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Effects of Cement Kiln Dust on Some Soil Chemical Properties, Growth and Yield of Wheat and Fodder Sorghum

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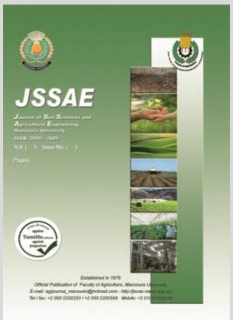

ABSTRACT

Agronomic use of cement kiln dust (CKD) improves sandy soil properties and promotes growth and development of plants to enhance crop yield. Field experiments were carried out on a private farm at a newly reclaimed land in the Western district of Nile valley, El-Minia Governorate, Egypt. The aim of this study was to investigate effects of white and black cement kiln dusts applied at six rates (0, 4, 8, 12, 16, and 20 Mg feddan^{-1}) to sandy loam soil on some soil chemical properties, growth, yield, and heavy metals uptake of lead, nickel and cadmium by wheat and fodder sorghum plants. The results indicated that white and black CKDs are considered to be safe by-product materials in terms of pH and content of lead, nickel, and cadmium, however; they are potentially hazard in terms of salinity build up in the investigated soil. Heavy metals concentration in the investigated soil was in the following descending order: Lead > Nickel > Cadmium. The investigated soil remains at a safe level of lead and nickel, while in a potential level of unsafe cadmium. The highest value of wheat yield and fodder sorghum was recorded when white CKD was applied at the rate of 16 Mg feddan^{-1}. From these results, it could be recommended to apply white CKD at an application rate of 16 Mg feddan^{-1} only once for common crops cultivated in sandy soils under conditions of El-Minia Governorate, Egypt.

Keywords: White and Black CKDs, Heavy Metals, Health Risk Assessment.

INTRODUCTION

Egypt lies in the arid region of the world and its area is 1.0 million Km^2. Although the unique and vital location of Egypt in the heart of the world, about 95% of Egypt's area is desert lands, which are mainly sandy soils (Abd El-Azeim *et al.*, 2020). The population in Egypt is increasing gradually year after year. The food production is not sufficient for the dense population in Egypt. Therefore, in the view point of national security in Egypt, it is important to reclaim and cultivate the desert lands in order to increase the agricultural production to secure the food security (Abd El-Azeim *et al.*, 2020).

Sehgal *et al.* (1992) indicated that sandy soils are potentially fertile as observed from their mineralogical make up. However, they pose severe physical constraints associated with their inherent and site characteristics, such as climate, texture and single grained structure, wind erosion, drought, low available moisture and nutrients, high percolation resulting in loss of added nutrients to deeper depths and low organic matter. Moreover, it is frequently found under dried conditions that such soils contain high concentration of $CaCO_3$, which in turn, adds more nutritional problems to plants Sehgal *et al.* (1992).

Cement industry is an important industry all over the world, but it is one of the polluting industries in the ecosystem. As a large manufacturing industry, cement kiln dust (CKD), a by-product dust, is generated in large quantities during the manufacture of the cement. It has been used in many different economical and beneficial applications in different parts of the world. Its pollutions have been found to be a problem around cement factories (Rahman *et al.*, 2011). It may contain hazardous compounds that poses harmful effects to the human, animals, plants, and environment. Therefore, the cement kiln dust should be managed properly to avoid its harmful effects on humans, animals, and plants. The disposal of CKD is very difficult and causes an environmental hazard. In order to minimize the undesirable environmental impacts of CKD, many researches have been performed to study the beneficial commercial uses of CKD (Abd El-Aleem *et al.*, 2005 and Rahman *et al.*, 2011).

Large quantities of cement kiln dust (CKD) are produced during the manufacture of cement clinker by the dry process (Abd El-Aleem *et al.*, 2005 and Rahman *et al.*, 2011). In Egypt, production of different types of cement reached nearly 30 million tons, with 3.0 million tons CKD/year in dry lines. The dry process of cement production produces three times more dust than the wet process (Abd El-Aleem *et al.*, 2005). Kunal *et al.* (2012) showed that cement kiln dust is solid, highly alkaline particulate materials chiefly composed of oxidized, anhydrous, micro-sized particles collected from electrostatic precipitations during the production of cement clinker.

