ($cmol.kg^{-1}$)	12.55	12.97	13.61
EC (dS/m)	0.65	2.38	1.77
pH	8.25	8.21	8.60
Total N (%)	0.16	0.02	0.16
Available P (mg/kg)	26.5	125	90
Available K (mg/kg)	360	447	147
Pb	21	16	11.5
DTPA-extractable Pb	3.0	2.8	2.0
Cd	3.5	3.5	2.5
DTPA-extractable Cd	0.31	0.18	0.23

Table 2. Chemical properties of used sewage sludge.

Component	Unite	Amount
pH	-	7.85
EC	$dS\ m^{-1}$	7.05
OM	%	54.0
N	%	1.87
P	$mg.kg^{-1}$	750
K	$mg.kg^{-1}$	1080
Pb	$mg.kg^{-1}$	90
Ni	$mg.kg^{-1}$	34
Cu	$mg.kg^{-1}$	173
Zn	$mg.kg^{-1}$	655
Cd	$mg.kg^{-1}$	3.0

Sewage sludge characterization and treatment

The sewage sludge was provided from the Isfahan northern refinery of Zeynabie district which was a kind of digested and anaerobic. Chemical components of the used sewage sludge are shown in Table (3). Effect of application of the sewage sludge on parsley was examined by using the treatments of 0, 1, 2, 4, 8, and 16 in soil of Baharan, Najvan and Shahrekord. Parsley, as a vegetable used in people diet, was selected for this experiment. It was done in the form of factorial and a completely randomized design with three replications. The sewage sludge was added to the soil individually and poured in the plastic vase having 1 kg capacity. In each vase, 3 or 4 parsley transplanting was planted. After that, the numbers of plants were decreased in 5. During growth period, the vases were irrigated monotonously according to the plant need. The wedding and fighting with pests diseases were done manually.

Laboratory analysis of soil and crop samples

Two month later, reaching to the 4-leaf stage, the plants were harvested and the vases soil sampled gathered. Having transferred to the laboratory, the samples were beaten and passed from a two-mm sieve. Their pH and electric conduct were measured in 1:2 suspensions of distilled water and saturation extract respectively. The soil texture (hydrometer method, the cation exchange capacity (sodium acetate method), the available P (Olsen method), the

available K (ammonium acetate method), the organic matters (wet oxidation method), the total nitrogen (kjeldahl method), the available of lead and cadmium (0.005 N DTPA) were determined via procedures described in Baruah and Barthakur (1997). Their total concentration and the sewage sludge were extracted by digestion by the help of concentrated nitric acid and 30% hydrogen peroxide (Pyatt, 1999). Then, their concentration in the extracts was determined by Perkin Elmer Analyst 800. After harvesting the samples, the yield of wet weight was determined. Then, they were dried in ventilation oven in 65^{oc} for 48 hours and were weighted again. For determining the concentration of lead and cadmium, the plants samples were powdered at first, and the wet oxidation method, having concentrated nitric acid and hydrogen peroxide, was used for digestion. These metals concentration in extracts was measured by atomic absorption device Weling *et al*. 1989.

Statistical analysis

In order to analyze the data, SAS software were used. Means were compared by least significant difference (LSD).

Results and discussion

Effect of sewage sludge application on some Soil properties

Soil pH

The most eminent chemical property of soil is its pH. Most of soil chemical properties and, accordingly, the plant growth, activities of the soil organisms and the plant accessibility to the needed elements is dependent on soil pH Mojalali (1999).

In this research, the application of sewage sludge decreased the soils' however different was not statistically significant (Fig. 1). It may be as a result of the soil calcareous Property and its high buffering power. The decrease of soil pH due to adding the organic waste to farmlands was reported by many researchers. Mohammad and Athamneh (2004) reported the reduction of soil pH from 8.15 to 7.22 after adding 160 tons sewage sludge in a hectare because of degrading and mineralizing the organic matters leading to releasing the amine acids. Generally, in calcareous soils, because of highness of the soil buffering capacity, the soil pH is very low due to application of sewage sludge Karami *et al* (2009). Harding *et al* (1984) revealed that in calcareous soils, because the buffering capacity is high, it was very low and even after 3 years of using sewage sludge no significant effect on pH was shown.

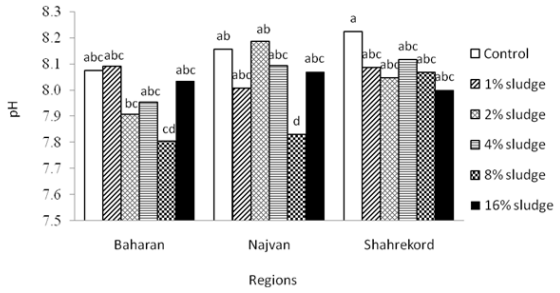

Fig. 1. Effect of sewage sludge on soil pH. Means with different letters are significantly different at 5% level test (LSD= 0.31).

