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REDUCING AVAILABILITY OF SOME HEAVY METALS IN A CONTAMINATED SOIL USING PHOSPHATE ROCK AND BENTONITE AMENDMENTS

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ABSTRACT

The present work was carried out to assess the immobilization efficiency of some amendments induced some heavy metals in contaminated soil. Two types of amendments phosphate rock and bentonite were mixed with soil at different rates 1, 2, 4, 6 and 8 ton fed^{-1}, then incubated with soil samples at periods of 20, 30 and 60 days in three replicates, then seeded maize (*Zea maize*) after incubation of soil to monitoring reducing values of available heavy metals in plant and soil.

The obtained data showed that:

- Both applied phosphate rock and bentonite succeeded in reducing the availability of (Cu, Zn, Mn and Pb) as well as that phyto-availability to the grown plant of maize. Available heavy metal contents showed a tendency to decrease by increasing the applied amendment levels.
- Lower values of available (Cu, Zn, Mn and Pb) could be obtained as a result of application of phosphate rock and bentonite at rates of 6 and 8 ton/fed., respectively, after 60 days of incubation.
- The important role of phosphate rock and bentonite application for improving soil physical and chemical properties.
- The previous beneficial effects of studied amendments were actually reflected on increasing the plants ability for improving the vegetative growth parameters, i.e., fresh weights and dry weights of shoots and roots yields, with similar parallel trends for the heavy metals immobilization in soil and uptake by plant organs (shoots and roots) .
- Likewise, phytotoxicity of (Cu, Zn, Mn and Pb) alleviated rather easily by increasing the levels of phosphate rocks and bentonite at rates of 6 and 8 ton/ fed., respectively, after 60 days or incubation.

Keywords: Phosphate rock, betonite, availability, heavy metals.

INTRODUCTION

Remediation of heavy metals in contaminated soils is necessary in order to alleviate their potential risks that pose to both environment and human health. Clay minerals and other amendments play an important role in the chemical behavior of heavy metals in soil. Decomposition of organic matter is followed by formation of active groups which have the ability to retain the metal in the complex and chelated form. The chemical behavior of the metal changed from cation to anion as well as the release of organic acids which reduced the soil pH by Traina and Logan (1993).

Depending on the source, soil application of phosphate can cause direct adsorption of metals onto these compounds through increased surface charge and enhanced anion-induced metal adsorption. Adsorption of metals onto hydroxyapatite surfaces has been observed for a number of metals including Cd, and Zn. Traina *et al*. (1994).

Homenauth and McBrid (1994) indicated that treating of contaminated soils with certain amendments that enhance key biochemical processes in soils that effectively immobilize heavy metals have already been treated with bentonite and phosphate rock amendments. Such soil chemical amendments enhanced natural remediation and resulting in substantially improved plant growth and reduced offsite metal transport. The immobilization efficiency induced by such assisted natural remediation may be offered some potential. A suite of chemical amendments are available to monitor the efficiency of assisted natural remediation as well as such technique is now available ensuring the long-term efficiency of a chosen cleanup tool.

The application of phosphate and bentonite amendments to contaminated soils has been identified as a potentially efficient remediation method, (Cao *et al*., 2003). This technique is to immobilize metals primarily through the formation of metal phosphates which reduced solubility and enhanced geochemical stability in a wide range of environmental conditions. Precipitation appears to be the predominant process of metal immobilization in the presence of different anions, i.e. carbonate, hydroxide and phosphate, especially when the concentration of metal ion is high, (Adriano, 2001).

Ciecko *et al*. (2005) showed that the addition of compost, brown coal, lime and bentonite reduced the undesirable effect of cadmium contamination on the plants, on the other hand, the amount of magnesium increased in all the examined parts of the oats, in the above-ground parts of yellow lupine and radish as well in the roots of maize as a result of soil contamination with cadmium.