The disposal of the fine kiln dust is very difficult and poses an environmental threat. To overcome this problem, research is being carried out in different parts of the world to find out economical and efficient ways and means of using cement kiln dust in various application (Adaska and Taubert, 2008 and Rahman *et al.*, 2011). Several researchers have reported on some aspects of the utilization of cement

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kiln dust, which are covering a wide variety of applications including a raw material for return to a Portland cement kiln or an additive in a blended Portland cement, base stabilizer for pavements, solidifier and stabilizer for contamination wastes, waste treatment, low-strength back fill cover, agriculture and cement products, a replacement or supplementary material to Portland cement and fly ash, a substitute for lime in stabilizing wastewater streams, soil stabilization, soil conditioner, source of nutrient to enhance crop yield, and other uses (Adaska and Taubert, 2008; Rahman *et al.*, 2011; and Kunal *et al.*, 2012).

Soil is an important component of the environment and it must be managed properly to conserve its quality for plants, animals, and humans. Heavy metals in soils are one of the main sources of environmental pollution. Heavy metals are environmental pollutants due to their toxic effects on plants, animals, and human health. Soil contamination by heavy metals results from anthropogenic and natural activities (Haddad *et al.*, 2019). Consequently, it is important to assess and monitor the levels of heavy metals in the environment due to the anthropogenic activities Abd El Azeim *et al.*, 2016).

Soil is a crucial component of rural and urban environments, and in both places land management is the key to soil quality (USDA, 2000). Heavy metals pose a number of hazards to human health. Consequently, it is imperative to assess and monitor the levels of heavy metals in the environment due to anthropogenic activities for evaluation for human exposure and for sustainable environment (Sharma and Agrawal, 2005 and Siti Norbaya *et al.*, 2014). In addition, Sharma and Agrawal (2005) pointed out that dietary intake of many heavy metals through consumption of plants has long term detrimental effects on human health. Moreover, Pourrut *et al*. (2011) showed that the reduced lead uptake by vegetables minimizes the threat of lead introduction to the food chain. Furthermore, USDA (2000) reported that chronic problems associated with long-term heavy metal exposures are: (1) lead: mental lapse; (2) cadmium: affects kidney, liver, and GI tract; and (3) arsenic: skin poisoning, affects kidneys and central nervous system.

Keeping in mind the prevailing scientific facts and results all over the world, the main objectives of the current study are: (1) to evaluate and assess the possibility of using white and black cement kiln dusts for the agricultural purposes in a safe manner as a soil amendment and a fertilizer material to enhance growth and yield of wheat and fodder sorghum and (2) to investigate the beneficial effects of white and black cement kiln dusts on some soil chemical properties (soil health), and growth, yield, and uptake of lead, nickel and cadmium by wheat and fodder sorghum plants.

MATERIALS AND METHODS

Study site description

The current study was accomplished on a private farm at a newly reclaimed land in the Western district of Nile valley, El-Minia Governorate, Egypt. To characterize the soil of study site, a representative soil sample was collected from the soil surface at a depth of 0.0-30 cm. The soil sample was homogenized by the quartering method. Then, it was air-dried, grinded with mortar and pestle, and sieved to pass through a 2.0 mm stainless steel sieve for the chemical analysis. Some physical and chemical properties of the studied surface soil at a depth of 0.0-30 cm are shown in Table1.

Table 1. Some physical and chemical properties of the studied surface soil at a depth of 0.0-30 cm.

