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The Effects of Sewage Sludge Usage and Manure on Some Heavy Metals Uptake in Savory (*Satureja hortensis* L.)

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***Abstract*—**In recent decades with the development of technology and lack of food sources, sewage sludge in production of human foods is inevitable. Various sources of municipal and industrial sewage sludge that is produced can provide the requirement of plant nutrients. Soils in arid, semi-arid climate of central Iran that most affected by water drainage, iron and zinc deficiencies, using of sewage sludge is helpful. Therefore, the aim of this study is investigation of sewage sludge and manure application on Ni, Pb and Cd uptake by Savory. An experiment in a randomized complete block design with three replications was performed. Sewage sludge treatments consisted of four levels, control, 15, 30, 80 tons per hectares; the manure was used in four levels of control, 20, 40 and 80 tons per hectare. Results showed that the wet and dry weights was not affected by sewage sludge using, while, manure has significant effect on them. The effect of sewage sludge on the cadmium and lead concentrations were significant. Interactions of sewage sludge and manure on dry weight values were not significant. Compare mean analysis showed that increasing the amount of sewage sludge had no significant effect on cadmium concentration and it reduced when sewage sludge usage increased. This is probably due to increased plant growth and reduced concentrations of these elements in the plant.

***Keywords*—**Savory, lead, cadmium, sewage sludge, manure.

I. Introduction

AROMATIC, antiseptic properties and different medical purposes of aromatic plants have been known. Savory (*Satureja hortensis* L.) in as a vegetable and aromatic spice kitchen to be used many parts of the world.

Sewage sludge is an insoluble residue from waste water treatment plants, where incineration, landfilling, agricultural land application and discharge to the sea are disposal options. Domestic waste predominates over industrial one and heavy metal levels and pathogens are within the acceptable range for agricultural use [1].

Municipal wastes such as sewage sludge have been used as an amendment to agricultural soils for many years. In Iran approximately 64 million cubic meters of dry matter sewage sludge is produced per year in big cities. Wastewater and sewage sludge contain large amounts of heavy metals and microelements. Absorption of micronutrients and heavy metals in large amounts can contaminate human food chain by plants and animals.

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Application of sewage on agricultural land increases the amount of heavy metals in soil and plant significantly. Sewage sludge application in agricultural lands has low environmental risks with high crop production advantageous [2]. Sewage sludge increase organic matter, soil aeration, infiltration and porosity, aggregate stability, bulk density, and water retention and movement and it changes some physicochemical soil properties such as pH. In particular, semiarid climatic conditions in the Mediterranean, coupled with intensive tillage systems have resulted in soil organic matter losses and consequently low organic matter stocks [3].

Manures and organic residues application and sewage sludge improves soil organic matter content, soil structure, water holding capacity and nutrients statues of soil and also increases microbial activities in soil [4].

Attention to environment, specially, solid waste, is an issue that has received international attention in recent years. These compounds add the organic matter, plant nutrients, especially nitrogen and phosphorus to agricultural soils [5]. Also they improve the physical, chemical and biological soil properties, such as porosity, aggregate stability, bulk density, pH, concentration of nutrients, organic matter content, and activity of soil organisms [6].

Despite the beneficial effects of sludge, the use of this substance has the potential risks that should be evaluated before the economic value of manure. However, the main problems of an excessive application of sewage sludge are plant toxicity due to accumulation of heavy metals in soils. Repeated application of sludge accumulation of these elements in the soil and may be issues such as toxicity and damage to plants and soil microorganisms or transfer of toxic elements into the human food chain cause [7].

In recent decades with municipal waste application, some environmental concerns have been found concurrent to improve soil quality, plants nutrient and crop production. The macronutrients in the sewage sludge serve as a good source of plant nutrients and the organic constituents provide beneficial soil conditioning properties [5].

Contaminants transferring from soil to groundwater and accumulation of heavy metals and toxic organic, particularly in plants are serious concerns. The main aim of this study is evaluation of manure and sewage sludge and manure on heavy metals (cadmium, nickel and lead) absorption and the yield of plant savory.