Csillag and Lukcas (2006) stated that addition of phosphate rock generally decreased heavy metal concentrations in the soil solution, due to its pH elevating immobilizing effect. Except for Pb, extreme acid treatment compensated for the immobilizing effect of phosphate rock. Usman *et al*. (2006) investigated the additions of clay minerals (Na- bentonite, Ca bentonite and zeolite), Fe oxides (hematite and goethite) and phosphate fertilizers (super-phosphate and Novaphos) on the heavy metal contents in the shoots of wheat plant. The results indicated that the labile fraction of heavy metals reduced due to the addition of Na- bentonite and Ca bentonite by 24 % and 31% for Zn, by 37 % and 36 % for Cd, by 41% and 43 % for Cu, by 54 % and 61% for Ni, and by 48 % and 41% for Pb, respectively., However, the addition of phosphate fertilizers strongly reduced the bioavailability of heavy metals for wheat plants.

Herwijnen *et al*. (2007) showed that the metal immobilization and bioavailability are governed by the formation of complexes between the metals and organic matter. Also, Kireicheva *et al*. (2009) found that the application of bentonite to the heavy metal-contaminated soils had a positive effect on the soil's agrochemical properties and production processes. They also added that a decrease in heavy metal concentration was noted in the biomass of oats, which depends substantially on the level of soil contamination in the name of the metal. Chen *et al*. (2009) indicated that the phosphate amendments converted significant amount of the soil Pb, Zn and Cd from exchangeable to organic bound, carbonate bound, amorphous Fe and Al oxides bound and non- residual fractions. The present investigation was carried out to study the immobilization efficiency of some amendments induced some heavy metals in a contaminated soil

MATERIALS AND METHODS

A. Soil:

A soil sample was collected from the 0-30 cm surface layer at the agricultural farm of EL-Gabal EL-Asfar that is located adjacent to Greet Cairo, Egypt. This soil irrigated continuously with sewage effluent for about 80 years. Soil sample was air dried and then ground to pass through a 2mm sieve. Some physical and chemical analyses were carried out according to the standard methods undertaken by Black. (1965) and Page *et al*., (1982), the results are shown in Table 1. Also, available Cu, Zn, Mn and Pb were determined in the experiment soil using ammonium bicarbonate-DTPA extractable according to Soltanpour and Schwab (1977) and their contents in the obtained extract were measured by atomic absorption spectrophotometer.

B. Amendments:

Two types of amendments were used phosphate rock and bentonite: pretreatment of samples for mineralogical analysis was carried out according to Black (1965), and the identification of the clay minerals in the separated clay was conducted by X -ray diffraction using Philips goniometry type PW 1830.

Table 1. Some physical and chemical properties of the soil.

Soil Properties	value
Particle size distribution %	
Coarse sand	56.32
Fine sand	21.54
Silt	9.92
Clay	12.22
Textural class	Sandy loam
O.M. %	2.71
$CaCO_3$ %	1.23
pH (soil past extract)	7.62
EC dS m^{-1}	1.13
Soluble ions (meq L^{-1})	
Ca^{++}	2.45
Mg^{++}	1.55
Na^{++}	5.53
K^{+}	0.54
CO_3^{--}	0.00
SO_4^{--}	2.27
Cl^{-}	5.85
HCO_3^{-}	1.95
Heavy metals ppm (available)	
Cu	16.02
Zn	65.13
Mn	27.80
Pb	14.10

Table 2: Some chemical analysis of the used materials phosphate rock and bentonite:

Amendments	P_2O_5 %	CaO %	SiO_2 %	Fe_2O_3 %	AL_2O_3 %	MgO %	K_2O %	MnO %
Phosphate rock	25.06	41.08	6.65	4.17	0.76	2.05	0.20	0.23
Bentonite	6.8	3.7	50.0	7.0	20.0	0.6	2.4	0.6

C- Experiments:

Out door experiment were carried out in the farm of Agriculture Faculty, Al-Azahr University during the summer season of 2009. Using soil samples were collected from EL-Gabal- EL-Asfar farm located at 25 km northeast Cairo, Egypt, using plastic pots 30 cm inside diameter, 35 cm depth and contain 10 kg soil. Soils were mixed with phosphate rock and bentontie at different rates (1, 2, 4, 6 and 8 ton/fed), then incubated at periods of (20, 30 and 60 days) in three replicates, beside the untreated soil (control treatment). All pots were conducted in a split-split design, during soil incubation the moisture content of the pots were kept at the field capacity, then seeded maize (*zea maize*) after incubation periods with amendments of soil. Five plants in each pot were planted on the 30th March. During the growth the moisture content adjusted at field capacity. The conventional agricultural practices, especially the fertilization with the recommended doses of N and K, were applied. Plant shoots and roots were harvested after 60 days from planting, at which time there was sufficient plant material for analysis. Plant organs were rinsed in distilled water and then dried at 60-70° for 24 hr, dry weights were recorded. The plant samples were ground and wet digested with acids mixture (HNO_3 and $HC1O_4$) according to Jackson (1973). Heavy metals under investigation (Cu, Zn, Mn and Pb) in clear digested solutions were determined using Perkin Elmer Inductively Coupled Spectrophotometer Plasma 400 (ICP). At the same time, DTPA extractable contents of the studied heavy metals were determined, as mentioned before, at harvest to evaluate the response of their potential mobility and biological uptake by grown plants to the applied chemical amendments.

RESULTS AND DISCUSSION

1. Effect of phosphate rock on available Cu, Zn, Mn and Pb in soil.

Data in Table 3 represent the available and % of the residual in soil from native Cu, Zn, Mn and Pb as affected by different levels of phosphate rock after 20, 30 and 60 days of incubation at rates of (1, 2, 4, 6 and 8 ton fed^{-1}). The results show that the available amounts of Cu, Zn, Mn and Pb were reduced with increasing time of incubation and with increasing rates of applied phosphate rock compared with the control. However the data revealed that the lower values of available Cu, Zn, Mn and Pb could be obtained as a result of application of phosphate rock at 6 and 8 ton fed^{-1} after 60 days of incubation. Whereas, the unavailable values of Cu, Zn, Mn and Pb reached to 40 %, 35 %, 55% and 40 %, respectively. This could be due to the important role of phosphate rock to retain heavy metals in soils as unavailable form. These results may be attributed to the formation of stable form compounds with a wide range of cationic contaminants or immobilization of heavy metals as oxide, hydroxide or phosphate. These findings are in agreement with those of Csillag and Lukcas (2006); who found that addition of phosphate rock generally decreased heavy metal concentrations in the soil solution, due to the immobilizing effect of phosphate rock. Also, Chen *et al*., (2009) indicated that the phosphate amendments converted significant amounts of the soil Pb, Zn and Cd from exchangeable to organic bound, Carbonate bound, amorphous Fe and Al oxides bound and non- residual fractions. The results suggested that phosphate rock had directly greater potential to immobilize Cu, Zn, Mn and Pb in the studied contaminated soil at 6 and 8 ton/fed after 60 days of incubation. The ability of phosphate rock to immobilize heavy metals under consideration in contaminated soil through precipitation as metal- phosphate compounds had been well documented by Bolan *et al*. (2003). The heavy metals could be represented the following Mn > Pb > Zn > Cu.

Table 3. Effect of phosphate rock on available and % of the residual from native of Cu, Zn, Mn and Pb in soil at different periods.