Soil properties	Value
Particle size distribution:	
Coarse sand (%)	50.33
Fine sand (%)	30.40
Silt (%)	4.77
Clay (%)	14.50
Texture grade	Sandy loam
E.C. (Ratio 1:5) (dS m^{-1})	1. 40
pH (Ratio 1:2.5)	7.95
$CaCO_3$ (g kg^{-1})	94.40
O.M. (g kg^{-1})	3.40
DTPA-extractable heavy metals (mg kg^{-1}):	
Pb	2.55
Ni	1.47
Cd	0.61

Collection and preparation of cement kiln dust

Two cement kiln dusts, white and black, were collected from two cement factories in El-Minia Governorate, Egypt. The white CKD was collected from the White El-Minia cement factory at Beni Khaled village, Samalout district, El-Minia Governorate, Egypt, and the black CKD was collected from the ASEC Minia cement factory at Al-Bostan village, Samalout district, El-Minia Governorate, Egypt. Both of CKDs were used in the field experiments. A sample of each CKD was taken, air dried at 105 ^oC for 24 hours, grinded with mortar and pestle, and sieved to pass through a 2.0 mm stainless steel sieve for the chemical analysis.

Experimental design and set up of the field experiments

Initial effects of applying white and black CKDs on wheat crop

This field trial included 36 treatments in total, which were six CKD rates (0, 4, 8, 12, 16, and 20 Mg $feddan^{-1}$) from each CKD studied with three replications. The experimental design was a complete randomized plot in 3 replicates. The experimental unit area (plot area) was 16 m^2 (4×4 m). After plowing the soil, the area was splinted to plots. The respected rates of each CKD were added to the soil and mixed thoroughly with the soil in every plot. Then, Beni Suef 5 variety of durum wheat (*Triticum aestivum* L.) was cultivated at a rate of 60 kg/feddan in November 2017. Wheat plants received the recommended fertilization rates of N, P, and K at the equivalent rates of 100 kg N, 62 kg P_2O_5, and 24 kg K_2O/feddan. Wheat plants were irrigated by the surface irrigation. Wheat plants were harvested in May 2018. At harvesting, the plant height of wheat was recorded. After that, wheat grains were separated from straw, then grains and straw yield of wheat was recorded. Samples of wheat grains were taken, then dried in the oven, grinded in a plant mill, sieved to pass through a 0.5 mm screen mesh, and a representative sample was taken and analyzed for Pb, Ni, and Cd.

Residual effect of applying white and black CKD on fodder sorghum crop.

After wheat harvest in May 2018, soil was cultivated with Dorado variety of fodder sorghum (*Sorghum bicolor* L. Moench) at a rate of 5 kg/feddan in July 2018. The fodder sorghum plants received the recommended fertilization rates of N, P, and K at the equivalent rates of 100 kg N, 31 kg P_2O_5, and 24 kg K_2O/feddan. After 60 days from cultivation, fodder sorghum plants were harvested as the first cut in September 2018. After one month from the first cut, fodder sorghum plants were harvested as the second cut in October 2018. At harvesting of first and second cuts, plant height of fodder sorghum was recorded. Then, fodder sorghum plants were cut at 2.0 cm from the soil surface. After that, samples of the first and second cuts of fodder sorghum plants were taken, then dried in the oven, grinded in a plant mill, sieved to pass through a 0.5 mm screen mesh, and a representative sample was taken and analyzed for Pb, Ni, and Cd.

Risk assessment of the soil pollution

In order to determine effects of applying white and black CKDs on soil pollution; soil samples were collected from all treatments before the cultivation and at the harvest of two successive crops (wheat and fodder sorghum). Soil samples were taken from the soil surface at a depth of 0.0-30 cm. Then, soil samples were prepared as mentioned above in section 2.1. for chemical analysis. The risk assessment of soil pollution was performed using the following three international guidelines:

1- Guidelines for the soil salinity classes as proposed by Scianna (2002) from the United States of America.
2- Guidelines for the soil pH classes as proposed by Scianna (2002) from the United States of America.
3- Guidelines for the permissible limit of DTPA-extractable heavy metals in soils as proposed by Maclean *et al*. (1987).

Health risk assessment for human and animals.