Soil electrical conductivity

According to Fig. 2 application of sewage sludge increased the soils electrical conductivity, although this increase was significant in Baharan soil in amount of 8% amore and in Shahrekord soil in amount of 4% and more (≥4). The most amount of electrical conductivity was related to the treatment 16% in Najvan soil and the least one were related to the treatment 4% in Baharan soil. Guskin *et al* (2003) revealed that soil electrical conductivity was increased with application of sewage sludge.

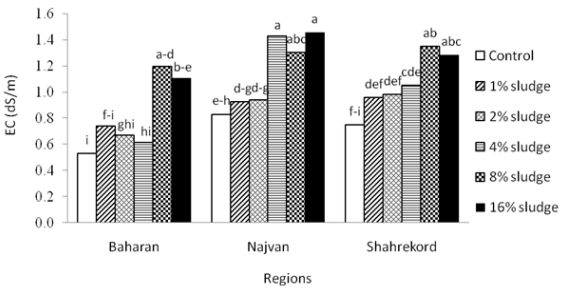

Fig. 2. Effect of sewage sludge on soil electrical conductivity. Means with different letters are significantly different at 5% level test (LSD= 0.28).

In all treatments, this increase in surface soil was more than subsurface. Adding 90 tons/hectare of sewage sludge and compost to light texture calcareous soil led to a significant increase in soil electrical conductivity due to releasing the ions during the mineralization of the organic matters .In reports about effect of the sewage sludge on soil, the increase of electrical conductivity has been mentioned (Erfanmanesh, 1998).

Effect of sewage sludge application on soil heavy metal concentration

The total and available amounts of heavy metals in soil because of using sewage sludge is an important index which can be applied for evaluation of the soil contaminations under the treatment of sewage sludge. Table (3) revealed the total and available lead and cadmium concentration. Generally, the sewage sludge increases the total and available concentration of lead and cadmium in soil.

Soil total cadmium concentration

Sewage sludge application increased the all soils' cadmium concentrations which were significant in Baharan and Shahrekord soils in 16% level and in application of 1% and more in Najvan soil, in comparison with the control group. The highest concentration was related to the sludge 16%treatment. In Shahrekord soil, it was more than that of others (Fig. 3).

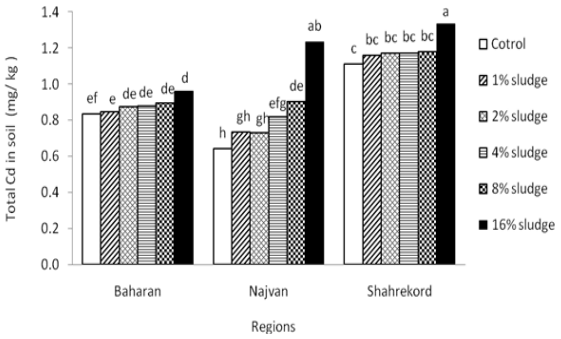

Fig. 3. Effect of sewage sludge on total cadmium concentration of three soils. Means with different letters are significantly different at 5% level test (LSD= 0.1).

The cadmium concentration increase was probably related to the sewage sludge total cadmium (Table 2). Also, Latare *et al.* (2014) reported that Application of sludge also increased the heavy metals contents in soil and rice. Comparison of the soils' cadmium concentration in experimental treatments with amounts of USEPA (2002) and NYSDEC (2006) and human environment deputy standards revealed that the cadmium concentration in these treatments are less than that of the permitted proposed.

Soil available cadmium concentration

Sewage sledge application increased the soils' available cadmium amounts (Fig. 4) .This increase in Shahrekord soil was somewhat in accordance with the sludge application. The increase in Baharan and Shahrekord soils was significant at 8% and more, but it was not significant in Najvan soil. The low effect of sewage sludge on the soil available cadmium concentration may be because of the low amount of cadmium in the sewage sludge. McBride (1997)، Keller *et al.* (2002) reported that adding sewage sludge to soil increases the soil available cadmium concentration.

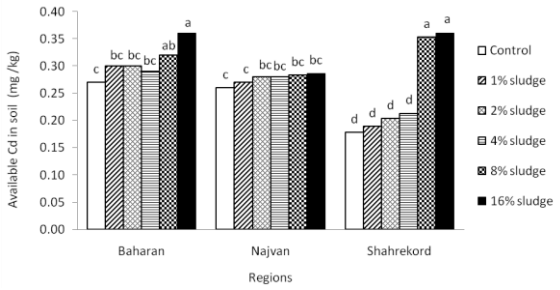

Fig. 4. Effect of sewage sludge on available cadmium concentration of three soils. Means with different letters are significantly different at 5% level test (LSD= 0.07).