Incubation period	phosphate rock ton fed^{-1}	Available ppm				% of the residual from native			
		Cu	Zn	Mn	Pb	Cu	Zn	Mn	Pb
20 days	control	16.02	65.13	27.80	14.10	100	100	100	100
	1	16.00	62.30	25.11	14.10	99.87	95.65	90.32	100
	2	15.10	62.21	24.60	13.81	94.25	95.51	88.48	97.94
	4	14.12	61.35	24.32	13.61	88.13	94.19	87.48	96.52
	6	14.09	61.30	23.61	13.55	87.95	94.11	84.92	96.09
	8	14.00	60.80	22.31	13.50	87.39	93.35	80.25	95.74
40 days	1	12.61	57.62	18.91	13.71	78.71	88.46	68.02	97.23
	2	11.65	57.55	17.80	13.50	72.72	80.36	64.02	95.74
	4	11.42	48.91	15.62	12.61	71.28	75.09	56.18	89.43
	6	10.10	48.60	14.27	11.33	63.04	74.62	51.33	80.35
	8	10.11	47.31	14.23	11.20	63.10	72.63	51.18	79.43
60 days	1	11.69	46.60	15.52	10.61	72.97	70.01	55.82	75.24
	2	10.30	44.61	14.56	10.32	64.29	68.49	52.37	73.19
	4	10.29	43.50	13.91	9.16	64.23	66.78	50.03	64.96
	6	9.75	42.45	13.80	8.35	60.86	65.17	49.64	59.21
	8	9.70	42.50	12.66	8.21	60.54	65.25	45.53	58.22
after harvesting	1	10.92	40.80	16.51	9.61	68.16	62.64	59.38	68.15
	2	9.65	35.81	15.60	9.50	60.23	54.48	56.11	67.37
	4	9.33	33.90	13.91	8.83	58.23	52.04	50.03	62.62
	6	7.35	28.31	12.30	7.90	45.88	43.46	44.24	56.02
	8	7.18	28.16	12.15	7.81	44.81	43.23	43.70	55.39

2. Effect of bentonite on available Cu, Zn, Mn and Pb in soil.

Data in Table 4 represent the available and % of the residual in soil from native Cu, Zn, Mn and Pb as affected by different levels of bentonite after 20, 30 and 60 days of incubation at rates of (1, 2, 4, 6 and 8 ton fed^{-1}). The results showed that the available amounts of Cu, Zn, Mn and Pb were reduced with increasing time of incubation and with increasing rates of applied bentonite compared with the control. However, data revealed that the lower values of available Cu, Zn, Mn and Pb could be obtained as a result of bentonite application at the rate of 6 and 8 ton fed^{-1} after 60 days of incubation. Whereas the unavailable values of Cu, Zn, Mn and Pb reached to 45 %, 40 %, 55% and 49 %, respectively. This pointed out the important role of bentonite application, which significantly reduced the solubility of heavy metals in contaminated soil. These results are in agreement with those of Abd-Elhady (2007); who recorded that the application of surfactants to clay minerals succeeded to enhance retention of organic pollutants. He also, added that clay was an important soil component in the adsorption of metals. Also, Herwijnen *et al*. (2007); suggested that metal immobilization and bioavailability are governed by the formation of complexes between the metals and organic matter.

Table 4. Effect of bentonite on available and % of the residual from native of Cu, Zn, Mn and Pb in soil at different periods.

Incubation period	Bentonite ton fed^{-1}	Available ppm				% of the residual from native			
		Cu	Zn	Mn	Pb	Cu	Zn	Mn	Pb
20 days	Control	16.02	65.13	27.80	14.10	100	100	100	100
	1	15.12	63.18	25.34	14.00	94.39	97.00	91.15	99.29
	2	15.08	63.15	25.23	13.89	94.13	96.95	90.75	98.51
	4	14.88	63.10	25.10	13.80	92.88	96.88	90.28	97.87
	6	14.70	62.17	24.66	13.37	91.76	95.45	88.70	94.82
	8	14.30	62.16	24.21	13.32	89.26	95.43	87.08	94.48
40 days	1	12.60	47.30	21.21	13.80	78.65	72.62	76.29	97.87
	2	11.33	45.80	20.11	13.37	70.72	70.32	72.33	94.82
	4	10.90	42.80	19.30	12.81	68.03	65.71	69.42	90.85
	6	9.82	41.50	17.29	12.32	61.29	63.71	62.19	87.37
	8	9.43	39.41	14.18	11.31	58.86	60.50	51.00	80.21
60 days	1	10.92	41.81	15.22	10.11	68.16	64.19	54.74	71.70
	2	9.85	41.30	14.32	9.85	61.48	63.41	51.51	69.85
	4	9.55	40.22	13.68	8.32	59.61	61.75	49.20	59.00
	6	8.37	39.42	12.48	7.20	52.24	60.52	44.89	51.06
	8	8.11	38.30	12.31	7.19	50.62	58.80	44.28	50.9
after harvesting	1	9.93	40.60	15.16	9.47	61.98	58.80	54.53	67.16
	2	9.81	36.60	14.15	9.42	61.23	56.19	50.89	66.80
	4	9.43	35.81	13.43	8.19	58.86	54.98	48.30	58.08
	6	8.30	33.63	12.21	7.10	51.63	51.63	43.92	50.35
	8	8.10	33.60	12.13	6.18	51.58	51.58	43.63	43.82

