Effect of Biochar on Chemical Behavior and Radish Plant Uptake of Heavy Metals Grown in Polluted Soils

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ABSTRACT

In this research, we studied the effect of sugarcane bagasse biochar (SCBB) on the chemical behavior of Zn, Ni, Cr, and Cu through speciation experiment in two contaminated soils from Alsharqia governorate soil A, and from Burg El-Arab (Alexandria Governorate) as soil B. In addition to, investigate bioavailability of these metals in soil after soil treatment with different rates of biochar (0.5, 1, and 2%) via pot experiment using radish plant (*Raphanus sativus*) as a bio-indicator. The results showed that exchangeable, carbonate and oxides-bound fractions decreased with increase biochar dosage. However, the residual and organic fractions increased. Bioavailability of Zn, Ni, Cr, and Cu decrease with increasing biochar application rate. Thus, the heavy metals concentrations in shoot and root decreased with increasing biochar dosage., for example in soil A when biochar dosage was 1% the percentage decrease of Zn, Cu, Ni, and Cr in shoot was 8.63, 6.25, 47.15, and 35.02% respectively. It can be suggested that high surface area and surface functional groups of biochar played an important role in fixation and stabilization of heavy metals in the forms of organic and residual fractions in soils.

Keywords: Sugarcane bagasse biochar, contaminated soils, heavy metals fractionation, bioavailability

INTRODUCTION

Contaminated soils with heavy metals are found due to mining activity, emission of industrial wastes and irrigation with wastewater (Mench et al., 2010). Pollution of soil with heavy metals causes many problems such as decrease in soil fertility and grain yield, more over pollution of surface water. Therefore, reach to animal and human through food chain and threaten their life (Fellet et al., 2014) in addition to non-biodegradable and toxic nature of heavy metals (Niazi et al., 2017). Soil and water contamination with heavy metals effect on crop yield and plant growth for instance due to the high concentration of trace metals in wastewater (Alghobar and Suresha, 2016) reported lowering in growth and yield of rice crop. According to (Zhou et al., 2016), six vegetable types were cultivated on farmland contaminated with heavy metals (Pb, Cd, Cu, Zn, and As), the result showed that the ability of leafy vegetables to uptake and accumulate heavy metals was the highest, and this caused health risks due to vegetables consumption.

Immobilization of heavy metals and reducing their accumulation in plants by organic and inorganic amendments was studied by many authors (Rajkovich et al., 2012; Lu et al., 2017; Mehmood et al., 2017; Meng et al., 2017). Immobilization of heavy metals can be done by application of stabilization materials in soil, which can adjust or change proportion of bioavailable fraction of heavy metals that reduce biological availability and mobility of heavy metals in soil environment (Cao and Dai, 2011).

Biochar is considered an important stabilization material. Several studies illustrated that biochar can make stabilization to heavy metals in soils (Cao et al., 2009; Lehmann and Joseph, 2009). Stabilization of heavy metals by biochar depends on its surface reactivity (functional groups), so transition and non-transition metals can be sorbed on to biochar surface (Amonette and Joseph, 2009). Biochar is a carbon-rich pyrolysis product manufactured under oxygen-deficient or no-oxygen conditions (300-700 $_oC$) and, it is a kind of environmentally friendly, economicand renewable material (Chaosheng et al., 2018). Three kinds of feedstock substances can be used to produce biochar, plant residue, animals litter, and sewage sludge (Srinivasan et al., 2015).

Biochar production is not an important way to remediate soil pollution only but also it is a good way to get ride off wastes in benefit way. Where we are facing some problems in accumulation of agricultural wastes and how we can optimal use of it. The annual quantity of agricultural waste in Egypt reach 35 million tons, of which only 18% is used as fertilizer (El-Mashad et al., 2003 and Rashad et al., 2019). Addition of biochar to mine soil contaminated with heavy metals decreased the content of available Cd, Pb and Zn. Moreover, application of biochar during mine soil remediation could reduce plant concentrations of heavy metals in addition to symptoms of heavy metal toxicity were absent in plants growing in soil treated with biochar (Puga et al., 2015a).

DOI: 10.21608/asejaiqjsae.2021.214106

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Received November 25, 2021, Accepted, December 30, 2021.

Biochar is favorable material than organic materials because heavy metals retained by biochar will be released more slowly than other retained by fresh organic materials, which decompose rapidly (Tang et al., 2013). When raw organic materials turn into biochar through pyrolysis processes, many changes in chemical and physical properties will be done. These properties increase the affinity of biochar to retain heavy metals and remediate polluted soils (Agrafioti et al., 2013; Zhang et al., 2013; Trakal et al., 2014). Harvey et al., 2011 and Zhang et al., 2017 demonstrated that biochar structure has high degree of aromatization, providing π-electrons that could strongly bond heavy metal cations.

Wastewater contains many organic and inorganic pollutants. In Egypt,Sahl El Husseiniya region, Al-Sharqia governorate, agricultural soil is irrigated with wastewater from Baher El Baqar drain that causes contaminating of this soil by heavy metals. Baher El-Baqar drain is located at the east of Nile Delta and it is starting from east of Cairo and pours into El-Manzala Lake. Abdel-Fattah and Helmy (2015) mentioned that58percentage of the total wastewater of Bahr El-Baqar drain comes from agricultural drainage, 2% from industrial wastes and around 40% from municipal and commercial drainage.

In Egypt, sugar production from sugarcane crop is one of the oldest industries. Sugarcane plantations are concentrated in the Upper Egypt specifically in Menia, Sohag, Qena, Luxor and Aswan governorates. The total amount of sugarcane cultivated in Upper Egypt is about 16 million tons per year (Chauhan et al., 2011).

The percentage of by-products and co-products generated during the sugar production process are as follows: 30% bagasse, 3.5% Filter mud/cake and 0.4% Furnace ash. Bagasse reuse in power generation and production of paper and fiberboard (Nakhla and Haggar, 2014). Utilization of sugarcane bagasse in producing biochar is considered a new approach to get rid of this waste(Saleh and Hedia, 2018).

The objectve of this study was to provide an overview on the effect of sugarcane bagasse biochar on the behavior and plant uptake of heavy metals grown in contaminated soils from Alsharqia governorate and Burg Al Arab area, and also to demonstrates the potential of using biochar for remediation of polluted soils.

