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EFFECT OF SEWAGE SLUDGE APPLICATION ON THE GROWTH OF BARLEY *(Hordeum sativeum,* J.) AND HEAVY METAL CONTENT OF SOIL AND PLANT

Khalid S. Al- Shallash

Department of Environmental Technology, Riyadh College of Technology, Riyadh, Saudi Arabia.

KS alshalash@hotmail.com

Abstract: The use of sewage sludge as an organic fertilizer under arid conditions is an alternative disposal route to sacrificial land disposal. A greenhouse experiment was conducted to characterize the effect of sewage sludge application on yield of barley*(Hordeum sativeum, J.)* grown in sandy soil for 60 days and the content of the heavy metals (Pb, Cd, Zn, and Cu) in soil and plant tissue. The sludge treatment showed the highest yield for barley when compared to control plants (soil unamended). The amendment of sludge to the soil did indicate higher heavy metal content, although the increase was not as predicted, owing to the difficulty of obtaining a representative sample in the soil. Except for Cd, heavy metal values in the soils (at the beginning and end of experiment) exceeded the guidelines due to very high background values in the soil. No negative effects of heavy metal contamination in plant parts of the crops could be proven. The results showed that the application of sludge to soils could be useful as a soil conditioner and plant fertilizer, where crop yield significantly increased over a 60 day period in the greenhouse.

Keywords: sewage sludge, barley plants, plant yield, heavy metals soil and plant.

Introduction

The application of sewage sludge to the agricultural lands as an alternative route to sacrificial land disposal is not a new concept and has been practised throughout the world for the last few decades. The longterm benefits of the application of sewage sludge to these lands are, however, frequently limited by potentially harmful elements such as heavy metals and human pathogens. Toxic heavy metals, in particular Cd, Cu, Zn, Ni and Pb are frequently present in high concentrations in sewage sludge (Schmidt, 1997). Heavy metals may be transmitted in the food chain and, animal and human health (Korentejar, 1991).

However, through other research project reports, it appeared that adding sewage sludge to the soil significantly promoted plant growth more than when a commercial fertilizer was added. Christodoulakis and Margaris (1996) showed that the plant height increased in maize individuals by 77% in the sludge amended treatment compared to 25% in the case of the commercial fertilizer amendment Snyman *et al.* (1998) and Henning *et al.* (1999) had also demonstrated the short-term beneficial agricultural utilization of sewage sludge concerning heavy metal contamination risk and the cultivation of maize under arid conditions. According to the 1997 guidelines (WRC, 1997), the current standards for the unrestricted use of sludge on agricultural soils, cannot be attained within a reasonable framework of affordability Cu, Pb and Zn levels in the sludge which is intended for unrestrictive use in terms of the total metal content. Investigations that illustrate the benefits of sewage sludge are extremely important, since there is still a general reluctance among agriculturists to recognize the economic value of the sewage sludge in order to improve the soil organic status without contaminating the environment (Korentejar, 1991). This study was proposed to assess the effect of sewage sludge on growth and yield of barley (*Hordeum vulhare* L .) seedlings under greenhouse conditions. The content of heavy metals in sewage sludge, soil and plant tissue will be also evaluated.

Materials and Methods

Experimental Design

The experiment was carried out under the greenhouse condition using varying amounts of dried anaerobic digested sewage sludge taken from the drying beds of Riyadh Sewage Station after the sludge was left to dry for two weeks. Plastic pots containing 1.0 kg sandy soil were used and arranged in a randomized complete block design. The dried sewage sludge was added to the soil at the level of 24 t_{dry} ha $^{-1}$ before cultivation and mixed thoroughly with the soil in the pots. NPK fertilizers (100 kg N/fed, as ammonium nitrate, 15.5 kg P/ fed., as super phosphate, and 50 kg k/fed. as potassium sulfate) were added to the soil after one week after cultivation. The amount of NPK fertilizers was reduced to half after using irrigation water. Additional pots were filled with untreated soil, and all pots were lined with Whatman No. I filter paper in order to cover the drainage holes. Five barley (Hordeum *sativeum,* J.) seeds were planted, in each pot, and all pots were irrigated with well water at different moisture levels

(25,50,and 75%) of field capacity.

Sludge Analysis

Analysis of sludge was done for moisture, potential heavy metals (Ammonium EDTA method) and total heavy metal concentration (EPA 3050 method of Pb, Cd, Cu, and Zn. The EPA 3050 method is a total digestion of metals and does not predict the metal bioavailability. It is an acid digestion used to digest sediments, sludge, and soil samples. This method has been adopted by the U.S. EPA to recover almost 100% of the metal from the sample (Sims *et al.,* 1991).