3. Effect of amendments application on dry matter yield of maize after incubation in soil.

Data in Table 5 show that the dry matter yield of roots and shoots of maize after incubation of phosphate rock and bentonite in the contaminated soil samples were extremely higher than the control. The results conclude that the relative dry weight of roots and shoots of maize after incubation of phosphate rock were in treatment No. 1 (101.65) and (100.81%) then increased gradually until reached (138.03) and (115.05) with treatments No. 5 respectively. The same remark was found regarding the roots and shoots of maize after incubation of bentonite were in treatments No. 1 (101.24%) and

(100.82%) then increased gradually until reached (137.39) and (119.67) with treatments No. 5 respectively. This emphasized the effective role of the different treatments particularly treatment No. 4 and 5 for increasing the biomass production in soils after incubation with phosphate rock and bentonite. These results confirm again the important role of application of phosphate rock and bentonite for improving soil contaminated with heavy metals on the contrary lower uptake of heavy metals by maize roots and shoots after incubation of phosphate rock and bentonite in contaminated soils than in roots and shoots of the control. This remark insured the important role of application amount to reduce solubility and concentration of heavy metals, which could led to low plant uptake of heavy metals in contaminated soils. Similar results obtained by Ciecko *et al*. (2005).

Table 5. Effect of amendments application on dry matter yield of maize after incubation in soils at different periods.