MATERIAL AND METHODS

Soil collection and characterization

Two soil samples were collected at 0-20 depth named (soil A) from Alsharqia governorate within latitude 30◦ 50′ 48″ N and longitude 31◦ 58′ 53″ E, mainly irrigated with wastewater from Bahr El-Baqar drain and (soil B)from Burg Al Arab area in latitude 30◦ 53′ 13″ N and longitude 29◦36′ 36″ E. Second industrial area. The industrial activities in in Burg Al Arab are mainly food processing, detergents manufacturing, and textile. These two soils have been polluting with heavy metals (EL-Bady, 2014). Soil pH and electrical conductivity (EC)were measured in soil suspension (1:2.5 w/v) (Black, 1965). Cation exchange capacity (CEC) was measured using sodium acetate method. Soil organic carbon (SOC) was determined by Walkley-Black method (Black, 1965). DTPA-extractable of heavy metals was determined according to (Lindsay and Norvell, 1978) in soils A and B(Fe, Zn, Mn, Cu, Cr, Ni and Co) were determined and measured by ICP (Inductively coupled plasma-mass spectrometry).Total heavy metals were determined according to the method described by Ure (1995)and measured by ICP (Inductively coupled plasma-mass spectrometry).

Preparation of Biochar:

Biochar was prepared from feedstock of sugarcane bagasse (SCBF). The raw materials (SCBF) in this study were collected from the nearest cane juice stores and were washed with tap and then distilled water several times to remove dust and impurities then dried at 80 °C for 24 hours. Pyrolysis process was carried out using traditional method (El Gamal et al., 2017) at around 500 °C for two hrs. After cooling biochar sample was washed with distilled water then dried at 105 ◦C for 5.0 hours. After cooling, biochar sample was crushed and sieved using 0.5-mm polypropylene sieve.

Characterization of Biochar

Characterization of sugarcane bagasse biochar (SCBB) sample involved pH and EC determination at the ratio 1:20 w/v (biochar/water suspension), specific surface area measurement by the N_2- BET method and CEC determination according to Song and Guo (2012). Fourier transform infrared (FTIR) is used to determine surface functionalgroups, whichwere determining by scanning SCBB with infrared rays in the range 400 – 4000 cm^{-1} using SHEMATZU infrared spectrophotometer model FT/IR5300, JASCO Corporation, Japan. And the ash was determined according to (Samsuri et al., 2014). The scanning electron microscopy (SEM) was carried out for biochar sample using SEM Quanta FEG Unit, with accelerating voltage 30 k.v., (magnification 250x up to 20000 0061nd resolution for Gun.1m).

Planting experiment

Three kg soil mixed (or not) with either 0.5%, 1%, or 2% SCBB they transferred into plastic pots in three replicates to each biochar treatment for the two soils A and B. Treatments without biochar (0% biochar) were regarded as the control. The pot experiment was conducted using radish plant (*Raphanus sativus*) as a bio indicator for environmental pollution (Davies, 1993;

Hassan et al., 2018). Five seeds were sown in each pot and water was added to bring the soil moisture to 70% of water holding capacity. Thus, there were three replicates of each treatment giving 24 pots for each soil. The plants were harvested 40 days after sowing.

Soil analysis and chemical fractionation

After plant harvest, the soil content of each pot was air dried, crushed and sieved (<0.5mm) and chemically analyzed for determined the amount of available using (DTPA method) according to (Lindsay and Norvell, 1978) and total heavy metals Zn, Cu, Cr, and Ni (Ure, 1995). The rhizosphere soil was used for chemical fractionation. The sequential extract method (Tessier et al., 1979) was used to determine the speciation of heavy metals in the two soils A and B in control and SCBB-treated soils. The fractions were separated into exchangeable, carbonate, oxides, organic and residual fractions. Heavy metals content was determined by ICP (Inductively coupled plasma-mass spectrometry).

plant analysis

Radish plant shoot was cut just 2 cm above the soil surface, washed in taps water then by distilled water. Plant roots were separated gently from soil with portion of soil. Then washed in tap and distilled water. Plant shoot and root were oven dried for 48 hours at 70 ^{0}C and then ground in stainless steel mill before digestion. Plant shoot and root and were wet digested according to Jones (1989). Through filtered 0.45-mm membranes (GelmanSciences, USA) and the concentration of heavy metals were determined in the filtrate by ICP-MS.

Statistical Analysis

The significance test was carried out using ANOVA test, the least significant difference test (L.S.D) at 0.05 and 0.01 levels of probability according to Steel et al. (1997). On the other hand, Pearson's correlation coefficient, were performed for a better understanding of the relationship among the measurements of the two soils using the computer software program PAST version 4.03 (Hammer et al., 2020).

RESULTS AND DISCUSSION

Characterization of studied soils

Table 1 showed that the texture of two studied soil are sandy clay loam with increase in clay fraction in soil A than soil B. Also organic matter in soil A is greater than in soil B, these results may cause increase in cation exchange capacity in soil A (10.70 meq/100g soil) than in soil B (9.73 meq/100g soil). However, the total carbonate in soil B is greater than in soil A. This mainly attributed to the natural and composition of the parent material of Burg Al-Arab soil. Thus soil B is more alkaline (pH=8.66) than soil A (pH=7.75) (Wali et al., 2013). EC values are 2.55 dS/m and 2.63 dS/m in soil A and B, respectively. Table (2) showed available and total heavy metals in both soils. The data illustrated that soil A and B are considered polluted with Zn, Cu, Ni, Mn and Fe according to WHO (1996).

Characterization of biochar

Tables 2 and 3 illustrate some properties of biochar as pH, EC and elemental contents of H, N, C, and S with the predominant amount of C, and heavy metals contents. In addition, the surface area and CEC, FTIR of SCBB is present in Fig (1) which, based on the absorption of the infrared radiation at certain frequencies and allowed conclusions on the functional groups on the biochar surface.

Ten radiation spectra in the range of 4000–400 cm^{-1}were obtained to biochar sample. Peak at 3430.51 cm^{-1}informing the presence of H bond. This band confirms the presence of hydroxyl (OH-), ammonium, or amino. In addition, the existence of spectra at frequencies of 1602.90, 786.02, and 673.18 confirmed the presence of hydroxyl compound (Sahu et al., 2010). Peak below 3000 cm^{-1} showing aliphatic compound (aliphatic C-H) which indicates the presence of alkane functional group (Nandiyanto et al., 2019), for example peaks at 2942.15 and 2315.30 cm^{-1} show (asymmetric C-H stretching) and this confirmed by the presence of 1426.41 cm^{-1}, 1420.62 cm^{-1} and 786 cm^{-1}. The presence frequencies of 2000 cm^{-1} and 2500 cm^{-1} refer to triple bond region (-C≡C-), as in 2351.30 cm^{-1} and this confirmed by 1600 cm^{-1} -1300 cm^{-1} as, 1602.96, 1426.41, 1420.62 cm^{-1} (Nandiyanto et al., 2019). The peaks 1500-2000 cm^{-1} showed the presence of double bond (C=C, C=N, and N=N groups as in 1602.90 cm^{-1} below 1700 cm^{-1} replying amides or carboxylates function group as in 1602.90 cm^{-1}, and 1602.90 cm^{-1} inform double bond or aromatic compounds. Area around 786.02 and 673.18 cm^{-1} represent C-H aromatic compound and alkyl bind. In addition, it can be interpreted as Si-O-Si and Si-H reactive groups (Saleh et al., 2014).