In order to determine effects of applying white and black CKDs to the investigated soil on human health and animals; health risk assessment of lead, nickel, and cadmium concentration in wheat grains as a human food and in fodder sorghum plants as an animal food was performed using the following two international guidelines:

1- WHO/FAO guidelines for metals in foods and vegetables as proposed by FAO/WHO (1976).
2- Guidelines for the Indian standards for heavy metals in the soil, food, and drinking water as proposed by Awashthi (2000) from India.

Laboratory analysis

Chemical analysis of the soil and cement kiln dust

The chemical analysis of soil and white and black CKDs was performed according to the standard frequently used methods as described by Jackson (1973) and Page *et al*. (1982). Lead, nickel, and cadmium were extracted from the soil and each CKD with diethylene-triamine-penta acitic acid (DTPA). The solution is made up of a mixture of 0.005 M DTPA, 0.1 M triethanolamin (TEA) and 0.01 M $CaCl_2$, adjusted to pH 7.3. The concentrations of Pb, Ni, and Cd in the soil extracts and extracts of each CKD were analyzed using an Atomic Absorption Spectrophotometer; Model of VARIAN specter AA. 20 according to Mathieu and Pieltain (2003).

Chemical analysis of plants

Lead, nickel, and cadmium were extracted from wheat grains and fodder sorghum plants using method of micro wave digestion. 0.1 g from each plant sample was homogenized in a Teflon cups with 5 ml nitric acid (ultrapure), 2 ml H_2O_2 30%- and 0.5-ml hydrofluoric acid. The mixture was put in microwave apparatus at 37 wt/12 min. The mixture was frozen at –10 ºC/30 min and set up at 50 ml with redistilled water. The concentrations of Pb, Ni, and Cd were analyzed by electrothermal Atomic Absorption Spectrometry, Model of VARIAN specter AA. 20 as described by Kumpulainen *et al*. (1983).

Data handling

All the tabulated data of the current study were recorded at the oven dry weight basis (105 ºC).

1- The uptake of a heavy metal = Dry matter × Concentration of a heavy metal in the plant.
2- Wheat biological yield = Wheat grain yield + Wheat straw yield.
3- Wheat harvest index = (Wheat grain yield / Wheat biological yield) × 100.

Statistical analysis

All the obtained data were subjected to the statistical analysis of variance procedures using the Excel software 2016. Differences between treatments means were compared using the L.S.D. test at the 5% level.

RESULTS AND DISCUSSION

Quality evaluation of white and black cement kiln dusts

The chemical analysis of white and black cement kiln dusts is presented in Table 2. It is evident from results in Table 2 that white and black CKDs have high values of electrical conductivity (7.99 dS m^{-1} and 14.28 dS m^{-1}, respectively). The electrical conductivity value of black CKD was higher than that of white CKD. The results of our study are in harmony with those reported by Dollhopf and Mehlenbacher (2002) and Rahman *et al*. (2011).

Table 2. Some chemical properties of the white and black cement kiln dusts (CKDs).

Chemical properties of CKD	White CKD	Black CKD
E.C. (Ratio 1:5)	7.99	14.28
pH (Ratio 1:2.5)	6.89	7.84
DTPA-extractable heavy metals (mg kg^{-1}):		
Pb	9.73	15.62
Ni	3.62	6.16
Cd	2.10	4.79

Concerning the pH of white and black CKDs; it is prominent from the results in Table 2 that the white CKD was approximately in the neutral pH (pH 6.89), however, the black CKD was slightly alkaline (pH 7.84). The pH value of black CKD was slightly higher than that of white CKD. The results are in consistent with that reported by Naik *et al*. (2003) who pointed out that as an additional measure of chemical characteristic, the CKD is inherently, alkaline. This characteristic is a clear function of the large quantity of CaO and other alkaline compounds, such as K_2O, NaOH, Na_2CO_3, and Na_2SO_4, that comprise CKD (U. S. Environmental protection Agency, 1993).