Soil total lead concentration

Sewage sludge application had a significant effect on the soils' lead and increased their concentration (Fig. 5). The increase was significant in Baharan soil in application of 4% and more and in Najvan soil in application of 2% or more, in comparison with the control sample. In Shahrekord soil, application of

sewage sludge led to increase of the soil total lead which was significant in application of 8%, 2%, 1% and 16%. This increase was probably because the high concentration of lead in the sewage sludge. The results showed that the soil total lead concentrations were less than that of the permitted proposed with acceptable maximum concentration of USEPA (2002) and NYSDEC (2006). Weber *et al.* (2007) reported the increase in the soil total lead concentration after consuming the urban waste compost (50, 100, 200 and 400 tons per hectare).

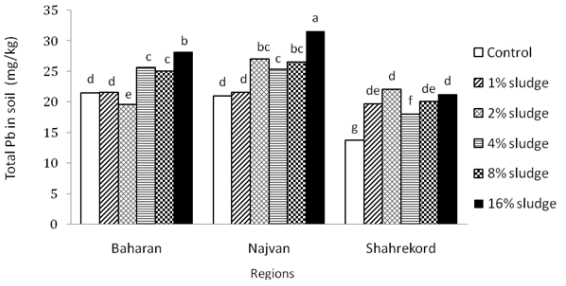

Fig. 5. Effect of sewage sludge on total lead concentration of three soils. Means with different letters are significantly different at 5% level test (LSD= 2.47).

Soil available lead concentration

Sewage sludge application increased the soils' available lead concentration (Fig. 6). This increase was significant in Shahrekord and Baharan soils in 4% and more toward the control sample. It was not significant in Najvan soil. The results showed that the lead available highest concentration was related to the sludge 16% treatment and the available lead of this treatment in Shahrekord soil was significantly more than that of the two other soils. It seems that increasing the soil organic matter, due to use of sewage sludge, is effective on increase of the lead available concentration. Afyuni *et al.* (1998) also reported that the use of sewage sludge significantly increased the concentration of lead in the soil available. Haghighat Jou and Asadi (2015) reported that since the concentration of heavy metal in wastewater is low, thus one may not expect a significant increase in the concentration of metals in soil by application of wastewater.

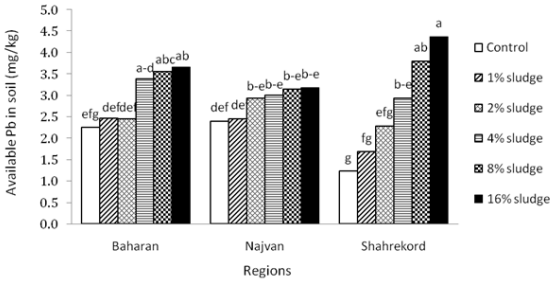

Fig. 6. Effect of sewage sludge on available lead concentration of three soils. Means with different letters are significantly different at 5% level test. (LSD= 1.08).

Effect of sewage sludge application on concentration of cadmium and lead in plant

Concentration of the heavy metals in edible plants, e.g. parsley, is an important index specifying the danger of entrance of elements into human food cycle by the soils treated by sewage sludge. The lead and cadmium concentration is presented in Table (4). Generally, the application sewage sludge increased the lead and cadmium concentration in parsley which was different according to the level of used sludge.

Cadmium concentration in plant

Sewage sludge application increased the cadmium concentration (Fig. 5). It was significant in Baharan soil in 4%treatment and in Najvan soil in application of 2% toward the control group. But in Shahrekord soil, the sludge usage increased the cadmium concentration in application of 2% which was not significant. This increase can be related to increase of the cadmium available amount with application of sewage sludge. Sloan *et al.* (1997) reported that the cadmium concentration of the lettuce aerial organs was increased significantly using the sewage sludge and there was a high correlation between the lettuce cadmium concentration with the concentration of this element in soil. They showed that 15 years after using the sewage sludge, the relative environmental accessibility of the added cadmium due to using sewage sludge is more than other heavy metals of soil. Comparison of the cadmium concentration in experiment treatments with the permitted amount of

heavy metals in vegetables on the basis of WHO standards revealed that the cadmium concentration in these treatments along with the control sample was more than that of the proposed amount.

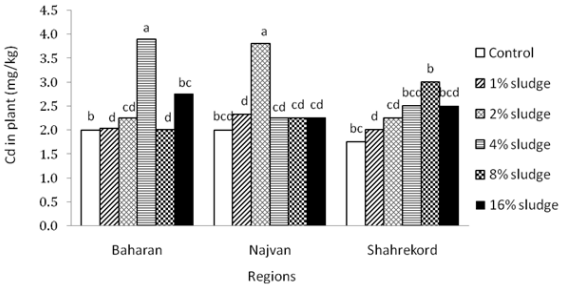

Fig. 7. Effect of sewage sludge on cadmium concentration of parsley. Means with different letters are significantly different at 5% level test. (LSD= 1.21).