As shown in Fig. (2), scanning electron microscope (SEM) images showed the surface morphology of biochar sample. It is clear that biochar surface contains many pores and canals with smooth surface and different size, which may be developed due to the thermal decomposition

Table 1. Some chemical and physical properties of soils used in the study

Soil	PH (1:2.5)	EC (1:2.5) dS/m	OM %	$CaCO_3$	CEC meq/100g	Sand %	Silt %	Clay %	texture
A	7.75	2.55	0.96	0.29	10.70	59	18	23	Sandy clay loam
B	8.66	2.63	0.86	28.99	9.73	79	5	16	Sandy clay loam

Soil A (Alsharqia governorate); Soil B (Burg Al Arab) area

Table 2. The amount of total and available content of heavy metals in soil A, soil B and SCBB

	Soil A	Soil B	Biochar
Total content of heavy metals mg.kg^{-1}			
Zn	182.25	142.25	127
Ni	75.25	78.00	8.90
Co	16.55	10.73	-
Cr	60.89	68.00	-
Mn	174.15	120.35	40.00
Cu	57.68	58.72	16.21
Fe	5005	5962	2480
DTPA extractable heavy metals mg.kg^{-1}			
Zn	40.12	20.42	1.80
Ni	17.61	10.54	0.07
Co	15.44	4.94	0.10
Cr	11.74	5.00	0.21
Mn	17.93	10.51	0.72
Cu	10.98	6.44	0.14
Fe	10.11	2.35	2.91

Table 3. Sugarcane bagasse biochar (SCBB) characteristics

pH* 1:20	EC** 1:20 dS/m	C	H	N	S	SA cm^2/g	CEC meq/100g	ASH content %
		%						
6.61	0.43	54.64	5.13	0.36	0.21	46.98	48.30	19.86

* In 1:20 biochar water suspension
** In 1:20 biochar water extract

cellulose and hemicelluloses and left of lignin, which is a very resistant to thermal degradation (Novotny et al., 2015). These results are in agreement with these obtained by El-Damarawy et al.. (2017).

<u>Effect of biochar application on heavy metals speciation in soil</u>

Figure 3 show the five fractions of Zn, Cu, Ni and Cr in soil after plant harvest with and without biochar treatment at different dosage of SCBB. As showed in the figure, the predominant fraction in the control of the two studied soils is residual fraction for three metals Cr, Zn and Cu, followed by carbonate fraction in soil B. However, for Ni, the predominant fraction was carbonate in soil B. After treatment, the percentage of residual fraction increased in the two soils for all elements followed by organic fraction.

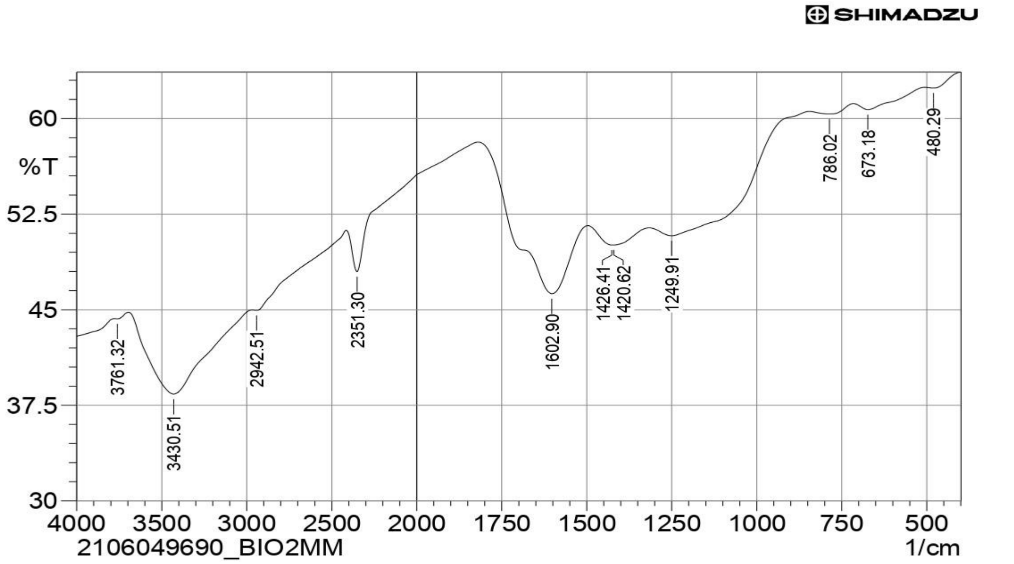


Fig. 1. Fourier-transform infrared spectra (FTIR) of the SCBB sample

Chromium

As shown in Fig 3 in soil A it is clear that exchangeable, carbonate and oxides-bound fractions of Cr decreased with increasing biochar dosage by 92.43, 63.68 and 39.14% for 2, 1 and 0.5% of applied SCBB, respectively. For exchangeable fraction, by 26.57, 7.11 and 5.93%, for 2, 1 and 0.5% of applied SCBB, respectively, for carbonate fraction, by 15.33, 12.24 and 7.82 for 2, 1 and 0.5% of SCBB, respectively, for oxide-bound fraction. Same trends were observed in soil B where the exchangeable fraction decreased by 90.63, 57.85, 11.07% for 2, 1 and 0.5% of applied SCBB, respectively. On the other hand, carbonate fraction decreased by 44.22, 26.39 and 23.45% for 2, 1 and 0.5% of SCBB dosage, respectively. The oxides-bound fractions of Cr decreased by 42.22, 24.93 and 15.14% for 2, 1, 0.5% of applied SCBB, respectively (Fig. 3).