II. Materials and Methods

Experiment was conducted at the agricultural farm of Islamic Azad University, Saveh, Iran, during April to July 2013. The sewage sludge was collected at the wastewater plant of Kaveh industrial city and it applied and mixed to a depth of 40cm of surface soil. The most significant characteristics of the sludge were: N 5.0%, pH 6.93, Ec 6.84mScm^{-1}, total organic carbon 17.5%, total P 8.23%, Cd 8.35 mg/kg, Pb 5.62 mg/kg (Table I). Sewage sludge treatments in four levels, control, 15, 30, 80 tons per hectares, and the manure in four levels of control, 20, 40 and 80 tons per hectare were mixed in their plots according randomized complete block design. After harvesting, plants were washed with tap water and rinsed twice with deionized water to remove any attached particles. Each sample was put into a paper envelope and then into ovens at 80ºC for drying to constant weight. Soil and sewage sludge physicochemical parameters were determined according standards methods.

Organic carbon was analyzed by Walkley-Black method [8]. The pH of substrate was measured in an aqueous solution (1:10, w/v) and electrical conductivity (EC) was measured in 1:10 dilution. Total sewage sludge content in Cd, Ni, and Pb were extracted following 3051a method [9].

Data on plant yield, plant heavy metal uptake were statistically analyzed using ANOVAs at a significance level of $P < 0.05$ with SPSS v.16. A multiple comparison of means was determined by the ''post-hoc'' Duncan test. Transport Factor, Bioavailability Factor and Bioaccumulation Factor were calculated. Table I shows Contents of some chemicals properties of sewage sludge from Kaveh Industrial wastewater treatment plant.

The bioavailability factor (BF) of heavy metals, also known as the bioavailability index, was calculated as BF = mg HM (kg plant leaves)$^{-1}$ ×100 /total content HM (mg kg soil^{-1}) [10]. The transport factor was calculated as the ratio of the metal content in plant leaves to that in the roots [11].

Standard reference material (GBW-07401) of soils was applied for quality assurance and control (QA/QC). The quality control performed included a daily analysis of standard and replicate analysis of samples and blanks. The satisfactory recoveries rate for Cd, Ni and Pb were 86.4-102.4%, 90.3-102.1%, 92.3-107.2%, respectively.

TABLE I
Contents of Some Chemicals Properties of Sewage Sludge from Kaveh Industrial Wastewater Treatment Plant

	Value	Unit	Standard
EC	6.84	mS/cm^{-1}	
Total Organic Carbon	17.5	%	
pH	6.93	%	
N	5		
P	8.23	%	
Cd	8.35	mg/kg	5
Ni	19.49	mg/kg	60
Pb	165	mg/kg	300

III. Results and Discussions

The results of data analysis showed that the amount of sewage sludge on dry weight was significant (Table II). However, the effect of sewage sludge on the cadmium and lead concentrations was significant. Interactions of sewage sludge and manure on dry weight values were not significant. While the interaction between the amount of cadmium and lead was significant. Significant effect on the amount of manure on fresh and dry weight and plant Cd concentrations, however, did not significantly affect the amount of lead and nickel concentration in plant.

TABLE II
Variance Analysis of Measured Parameters

Mean-square					
Pb	Ni	Cd	Shoot dry weight	Shoot fresh weight	Sources
0.208^{ns}	0.361^{ns}	0.112^{ns}	36.501^{ns}	585.775^{ns}	Treatment
0.141^{ns}	0.830^{ns}	0.057^{ns}	4.184^{ns}	49.045^{ns}	Replication
0.060^{ns}	0.731*	0.046^{ns}	7.423*	106/178*	Sewage sludge(S)
0.039^{ns}	0.187^{ns}	0.022*	6.550*	168.442*	Manure(M)
0.110**	0.045^{ns}	0.044**	22.527^{ns}	311.155^{ns}	M×S
0.613	0.543	0.478	156.355	2016.138	Error
1.397	3.65	1.305	197.040	43950.531	Total

ns: Not significant. **: Significance at 0.01 probability level. *: Significance at 0.05 probability level.

Compare mean analysis showed that increasing the amount of sewage sludge had a negative effect on cadmium concentration and the highest concentration of cadmium was observed at 15 tons per hectare. While significant differences were observed at 30 and 80 tons/ha application of sewage sludge. On the other hand, with increasing levels of sewage sludge, lead concentration dropped and the lowest concentration of lead was observed in 30 and 80 tons/ha (Fig. 1).