Soil and Plant Analyses

The soil samples were analyzed at two different times during the experiment at the start of the experiment after sludge application and after 60 days of plant growth. The soil samples which were analyzed at the end of the experiment consisted of soil samples and barley plant roots. Samples were analyzed for heavy metal content of four metals (Pb, Cd, Zn and Cu). The above-ground parts of plants were separated from the roots after 60 day of growth. Plant roots were left in the soil for further analyses. The plant foliage was weighed, dried at 70 C to determine its dry mass. The above-ground samples were analyzed for total heavy metal content after drying. Yield as dry mass of aboveground parts was measured. All means were compared by one-way analysis of variance, and differences were analyzed for significance using least significance difference (LSD) tests (Sokal and Rohlf, 1981).

Results and Discussion

Analysis of Dried Sewage Sludge

The dried sewage sludge had a solid content of 92.5%. Its content of Zn, Cu, Pb, and Cd are shown in Figure (1). This shows that the heavy metal content of the used sludge exceeded the EPA guidelines, except for Cd which was within the guideline limits.

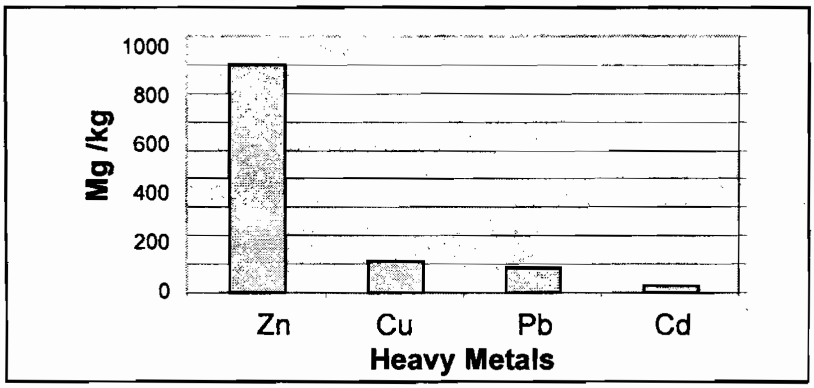

Fig. (1): Heavy Metal Concentrations in the sewage sludge

Soil and Plant Analyses

Soil PH. Soil pH is one of the major soil property controlling the availability of heavy metals in soils (Smith, 1996). In the present study, the soil mean pH was found to be 7.6. The availability of heavy metals for the uptake of plants depends to a large extent on the pH value of the soil. The higher the pH value, the lower is the solubility of the heavy metals. There is a decreasing mobility of heavy metals as listed in the following order: cadmium > zinc > nickel > copper> arsenic > chromium > lead and mercury (Sauerbeck, 1985).

The pH-limit for starting the heavy metal mobility is about 6.5 (Blume and Brumer, 1987). Arid soils, as found in Saudi Arabia, show pH values within the neutral to alkaline range (a medium pH-value of 7.4; Pagel, 1974). No dangerous risks are foreseen in Saudi Arabia soils , according to the available levels availability of the heavy metals that would grow in the future.

Zinc (Zn) . Zinc is a phytotoxic metal, but it is important as a micronutrient at the approximate levels (Alloway, 1995). As shown in Table (1), the concentration means of soil Zn before and after the cultivation by barley were above the guideline limits of soils due to high background concentrations. The mean concentrations of Zn in barley tissues after 60 days of growth in sludge amended soil and in untreated soil (control) are given in (Table 2).

Cadmium (Cd). Cadmium is very mobile and bioavailable metal which may accumulate in crops and humans (Alloway,1995).Soil background concentrations of Cd were low and did not exceed the guideline limits even after the sludge amendment (Table 1). There was a significant increase in the availability of Cd in soil during the experiment, indicating the extent of the mobility of Cd when amended as a sludge -borne metal to soil. Cadmium levels significantly decreased in the soil over 60 days of barley growth due to accumulation of Cd in the plant tissue. The uptake of Cd by barley tissues (Table 2) also did not reach the phytotoxic levels of 5 to 30 mg/kg (Smith, 1996).

Table(1): Concentrations of some heavy metal in the soil (mg /kg) cultivated with barley plant at the beginning (B)and after 60 days of sewage sludge Application.