Organic and residual fractions increased with increasing biochar dosage. For organic fraction, the increase was by 35.61, 30.24 and 17.33 % for 2, 1 and 0.5% of applied SCBB, respectively, compared to the control. The residual fraction increased by increasing biochar dosage by 3.13, 2.07 and 1.42% for 2, 1 and 0.5% biochar respectively, this was for soil A. In soil B, the organic fraction increased by 32.41, 26.79 and 5.62% for 2%, 1% and 0.5% biochar respectively. In addition, the residual fraction increased by 4.97%, 2.83% and 2.71%for 2%, 1% and 0.5% biochar dosage respectively (Fig. 3).

Zinc

Figure (4) illustrates the changes in zinc fractions as results of SCBB application to the two soils. The predominant Zn fraction in soil A is residual fraction followed by fractions bonded to oxides and organics. It is clearly that exchangeable, carbonate, and oxides-bound fractions decreased by increasing biochar dosage. For exchangeable fraction, the decrease was by 80.41, 29.55 and 25.82% for 2, 1 and 0.5% of SCBB dosage, respectively. For carbonate fraction, the percentage of decrease was by11.83, 28.25 and 18.61% for 2, 1 and 0.5% biochar treatment, respectively. For fraction of oxides-bound Zn, the decreases were by 35.75, 5.94 and 5.74% for 2, 1 and 0.5% biochar dosage, respectively. In soil B the predominant fraction was the residual followed by carbonate fraction then oxides-bound Zn. The decrease in exchangeable, carbonate, and fraction bound to oxides was by 95.25, 86.12 and 55.13%, 33.37, 16.10 and 11.42%, 24.81, 6.30 and 7.54% for 2%, 1% and 0.5% biochar treatments, respectively.

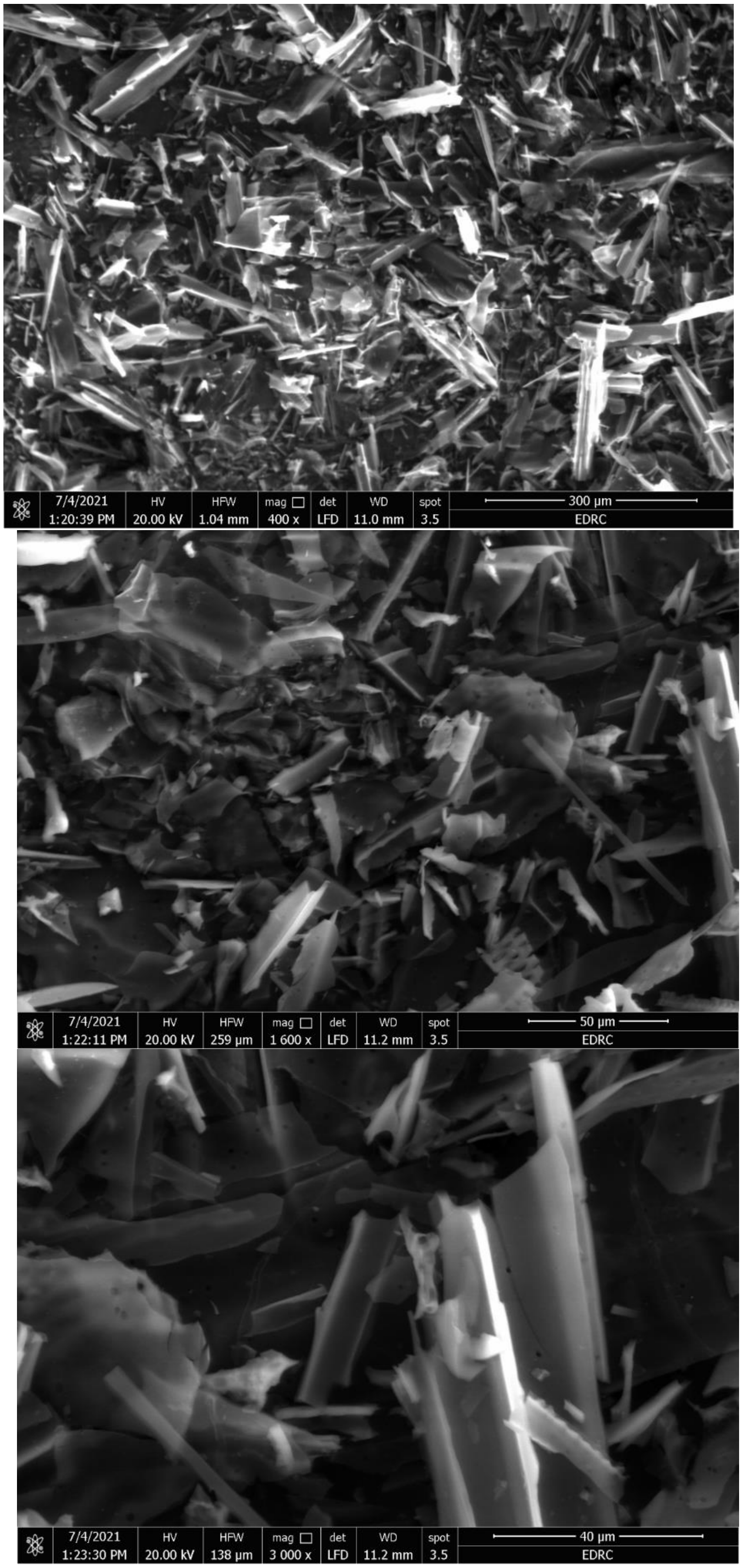
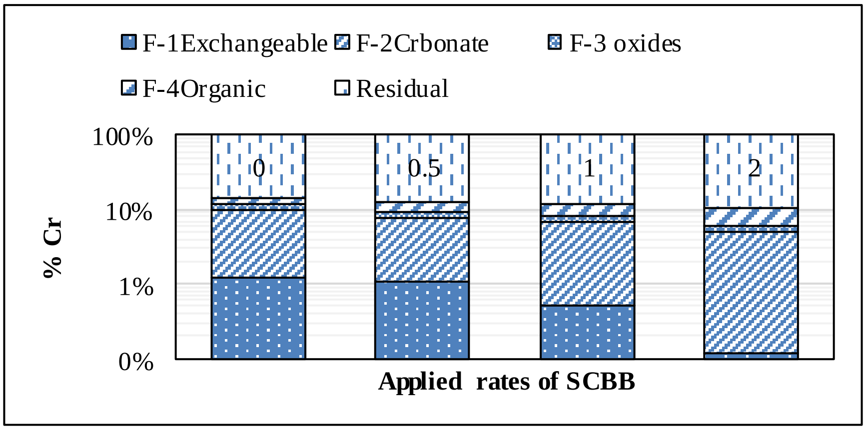
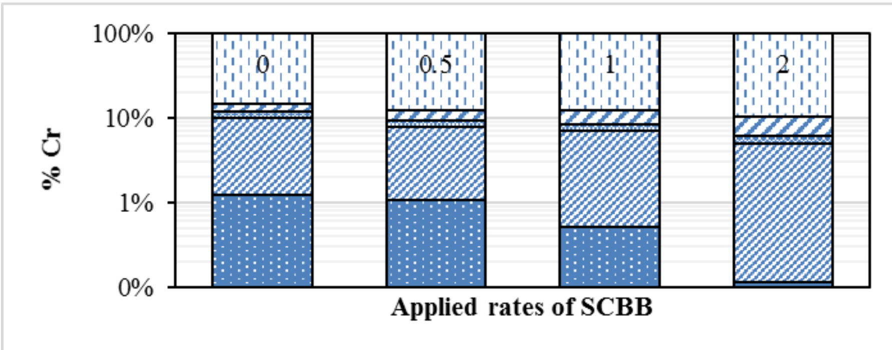