Lead concentration in plant

Sewage sludge Application increased the lead concentration significantly in soils of Shahrekord and Baharan in treatments of 1%, 8% and 16% and in soil of Najvan in treatments of 1% and 2% (Fig. 8). This increase can be related to the increase of the lead available amount with application of the sewage sludge and increase of salinity and the soil organic matter.

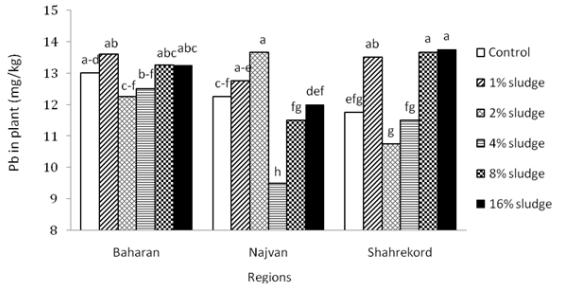

Fig. 8. Effect of sewage sludge on lead concentration of parsley. Means with different letters are significantly different at 5% level test. (LSD= 0.72).

The salinity increase results in increase of the concentration of the complex of lead with chloride and reduction of accumulation of lead in soil. In addition, increase of organic matter will form a sustainable complex of organic matters with lead and increase their absorption by the plant. Lovisa and Stig (2006) reported the increase in concentration of lead, chrome and nickel in barely due to application of sewage sludge. Comparison of the lead concentration in experiment treatments with the permitted amount in vegetables on the basis of WHO (1996) standards revealed that the lead concentration in treatments along with the control sample was more than that of proposed amount.

Effect of sewage sludge application on the plant growth

The parsley wet weight was increased by increase of the amount of sewage sludge in soils (Fig. 9). The increase of parsley wet weight in Baharan soil was in accordance with the increase of sludge amount. The parsley wet weight in Baharan and Najvan soils was increased from 1.35g and 0/35g in control treatment pots to 9.21 g and 9.63 g in treatment pots of the 16% sludge which was significant in the two soils between treatments of 8% and 16%. In Shahrekord soil parsley wet weight was increased from 2.32 g in control treatment pots to 10.28g in treatment pots of the 16% sludge. Among all soils, parsley showed the best yield in 16%treatment. Its main reason can be the effect of organic maters on soil physical properties and supplying the low consumption and high consumption elements by the sewage sludge.

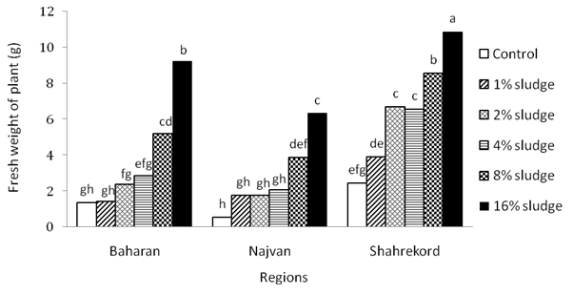

Fig. 9. Effect of sewage sludge on the fresh weight of parsley. Means with different letters are significantly different at 5% level test. (LSD= 52.1).

Kelling *et al.* (1997) reported that increase of sewage sludge in level of 15 tons per hectare increased the yield of rye products. In his research, Erfanmanesh (1998) revealed that increase of sewage sludge

amount will result in increase of tomato yield so that in treatment of 200 tons of sludge per hectare, the yield is increased up to 3 fold. In a farm research, Delgado *et al* (2002) reported that adding 1000 kg sludge along with 350 kg urea per hectare will increase the corn yield in amount of 20% of the control group. Vlamis *et al* (2005), doing a seven-year research on barley using two kinds of sludge and different treatments, concluded that addition of sewage sludge in a specific amount can increase the yield, but after that it has not a high effect. This range depends on the soil type and condition, the kind of sludge and its chemical composition and type of the plant.

Conclusion

Using the sewage sludge can decrease the soil pH and increase its electrical conductivity in comparison with the control group. These variations were in accordance with the amount of sludge usage generally. Also, application of sewage sludge also increased lead and cadmium (Total and DTPA-extractable) concentration in soil. However, the yield of parsley increased with the application of sewage sludge. Although there are other useful elements for the plant growth, some elements including lead and cadmium are in sludge. Adding sludge to soil will increases the total and available concentration of these elements and lead to accumulation of these elements in soil and transferring them to food chain in a long term.

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