Treatment ton fed^{-1}		D.W. gm pot^{-1}	The relative yield	Concentration ppm				Uptake µg pot^{-1}			
				Cu	Zn	Mn	Pb	Cu	Zn	Mn	Pb
Phosphate rock		Roots of maize									
Phosphate rock	control	7.23	100	4.60	3.65	2.91	5.66	33.25	26.30	21.30	40.92
Phosphate rock	1	7.35	101.65	2.15	2.31	2.60	2.53	15.80	16.97	19.11	18.59
Phosphate rock	2	7.50	103.73	2.13	2.12	2.58	2.51	15.97	15.97	19.35	18.82
Phosphate rock	4	8.67	119.91	1.11	0.98	1.59	1.42	9.62	8.49	13.00	12.31
Phosphate rock	6	9.63	133.19	0.82	0.89	1.49	1.41	7.89	8.57	14.34	13.57
Phosphate rock	8	9.98	138.03	0.83	0.89	1.48	1.39	8.28	8.88	14.77	13.87
Phosphate rock		Shoots of maize									
Phosphate rock	control	19.60	100	3.56	3.11	1.92	3.52	69.77	60.95	37.63	68.99
Phosphate rock	1	19.76	100.81	2.27	2.71	1.23	2.11	44.85	53.54	24.30	41.69
Phosphate rock	2	20.81	106.17	1.98	2.13	1.11	1.21	41.20	44.32	23.09	25.18
Phosphate rock	4	21.63	110.35	0.95	1.63	1.00	1.10	20.54	35.25	21.63	23.79
Phosphate rock	6	21.75	110.96	0.82	0.95	0.99	1.00	17.83	20.66	21.53	21.75
Phosphate rock	8	21.85	115.05	0.71	0.83	0.98	1.00	15.51	18.13	20.32	21.85
Bentonite		Roots of maize									
Bentonite	control	7.22	100	4.60	3.65	2.90	5.66	33.21	26.35	21.01	40.86
Bentonite	1	7.31	101.24	3.13	2.97	2.16	3.65	22.82	21.71	15.78	26.68
Bentonite	2	7.45	103.18	2.65	2.92	2.12	3.66	19.74	21.75	15.79	27.26
Bentonite	4	8.63	119.52	1.31	2.30	1.03	2.60	11.30	19.84	8.88	22.43
Bentonite	6	9.83	130.60	0.95	1.61	1.03	1.92	9.33	15.82	10.12	18.87
Bentonite	8	9.92	137.39	0.92	1.60	1.02	1.91	9.12	15.57	10.11	18.94
Bentonite		Shoots of maize									
Bentonite	control	18.20	100	3.56	3.11	1.92	3.52	64.79	56.60	34.94	64.06
Bentonite	1	18.35	100.82	2.11	2.92	1.77	2.14	38.71	53.58	32.47	39.26
Bentonite	2	18.96	104.17	1.60	1.97	1.63	2.13	30.33	37.35	30.90	40.38
Bentonite	4	19.80	108.79	1.23	1.35	1.20	1.98	24.35	26.73	23.76	39.20
Bentonite	6	21.65	118.95	0.93	1.11	1.01	1.31	20.13	24.03	21.86	28.36
Bentonite	8	21.78	119.67	0.61	1.10	1.00	1.28	19.81	53.95	21.78	27.87

4. Effect of amendments application on some soil properties.

a. The influence on soil density and total porosity.

Tables 6 and 7 show that the mean values of bulk densities for the soil under study were progressively reduced with increasing time of incubation from 20 to 60 days at rates (1, 2, 4, 6 and 8 ton fed^{-1}) of phosphate rock and bentonite, especially after maize planting compared with the initial soil samples. On contrary the mean values of total porosities were increased with increasing time of incubation from 20 to 60 days as well as at rates (1, 2, 4, 6 and 8 ton fed^{-1}) of phosphate rock and bentonite.

b. The influence on water movement.

Hydraulic conductivity coefficient was the parameter used for the measurement of water movement in the soil of the investigated treatments. Tables 6 and 7 reveal that the values of hydraulic conductivity coefficient (K) markedly increased with increasing time of incubation from 20 to 60 days especially after maize planting compared with the control. This could be attributed to the application of phosphate rock and bentonite which had affected on pore size distribution and to the improving effects of the investigated treatments on the physical soil properties, similar results were obtained by Mashour, (2005).

c. The influence on moisture content.

The data of Tables 6 and 7 shows the moisture content values for the soils under study which markedly increased with increasing time of incubation from 20 to 60 days, especially after maize planting compared with control treatment. Data in Tables 6 and 7 showed that soil moisture values (field capacity and saturation percent) were affected by application of different treatments of phosphate rock and bentonite at different incubation periods from 20 to 60 days.

4 - The influence on soil reaction (pH)

Data in Tables 6 and 7 show that the pH values of the soils under study were reduced with increasing time of incubation from 20 to 60 days as well as with increasing rates of applied bentonite (1, 2, 4, 6 and 8 ton fed^{-1}) comparing with control.

Table 6. Effect of phosphate rock on some soil properties at different periods.