Fig. 2. Scanning electron microscope (SEM) images of sugarcane bagasse biochar (SCBB)

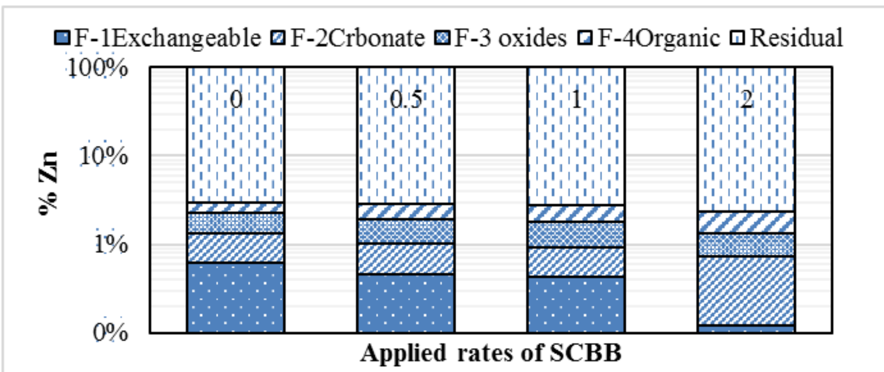


Cr in soil A

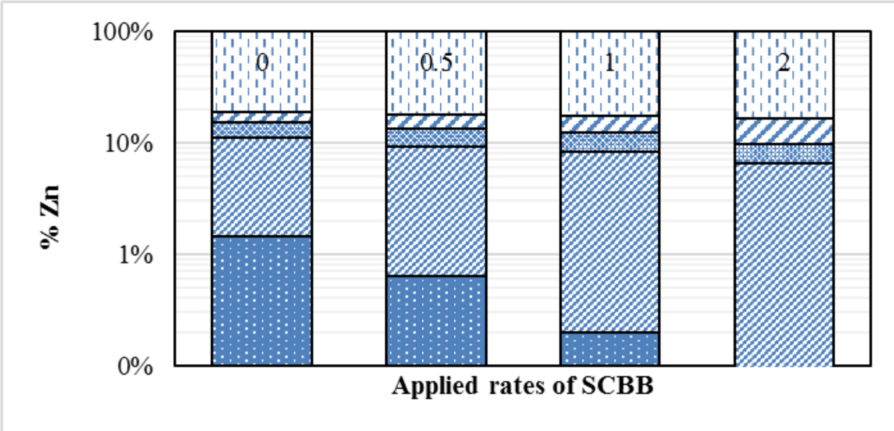


Cr in soil B

Fig.3. Changes in soil chromium fractions as result of sugarcane bagasse biochar (SCBB) application rate to the two soils A and B after plant harvest



Zn In Soil A



Zn in Soil B

Fig.4. Changes in soil zinc fractions as result of sugarcane bagasse biochar (SCBB) application rate to the two soils A and B after plant harvest

However, there were increases in the organic and residual fractions by 27.45, 20.10 and19.37% and 0.63, 0.38 and 0.16% for 2, 1 and 0.5% biochar dosage, respectively, in soil A. The increase percentages in soil B for organic and residual fraction were by 50.32, 33.11 and 24.44% and 2.76, 1.67 and 1.36% for 2, 1 and 0.5% biochar treatment, respectively.

Nickel

Figure (5) showed that the main Ni fraction is the residual followed by fractions bound to organics, carbonate and oxides. In soil A, the decreases in exchangeable, carbonate and oxides-bound fractions due to the addition of biochar was by 67.72, 64.46 and 5.6%, 36.00, 29.12 and 12.68%, 43.94, 38.07 and 4.40% for 2%, 1% and 0.5% biochar dosage, respectively. In soil B Ni found mainly in carbonate fraction followed by residual, organic and oxides-bound. The exchangeable, carbonate and oxide fractions decreased by 62.31, 61.06 and 46.57%, 38.64, 29.02, and 24.21%, 50.48, 53.64 and 44.56% for 2%, 1% and 0.5% SCBB dosage. On the other hand, addition of biochar caused increase in organic and residual fraction by 23.80, 18.71 and 13.00%, 25.83, 4.16 and 16.15% for 2%, 1% and 0.5% of applied biochar, respectively in soil A. Results of soil B showed that organic and residual fractions increased by 19.90, 6.75 and 1.92%, 27.90, 24.81 and 24.63% for 2%, 1% and 0.5% biochar, respectively.

Copper

Figure (6) showed that speciation of soil Cu indicated that the main fraction is the residual. The decrease in the exchangeable, carbonate and oxide fractions was by 82.97, 77.66 and 76.44%, 24.99, 13.21, and 9.59%, 33.81, 31.47 and 18.71% for 2%, 1% and 0.5% SCBB dosage, respectively in soil A. Cu fractions in soil B are dominated by residual followed by organic then oxides fractions. The decrease in the exchangeable, was by 99.53, 98.60 and 80.84%, in carbonate-Cu was 22.31, 5.48 and 2.93% and in oxides-bound Cu was 23.7, 15.13 and 12.83% for 2%, 1% and 0.5% biochar dosage respectively. The application of SCBB to soil caused increase in organic and residual fractions by 54.66, 53.05 and 36.80% and 1.47, 1.29 and 1.59% for 2%, 1% and 0.5% SCBB dosage, respectively, in soil A. The increase of these fractions in soil B was by 20.93%, 17.64%,18.17%,4.27%,2.92%, and 1.96% for 2%, 1% and 0.5% biochar dosage respectively.