In the case of heavy metals of white and black CKDs, it can be seen from the results in Table 2 that white CKD contained low levels of DTPA-Extractable lead, nickel, and cadmium. While, black CKD contained high levels of lead and nickel as well as it contained relatively higher concentration of cadmium as proposed by several authors in their researches all over the world. Lead, nickel, and cadmium concentration of black CKD was higher than that of white CKD. Kunal *et al*. (2012) showed that number of factors that affect the level of contaminants in the cement kiln dust are: (1) material usually varies in cement from facility to facility, and differences can even be apparent within a single cement kiln; (2) finer particles contain higher concentrations of sulfates and alkalis, while coarser particles that are usually collected close to the kiln have higher concentrations of free lime; (3) waste fuel used in some cement kilns may increase the toxic metal content of CKD; and (4) dust recirculation can cause increased contaminant concentrations.

Concerning the chemical constituents of white and black CKDs as shown in Table 3, it is obvious from the results in Table 3 that white and black CKDs consist primarily of calcium oxide and silicon oxide.

Table 3. Some chemical constituents of white and black cement kiln dusts (CKDs).

Chemical constituents of CKD (% by weight)	White CKD*	Black CKD**
SiO_2	19.84	14.14
Al_2O_3	2.75	4.46
Fe_2O_3	0.03	2.01
CaO	57.39	56.44
MgO	0.14	0.78
SO_3	5.28	7.60

***White CKD = Analytical chemical composition of the white CKD is provided by the White cement factory.**
****Black CKD = Analytical chemical composition of the black CKD is provided by the ASEC Minia cement factory.**

The results are in agreement with those reported by many authors. Naik *et al*. (2003) pointed out that although wide concentration ranges exist for most constituents, the primary bulk constituents in CKD are silicates, calcium oxide, carbonates (expressed as loss of CO_2 and H_2O on ignition), potassium oxide, sulfates, chlorides, various metal oxides, and sodium oxide (U. S. Environmental Protection Agency, 1993). In addition, Kunal *et al*. (2012) showed that compounds of lime, iron, silica, and alumina constitute the major chemical composition of CKD. CKDs on the average are typically characterized by higher alkali and sulfur content which is one of the main reasons for removing dust from kilns.

The chemical composition of white CKD varied from the chemical composition of black CKD. The amount by weight of Al_2O_3, Fe_2O_3, MgO, and SO_3 of black CKD was higher than that of white CKD. While, the amount by weight of SiO_2 and CaO of white CKD was higher than that of black CKD. Kunal *et al*. (2012) showed that significant variation in physical and chemical composition of CKDs obtained from different cement plants has been observed. Moreover, Adaska and Taubert (2008) concluded that CKD containing high CaO content and low loss on ignition (LOI) performs best for most applications.

Effect of applying white and black CKDs on some soil chemical properties

For a successfully conducted environmental monitoring at the investigated site and in order to determine the impact of white and black CKDs on soil properties (soil health), plant health, human and animal health, and surrounding environment in the studied site, the risk assessment of soil pollution was performed using three international guidelines.

The risk assessment of soil pollution helps in screening out the low-risk areas (potential safe areas) and high-risk areas (hot spot areas) of the investigated site located in the Western district of Nile valley, El-Minia Governorate, Egypt; in terms of soil salinity build up, changes in the soil pH, and spatial distribution and accumulation of lead, nickel, and cadmium in the soil.

Soil salinity build up.

It can be seen from the results given in Table 4 that addition of white and black CKDs at the studied six rates (0.0, 4, 8, 12, 16, and 20 Mg feddan^{-1}) to soil resulted in an increase in the electrical conductivity of the soil at the harvest of wheat and fodder sorghum plants when compared to that before cultivating wheat and fodder sorghum plants (Table1).

Table 4. Effect of applying white and black CKDs on some soil chemical properties after harvesting.