Incubation period	phosphate rock ton fed^{-1}	pH soil past	Ec dSm^{-1}	OM %	CEC meq100 g $soil^{-1}$	$CaCO_3$ %	Sp %	F.C. %	K cm h^{-1}	B.D. g cm^{-3}	Porosity %
20 days	control	7.62	1.13	2.71	14.85	1.23	42.10	29.15	23.33	1.30	50.94
	1	7.63	1.10	2.80	14.98	1.33	45.71	29.49	27.50	1.28	51.69
	2	7.65	1.17	2.85	15.32	1.37	46.80	29.50	27.60	1.28	51.69
	4	7.65	1.18	2.87	15.28	1.37	47.60	29.51	28.55	1.28	51.69
	6	7.66	1.19	2.88	15.90	1.40	48.71	29.55	28.60	1.28	51.69
	8	7.67	1.19	2.88	16.11	1.41	49.51	29.60	29.62	1.28	51.69
40 days	1	7.63	1.20	2.86	16.80	1.47	47.12	29.30	27.59	1.27	52.07
	2	7.66	1.20	2.87	16.30	1.48	47.19	29.58	27.70	1.27	52.07
	4	7.67	1.21	2.89	16.31	1.50	48.11	29.60	28.81	1.27	52.07
	6	7.67	1.22	2.90	16.39	1.54	49.88	30.68	28.90	1.27	52.07
	8	7.68	1.22	2.90	17.40	1.55	49.90	30.71	30.11	1.27	52.07
60 days	1	7.67	1.21	2.89	16.80	1.48	48.90	29.80	28.51	1.27	52.07
	2	7.68	1.22	2.90	16.82	1.50	48.92	29.81	29.77	1.27	52.07
	4	7.68	1.23	2.90	17.43	1.50	48.98	29.85	29.80	1.26	52.45
	6	7.69	1.23	2.91	17.50	1.56	50.81	30.89	29.82	1.26	52.45
	8	7.69	1.23	2.91	17.52	1.57	50.81	30.90	30.30	1.26	52.45
after harvesting	1	7.68	1.22	2.90	17.50	1.52	50.60	30.55	38.60	1.26	52.45
	2	7.69	1.23	2.91	17.51	1.53	51.71	30.59	39.90	1.26	52.45
	4	7.69	1.23	2.91	17.56	1.55	52.90	30.60	29.91	1.25	52.83
	6	7.70	1.24	2.92	17.65	1.60	53.66	31.10	30.49	1.25	52.83
	8	7.70	1.24	2.92	17.65	1.60	53.66	31.11	30.50	1.25	52.83

On the other hand the pH values increased with the application of phosphate rock at rates (1, 2, 4, 6 and 8 ton fed^{-1}) as well as with increasing time of incubation from 20 to 60 days compared with the control treatments. These results are in agreement with those of Abd – Elall (2009); who stated that the order of increase in pH from the various chemical treatments were lime > phosphate rock > charcoal > farmyard manure. The same trend was found by Chen (1994); who pointed out that the application of phosphate rock significantly reduced the solubility of heavy metals in contaminated soils as a result of increasing pH values in contaminated soils with heavy metals.

Table 7. Effect of bentonite on some soil properties at different periods.