These results demonstrated that exchangeable, carbonate and oxides-bound fractions of Cr, Zn, Ni and Cu decreased with increasing in applied rate of SCBB, while the residual and organic fraction increased. The current results agree with (Xu et al., 2014). This means that treating of the soil with biochar change soil heavy metals speciation due to change some chemical and physical properties (Yang et al., 2014). Decreasing the exchangeable fraction means decrease the available and mobile content of heavy metals. The reduction in oxides-bound fraction by addition biochar may be due the increase in soil aeration and increase soil aggregation thus encouraging microbial activity, which can solubilize fraction bound to oxides, this result in agreement with result obtained by (Nie et al., 2018). The reduction in carbonate fraction may be attribute with little drop in pH value after addition of SCBB with low pH value (6.61) to soil A. However, the reason is not clear in soil B (Nie et al., 2018). Residual fraction is considered invalid fraction and does not easy to use by living organisms (Chen, 2005). The reason for the increase of residual and organic fractions demonstrated by some previous studies as (Yuan et al., 2016; Lu et al., 2017) who elevated that addition biochar to soil increase the nutrient elements such as P, Ca and Si which may cause the immobilization of Cr, Zn. Ni and Cu by forming insoluble precipitation or co-precipitation.

High biochar surface area and presence of functional groups, which contain double and triple bounds, contribute to metals stabilization (Abdelhafez et al., 2014). Also, Abdel-Fattah et al. (2015) reported that biochar increases organic matter and cation exchange capacity which increase complexation of soil heavy metal ions, and thus decrease available content of heavy metals. Biochar application increases soil organic matter (Saleh et al., 2020), which stimulate transformation of the available and less available metals to residual fractions (Xu et al. 2012).

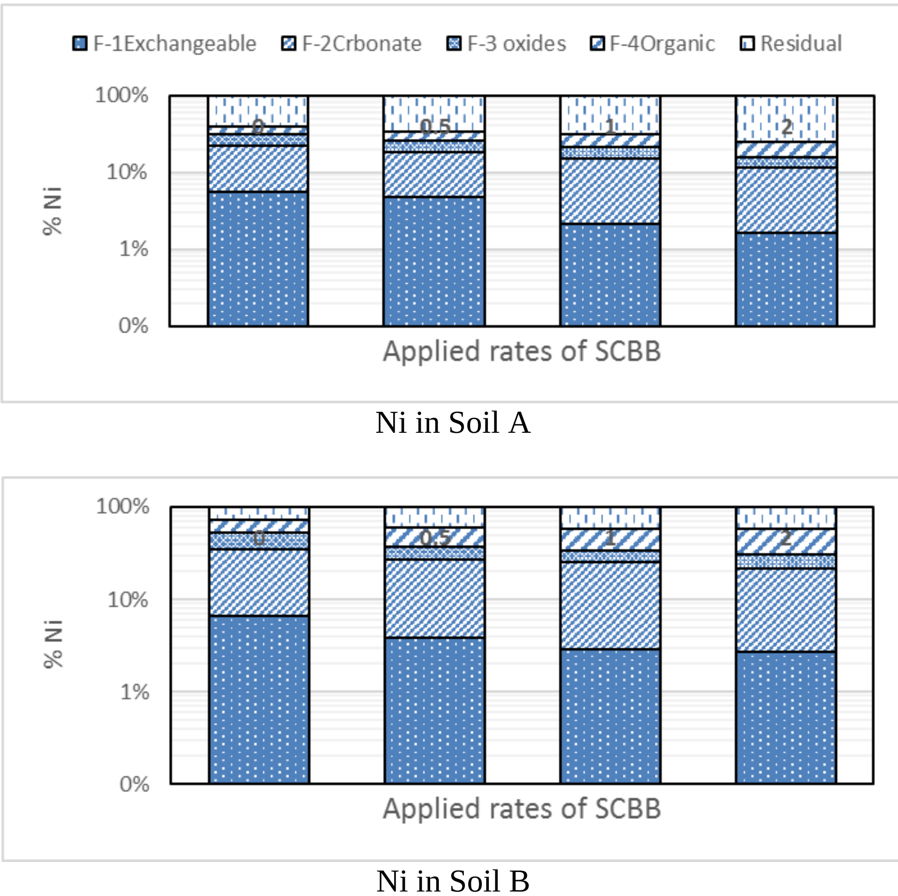
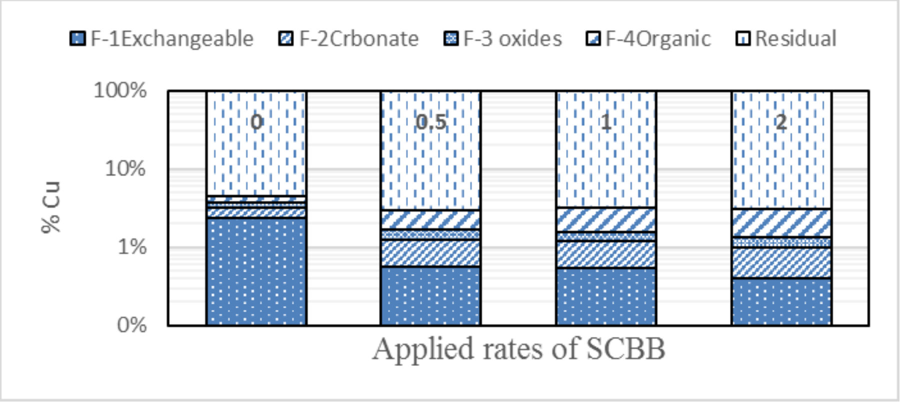
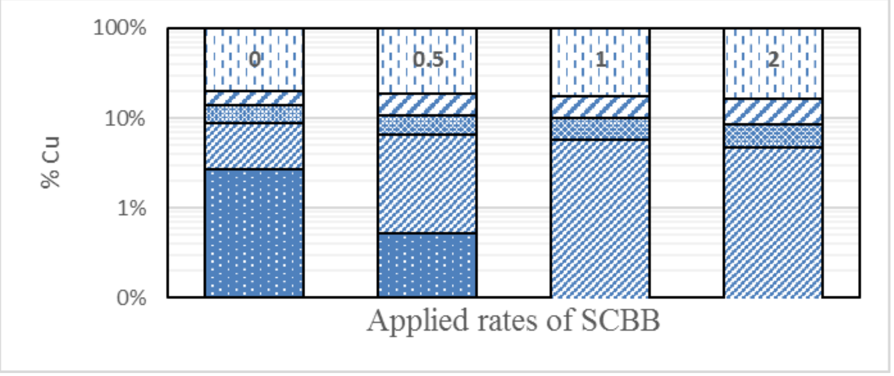