Treatment	Zn		Cd		Cu		Pb	
	B	E	B	E	B	E	B	E
Sludge treated soil	89.65	58.66	0.48	0.16	21.18	22.81	12.65	12.55
Untreated Soil	63.92	55.72	0.59	0.12	20.92	22.15	13.74	13.56

Copper (Cu). Copper is one of the most important essential element for the plants and animals (Alloway, 1995). Concentrations of Cu remained constant over the 60 days of the experiment emphasizing the fact that Cu is a relatively immobile element (Alloway,1995). Copper concentrations in plant tissues (Table 2) did not reach the phytotoxic levels of 20 to 100 mg/kg (Smith,1996).

Lead(Pb).Lead, being a zootoxic metal, needs to be monitored in plant parts used by humans and animals (Alloway 1995).No significant changes were found in Pb concentrations in the sandy soil over the 60 day growth period, indicating the immobility of Pb in the soil. (Table1) shows that Pb concentrations exceeded the guideline limits, mostly due to the high background levels in the soil. The increase in total Pb concentrations in the sludge treatment during the experiment could be due to the high pb accumulation in plant roots. The uptake of Pb by barley tissues (Table 2) was low and did not reach the phytotoxic levels of 30 to 300 mg/kg (Smith 1996).

Plant Yield

It is obvious that the application of sewage sludge resulted in a significant increase in the dry matter yield of barley (Table 2) compared to the control treatment. This emphasized the potential short-term beneficial effects of sludge to soil as an organic soil conditioner. Soil pH is probably the soil property that affects the uptake of heavy metals by plants. It is commonly recommended that soil pH should be maintained above 6.5 for sludge – amended soils, although some reports indicated an adequate control of metals uptake at pH 6.0 (Sommers et al., 1987). However, the uptake of metal never reached the phytotoxic levels in barley tissues and consequently did not have an effect on the plant growth and yield.

Table(2): Effect of sewage sludge application on the yield (dry matter) and heavy metals concentrations in barley tissues after grown for 60 days .

Treatment	Dry matter (g)	Heavy metal (mg/kg)			
		Zn	Cd	Cu	Pb
Sludge treated soil	5.16	70.35	0.27	8.21	2.65
Untreated soil	3.74	43.85	0.21	4.82	2.45

Conclusion

In the present study, it was found that the current heavy metal guidelines for soil metal concentrations were exceeded in the soil and sludge for Pb, Cu and Zn, mostly due to the high background levels . Long –term experiments still need to be performed on heavy metals in different soil types However, no phytotoxic effect could be proven, because phytotoxic levels were not exceeded in barley tissues. The sludge positively affected the yield of barley plants, when compared to control plants. However, a similar large –scale field experiment will be needed, taking into consideration the different environmental conditions.

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تأثير إستخدام مخلفات الصرف الصحي الصلبة (الحماءة) على نمو الشعير ومحتوى التربة و النبات من العناصر الثقيلة.

خالد سليمان الشلاش

قسم تقنية البيئة ، كلية التقنية بالرياض ، المملكة العربية السعودية

تم دراسة استخدام مخلفات الصرف الصحي الصلبة (الحماءة) كسماد عضوي لتحسين نمو محصول الشعير وتحسين خواص التربة في هذا البحث. فقد أجريت تجربة في صوبة زجاجية لتحديد تأثير استخدام التسميد بالمخلفات العضوية الصلبة على النمو الخضري لمحصول الشعير وكذلك قياس محتوى العناصر الثقيلة (الرصاص ، الكادميوم ، الزنك ، النحاس) في كل من التربة وانسجة نبات الشعير. أدى التسميد بالحماءة الى زيادة معنوية في المادة الجافة لمحصول الشعير بالمقارنة بمعاملة التحكم . كما أوضحت الدراسة زيادة نسبية في محتوى العناصر الثقيلة في كل من التربة وأنسجة نبات الشعير فيما عدا الكاديوم حيث تركيز العناصر الثلاثة الأخرى في التربة عند بداية ونهاية التجربة تعدت المستويات المتوقعة وذلك بسبب وجودها عند تركيزات مرتفعة قبل التسميد بالحماءة. و قد وجد أنه لم يظهر أي تأثيرات سلبية على محصول الشعير نتيجة ارتفاع محتوى هذه العناصر في كل من التربة و النبات . و بالتالي النتائج توضح أن التسميد بالحماءة يحسن من خصوبة التربة ويؤدي إلى زيادة نمو نبات الشعير في ظروف الصوبة الزجاجية.