Incubation period	Bentonite ton fed^{-1}	pH soil past	Ec dSm^{-1}	OM %	CEC meq100 g soil^{-1}	$CaCO_3$ %	Sp %	F.C. %	K cm h^{-1}	B.D. g cm^{-3}	Porosity %
20 days	control	7.62	1.13	2.71	14.85	1.23	42.10	29.15	23.33	1.30	50.94
	1	7.60	1.13	2.71	14.90	1.25	48.11	29.62	28.32	1.26	52.45
	2	7.55	1.14	2.75	14.92	1.25	48.20	30.00	28.65	1.25	52.83
	4	7.53	1.14	2.77	14.93	1.26	49.12	30.01	28.83	1.24	53.20
	6	7.50	1.14	2.79	15.11	1.27	50.23	361.62	29.81	1.24	53.20
	8	7.50	1.14	2.80	15.12	1.27	51.71	31.70	29.92	1.24	53.20
40 days	1	7.50	1.14	2.80	15.80	1.26	50.23	30.15	28.50	1.23	53.35
	2	7.50	1.15	2.83	16.00	1.26	50.63	30.19	28.90	1.22	53.96
	4	7.50	1.15	2.85	16.20	1.28	50.72	30.20	29.83	1.21	54.33
	6	7.49	1.15	2.86	16.21	1.28	54.50	31.77	30.23	1.21	54.33
	8	7.49	1.15	2.85	16.22	1.29	54.61	32.75	30.30	1.20	54.71
60 days	1	7.49	1.15	2.88	16.12	1.28	51.13	31.22	29.60	1.20	54.71
	2	7.49	1.15	2.88	16.12	1.29	51.25	32.10	30.69	1.19	55.09
	4	7.48	1.15	2.89	16.15	1.30	52.20	33.19	30.80	1.19	55.09
	6	7.48	1.16	2.89	16.19	1.31	55.52	34.20	31.55	1.18	55.47
	8	7.48	1.16	2.90	16.75	1.31	55.59	34.16	31.60	1.18	55.47
after harvesting	1	7.48	1.15	2.90	17.16	1.30	50.11	30.21	30.50	1.14	56.98
	2	7.48	1.15	2.90	17.21	1.31	51.15	31.11	30.92	1.14	56.98
	4	7.48	1.16	2.91	17.51	1.31	52.20	32.62	30.80	1.14	56.98
	6	7.47	1.16	2.91	17.70	1.32	55.53	32.90	31.55	1.11	58.11
	8	7.47	1.16	2.91	17.66	1.32	55.60	32.91	31.61	1.11	58.11

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خفض تيسر بعض العناصر الثقيلة فى تربة ملوثة باستخدام محسنات صخر الفوسفات والبنتونيت

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معالجة الأراضى وتقييد حركة العناصر بها ضرورة لتجنب مخاطرها على البيئة وصحة الإنسان- لذا فان هذه الدراسة تهدف إلى تحديد كفاءة بعض المحسنات فى تقليل حركة وتيسر بعض العناصر الثقيلة فى تربة ملوثة حيث استخدم نوعين من المحسنات (صخر الفوسفات – البنتونيت) تحت مستويات مختلفة (1، 2، 4، 6 ، 8 طن/فدان) وتحت فترات تحضين متفاوتة 20، 30، 60 يوم مع عينات التربه ثم بعد ذلك زرع فى نفس الاصص نبات الذرة لمتابعة حركة وتيسر العناصر فى التربة والنبات وتشير النتائج إلى:

- أن كلا من المحسنين المستخدمين (صخر الفوسفات ، البنتونيت) قد نجحا فى خفض تيسر وتقييد حركة العناصر (النحاس ، الزنك، المنجنيز ، الرصاص) فى التربة الملوثة المنزرعة بعد 60 يوم من التحضين بنبات الذرة حيث اظهر المحتوى الميسر من تلك العناصر إتجاهاً متناقصاً بزيادة مستويات الإضافة.
- إنخفاض ملحوظ فى الميسر من العناصر الثقيلة عند استخدام 6، 8 طن/ فدان لصخر الفوسفات ، البنتونيت على التوالى وذلك بعد تحضين 60 يوم.
- أهمية اضافة محسنات التربة (صخر الفوسفات ، البنتونيت) حيث تعمل على تحسين الخواص الكيماوية والطبيعية للتربة الملوثة وتزيد من احتفاظ التربة للماء، وبالطبع انعكست كل هذه التاثيرات المفيدة لكلا من المحسنين على تحسين قياسات النمو الخضرى لنبات الذرة والوزن الجاف للمجموع الخضرى والجذرى باتجاهات مشابهة وموازية لتاثير كلا من المحسنين على تقييد حركة وتيسر العناصر الثقيلة فى التربة وخفض الكمية الممتصة منها فى الأنسجة النباتية، وعليه فان سمية هذه العناصر للنباتات النامية تناقصت بزيادة مستويات الاضافة من صخر الفوسفات ، البنتونيت خاصة عند معدل 6، 8 طن/فدان بعد تحضين 60 يوم على التوالى.

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