Fig.5 Changes in soil nickel (Ni) fractions as result of sugarcane bagasse biochar (SCBB) application rate to soil A and B



Cu in soil A



Cu in soil B

Fig. 6 Changes in soil zinc fractions as result of sugarcane bagasse biochar (SCBB) application rate to soils A and B

<u>Effect of biochar on DTPA-extractable heavy metals in soil</u>

Fig (7) showed a decreasing in DTPA-extractable concentrations of Cr, Zn, Ni and Cu in soil A and B according to different dosage of biochar compared to control. The data demonstrate that the metals availability decreased with addition of SCBB that can be related to high surface area and presence of exchangeable sites, which retained these elements and decreased their bioavailability (Fellet et al., 2014). The decreasing in availability increased with increasing application rate of SCBB ,which agreed with the results presented by Puga et al. (2015b) who studied the effect of different dosage of sugarcane straw biochar on availability of some heavy metals. The decreases in DTPA- extractable of Cr, Ni, and Cu in soil B was higher than in soil A, which may be due to that soil B has higher pH (7.88-7.96) than soil A (7.43-7.48) after plant harvest which encourage increase residual fraction (precipitation) and decrease availability (Zhu et al., 2015).

<u>Effect of biochar treatment on plant uptake of heavy metals</u>

Tables 4 and 5 shows the concentration of Cr, Zn, Cu and Ni in shoot and root in radish plant. It obvious the decrease in heavy metals content in shoot and root of plant with increasing the addition rate of SCBB.

The percentage reduction in concentration of Zn in shoot were 5.40, 8.63, and 11.95% and in root 2.57, 12.25, 17.28 % in soil A compared to control and by 2.16, 6.32, and 12.62% in shoot and in root was by 23.13, 31.25 and 64.06 % in soil B for biochar application rates 0.5, 1 and 2%, respectively.

For Cu the reduction concentration in shoot was by 3.17, 6.25 and 31.54%, however in root was by 33.78, 60.19, and 74.90 in soil A. Whereas, in soil B, the reduction was by 1.86, 13.96, and 30.89 in shoot, 5.47, 13.57, and 52.43% in root.

The reduction in Ni concentration was by 39.23, 47.15, and 84.66% in shoot however in root was by 42.17, 66.53 and 71.04% in soil A and by 22.41, 54.35, and 86.02 % in shoot and 34.55, 44.32, and 65.21% in root of soil B with application rate of SCBB 0.5, 1 and 2% respectively.

For Cr the reduction in concentration was by 19.88, 35.02 and 53.33 in shoot, however in root was by 3.96, 26.55, and 43.96 % in soil A and by 5.68, 34.12 and 39.79% in shoot and by 23.47, 57.29, and 66.51% in soil B for biochar treatment 0.5, 1, 2% respectively.

These results demonstrated the important role of biochar in reduction the concentration of Zn, Cu, Cr and Ni in plant, as a result of immobilization of these heavy metals in soil and reduce its bioavailability. This is in agreement with Hegab et al. (2016), Nie et al. (2018) and Zhu et al. (2015). In addition, Yang et al. (2017) who used tobacco stalk and dead pig biochars to decrease the content of Cd and Zn in tobacco plants, the results showed significant effective by the biochar application rate.

Table (6) showed that, there was a positive and significant correlation ($p < 0.05$ or 0.01) among all combinations of the studied parameters, except available after planting with total soil after planting, shoot and root of plants grown in Burg Al Arab location.

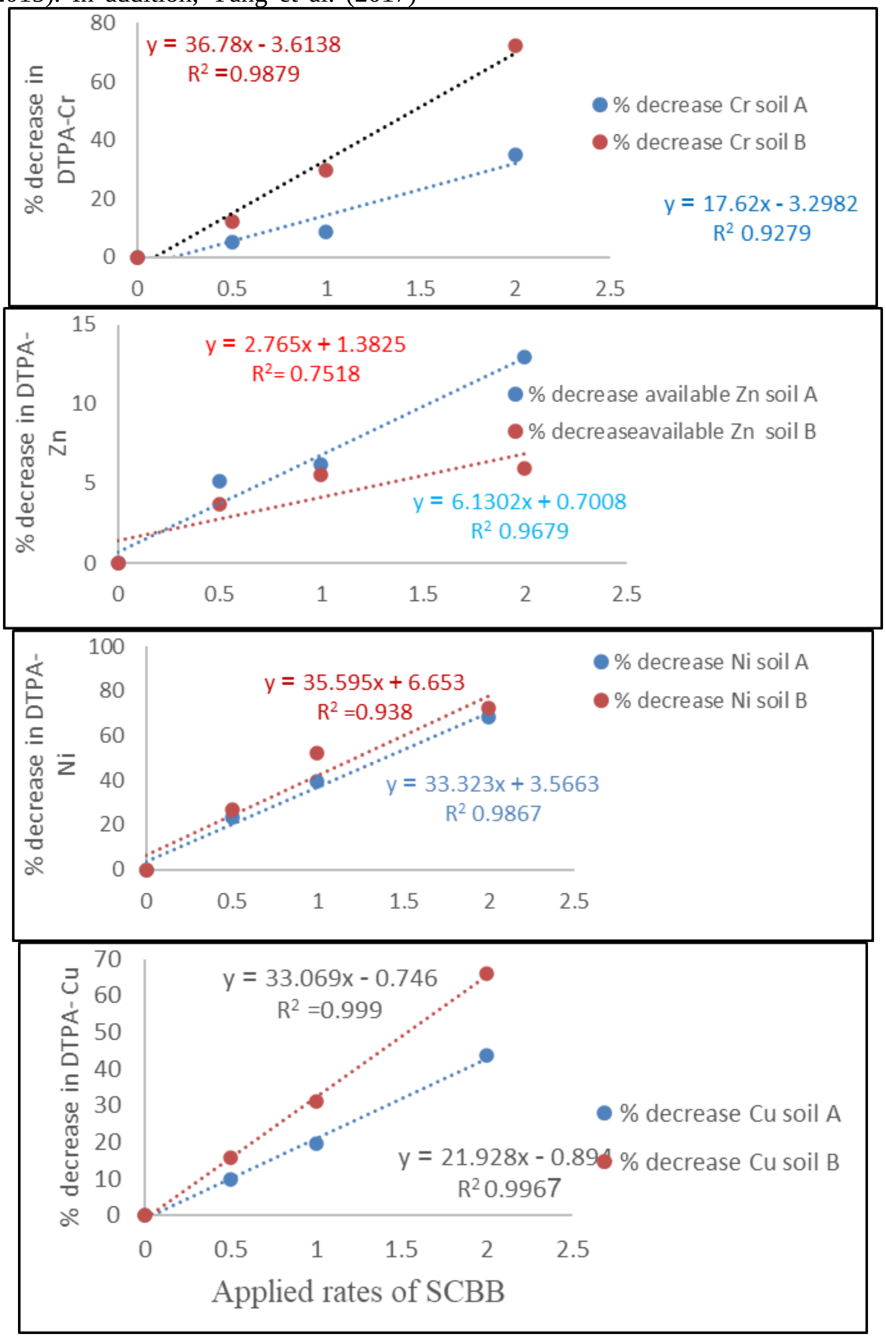


Fig 7. effect of sugarcane bagasse biochar (SCBB) on DTPA-extractable heavy metals in soils A and B