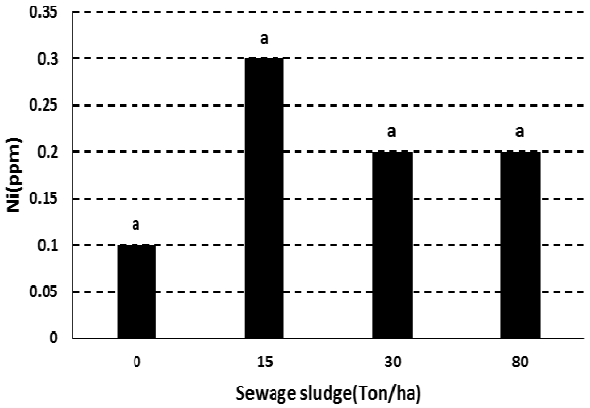

Fig. 1 The effect of sewage sludge on shoot Cd concentrations

Shoot Ni compare mean data analysis showed that there was an increase Ni concentration in 15 tons/ha sewage sludge application but it was not significant differences between sewage sludge treatment levels (Fig. 2).

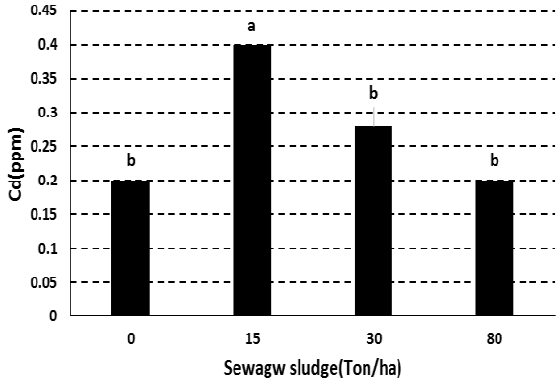

Fig. 2 The effect of sewage sludge on shoot Ni concentrations

Fig. 3 The effect of sewage sludge on Pb concentrations

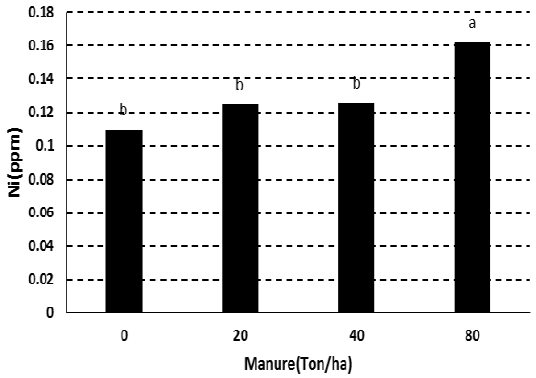

Fig. 4 The effect of manure on Ni concentrations in plants

There was not any significant effect of manure levels in compare with control on heavy metals concentrations (Ni, Pb and Cd) in plant (Figs. 4-6). Interaction results of sewage sludge and manure showed the highest concentration of lead, shoot dry weight, root dry weight were obtained in the combined use of 80 ton/hac sewage sludge application with lack of manure application. The lowest concentration of lead, shoot dry weight and root dry weight were shown in the combined of 80 ton/hac and no sewage sludge application. Also, results showed the highest uptake of cadmium in use of 80ton/hac sewage sludge and 20 tons of manure per hectare were found.