Table 4. Effect of biochar dosage on heavy metals content in shoot of radish plant

Biochar treatment %	Heavy metals in radish plant shoot (mg/kg)							
	Zn		Cu		Ni		Cr	
	Soil A	Soil B	Soil A	Soil B	Soil A	Soil B	Soil A	Soil B
0	7.255	5.693	11.35	2.729	12.26	11.02	8.85	3.87
0.5	6.863	5.570	10.99	2.678	7.45	8.55	7.09	3.65
1	6.629	5.333	10.64	2.348	6.48	5.03	5.75	2.55
2	6.388	4.974	7.77	1.886	1.88	1.54	4.13	2.33
Mean	6.784	5.393	9.94	2.410	7.02	7.51	6.46	3.10
LSD at	0.05	0.01	0.05	0.01	0.05	0.01	0.05	0.01
Locations	0.54*	0.75**	0.63*	0.88**	0.44*	0.60**	0.19*	0.26**
SCBB	0.77*	1.07**	0.90*	1.24**	0.62*	0.86**	0.26*	0.36**
Interaction	1.09*	1.51**	1.27*	1.76ns	0.87*	1.21**	0.37*	0.52**

Statistically significant differences at nsp> 0.05, *p < 0.05 and **p < 0.01.

Table 5. Effect of biochar dosage on heavy metals content in Root of radish plant (*Raphanus sativus*)

Biochar	Heavy metals in Root (mg/kg)							
	Zn		Cu		Ni		Cr	
%	Soil A	Soil B	Soil A	Soil B	Soil A	Soil B	Soil A	Soil B
0	8.395	7.464	21.28	24.68	25.49	33.66	11.60	15.29
0.5	8.179	5.737	14.09	23.33	14.74	22.03	11.14	11.70
1	7.366	5.131	8.47	21.33	8.53	18.74	8.52	6.53
2	6.944	2.682	5.34	11.74	7.38	11.71	6.50	5.12
Mean	7.721	5.253	14.54	21.27	14.78	21.28	9.44	9.91
LSD at	0.05	0.01	0.05	0.01	0.05	0.01	0.05	0.01
Locations	0.83*	1.15**	0.88*	1.22**	0.56*	0.77**	0.42*	0.58ns
SCBB	1.17*	1.62**	1.24*	1.72**	0.79*	1.10**	0.59*	0.82**
Interaction	1.65*	2.29**	1.76*	2.44**	1.12*	1.55**	0.83*	1.16**

Statistically significant differences at nsp> 0.05, *p < 0.05 and **p < 0.01.

Table 6. Pearson correlation between measurements of elements in soil A and soil B

Soil A / Soil B	Total after planting	DTPA-extracted after planting	Shoot	Root
Total soil after planting		0.02	0.97**	0.95**
DTPA-extracted after planting	0.48*		0.22	0.06
Shoot	0.97**	0.63**		0.93**
Root	1.00**	0.48*	0.98**	

Statistically significant differences at nsp> 0.05, *p < 0.05 and **p < 0.01.

Conclusion

Sugarcane bagasse biochar (SCBB) is a good tool to immobilize heavy metals in soil through changing their fractions in soil. In this study exchangeable, carbonate fractions and fractions bound to oxides for Cr, Zn. Ni and Cu decreased with increase in biochar dosage, however the residual and organic fraction was increased. The effect of biochar is related to its high surface area and presence of functional groups, which contain double and triple bounds, contribute to metals stabilization. Increase biochar rate significantly reduced the amount of DTPA – extracted metals in soil. It is also a clear that concentration of elements in shoot and root in radish plant significantly decreased with increase biochar dosage.

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الملخص العربي

تأثير الفحم الحيوي على السلوك الكيميائي للعناصر الثقيلة وامتصاص نبات الفجل النامي في أراضي ملوثة

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يهدف هذا البحث إلى دراسة تأثير الفحم الحيوي لتفل قصب السكر على السلوك الكيميائي لبعض المعادن الثقيلة، الزنك والنيكل والكروم والنحاس، وذلك من خلال تجربة التعرف على الصور الكيميائية لهذه المعادن في تربة ملوثة من محافظة الشرقية (التربة أ) والتي تروى بشكل رئيسي بمياه الصرف الصحي من مصرف بحر البقر، و(التربة ب) من برج العرب، محافظة الإسكندرية، بالإضافة إلى ذلك تمت دراسة المحتوى المستخلص كيميائيا لهذه المعادن في التربة بعد معاملة التربة بمعاملات مختلفة من الفحم الحيوي (٠.٥و١و٢٪)، عن طريق تجربة الزراعة في أصص لنبات الفجل كمؤشر حيوي، وأظهرت النتائج أن المعادن الموجودة في الصورة المتبادلة والصورة المرتبطة بالكربونات والمرتبطة بالأكاسيد قد انخفضت مع زيادة جرعة الفحم الحيوي، وعلى العكس من ذلك كانت الصورة العضوية والمتبقية؛ وكنتيجة لانخفاض التركيز المستخلص كيميائيا لكل من الزنك والنيكل والنحاس والكروم مع زيادة معدل الفحم الحيوي المضاف للتربة انخفضت تركيزات المعادن الثقيلة في أوراق وجذور نبات الفجل مع زيادة جرعة الفحم الحيوي. وترى الدراسة أن كل من مساحة السطح العالية والمجموعات الوظيفية السطحية للفحم الحيوي قد لعبت دورا هاما في تثبيت واستقرار المعادن الثقيلة في الصورة العضوية والمتبقية في التربة وهي الأكثر ثباتا بالتربة.

الكلمات المفتاحية : الفحم الحيوى لتفل قصب السكر, الأراضى الملوثة, الصور الكيميائية للمعادن الثقيلة, التيسر الحيوى