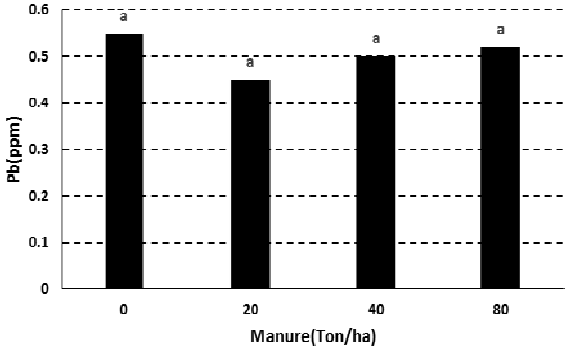

Fig. 5 The effect of manure on Pb concentrations in plants

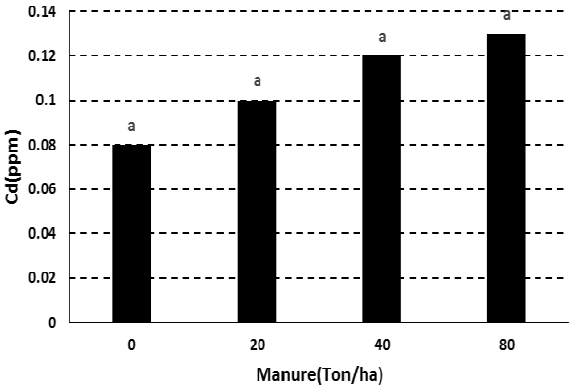

Fig. 6 The effect of manure on Cd concentrations in plants

The minimum amount of cadmium was obtained in 80 ton/hac manure application with 15 ton/hac sewage sludge application (Fig. 7). Finally, the use of 80 ha, 20 ha of manure and sewage sludge showed the least concentration of nickel in plant. The maximum amount of nickel was shown in 30ton/hac sewage sludge application with lack of manure application.

The result showed that the highest transport factor was in 15 tons/ha sewage sludge application in Pb and Cd while, 80 tons/ha had the highest transport factor in Ni. The lowest Bioavailability factor and Bioaccumulation factor was calculated in 80tons/ha control and 15 tons/ha for Cd, Ni and Pb respectively (Table III).

TABLE III
TRANSPORT FACTOR, BIOAVAILABILITY FACTOR AND BIOACCUMULATION FACTOR IN SAVORY

	Pb			Ni			Cd		
	Control	15	80	Control	15	80	Control	15	80
Transport factor	3.7	4.24	2.32	1.43	2.43	3.24	4.32	12.32	5.43
Bioavailability factor	6.87	2.65	3.54	1.87	4.65	5.43	3.91	9.43	3.54
Bioaccumulation factor	5.63	5.32	4.21	2.76	3.25	2.43	4.07	11.21	2.65

Transfer factor (TF) for Pb, Ni and Cd was higher in soil than those to which wastes had been added, and the transfer factor increased in compare with control and it decreased with the highest amount of sewage sludge. (Table III).

The highest bioavailability factor (BF) and bioaccumulation factor for Pb was shown in control while it was shown in 15 ton/hac sewage sludge for Ni and Cd.

As it show in Fig. 1, with increasing sewage sludge levels, Cd and Pb concentrations in shoot increased significantly in 15 tons/ha while there are no significant differences in 30 and 80 tons/ha as compared to control. Probably it is due to increase in biomass is high levels of sewage sludge applications. In a field experiment, a significant increase in Al, Ni and Zn in leaves of lettuce after three years of sludge application has showed [12]. Reference [7] indicated that Cu concentration in plants increased with application of sewage sludge.

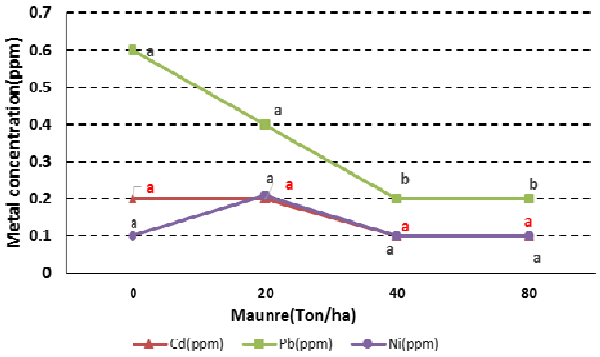

Fig. 7 The effect of manure on heavy metal concentrations in plants

IV. Conclusion

Sewage sludge application to agricultural land has been a widely accepted practice during recent years. By application of both manure and sewage sludge, wet and dry weight of shoot and shoot/root dry weight ratio were increased. The interactive effect of sewage sludge on manure, leaf area and shoot/root dry weight ratio was significant but on other studied characteristics was not significant. The highest amount of dry weight of shoot and root was found in 80 ton/hac of sewage sludge and 80 ton/hac manure application.

The manure increased Savory shoot and root growth more than sewage sludge. Finally, the highest concentration of heavy metals was shown in 15 ton/ha sewage application. This may be due to high concentrations of heavy metals in industrial wastewater that plants were under stress. In conclusion, the different levels of sewage sludge application had a significant effect on the yield and heavy metal concentration in plants and it was very rich sources of heavy metals (Cd, Ni and P). However, Sewage sludge use in agricultural land is promoted because it is considered that it will solve not only the problem of disposal but also will increase productivity in agriculture application. Higher rate of sewage sludge application leads to heavy metals accumulation in agricultural plants, which limits the suitability for human consumption.

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