CKD treatments (Mg feddan^{-1})		E.C. (dS m^{-1})		pH		Soil DTPA-extractable heavy metals concentration (mg kg^{-1})					
						Pb		Ni		Cd	
		At wheat harvest	At fodder sorghum harvest	At wheat harvest	At fodder sorghum harvest	At wheat harvest	At fodder sorghum harvest	At wheat harvest	At fodder sorghum harvest	At wheat harvest	At fodder sorghum harvest
Control		1.49	1.38	7.97	7.90	2.66	2.78	1.58	1.63	0.62	0.71
White CKD	4	1.64	1.61	8.13	8.06	3.42	3.96	1.90	2.12	0.65	0.76
	8	1.67	1.64	8.03	8.03	3.73	4.29	1.99	2.25	0.69	0.89
	12	1.73	1.68	8.14	8.06	4.03	4.69	2.13	2.40	0.87	1.01
	16	1.78	1.75	8.02	8.03	4.35	4.93	2.26	2.53	0.97	1.14
	20	1.90	1.85	8.13	8.05	4.64	5.23	2.37	2.67	1.13	1.25
	Mean	1.74	1.71	—	—	4.03	4.62	2.13	2.39	0.84	1.01
Black CKD	4	1.70	1.64	8.02	8.09	4.02	4.61	2.10	2.35	0.82	0.90
	8	1.81	1.73	8.03	8.04	4.23	4.85	2.19	2.45	0.92	1.03
	12	1.90	1.76	8.04	8.10	4.49	5.44	2.30	2.58	1.01	1.14
	16	1.97	1.80	8.06	8.01	4.66	5.34	2.39	2.68	1.13	1.24
	20	1.99	1.89	8.07	8.02	4.86	5.57	2.48	2.78	1.20	1.34
	Mean	1.87	1.76	—	—	4.45	5.16	2.29	2.57	1.02	1.13
LSD at 5% level		0.26	0.24	—	—	0.44	0.46	0.29	0.32	0.14	0.17

Increasing the application rate of white and black CKDs from 0.0 up to 20 Mg feddan^{-1} significantly increased the electrical conductivity of the soil ($p = 0.05$) in most of CKD treatments at harvesting of wheat and fodder sorghum plants when compared to that of control treatment (0.0 Mg feddan^{-1}) as shown in Table 4. Uysal *et al*. (2012) showed that according to the soil and CKD analysis, soil was sandy–loam in texture, moderately calcareous and non-saline.

However, CKD was strongly alkaline, moderately calcareous and saline. If CKD is mixed with soil, the final product becomes alkaline, calcium content increases, and salt levels increase.

The electrical conductivity values of soil treated with black CKD was insignificantly higher than those of soil treated with white CKD. One interpretation for this result is that the electrical conductivity value of black CKD (14.28 dS m^{-1}) was higher than that of the white CKD (7.99 dS m^{-1}) as presented in Table 2.

According to the guidelines of Scianna (2002), the electrical conductivity value of soils which were treated either with white CKD or black CKD is within the range of 0.0 - 2.0 dS m^{-1} under the salinity class of “non-saline”, indicating that these soils are classified as non-saline soils (safe soil salinity). Therefore, the electrical conductivity value of these soils has no salinity hazard due to CKDs addition (Table 5).

Table 5. Guidelines for soil salinity classes (Scianna, 2002).

Salinity class	EC (electrical conductivity) (dS m^{-1} or mmhos cm^{-1})
Non saline	0 - 2
Very slightly saline	2 - 4
Slightly saline	4 - 8
Moderately saline	8 - 16
Strongly saline	> 16

Changes in soil pH

It is appeared from the results shown in Table 4 that increasing the application rate of white and black CKDs from 0.0 up to 20 Mg $feddan^{-1}$ slightly increased the soil pH at the harvest of wheat and fodder sorghum plants when compared to that of the control treatment. The results are in agreement with those reported by Dollhopf and Mehlenbacher (2002) and Rahman *et al*. (2011). In addition, Scianna (2002) reported that a main implication of changing soil pH is plant nutrient availability, which is often a secondary response to microbial activity levels responding to changing soil pH. As soil pH climbs, elements such as iron, manganese, zinc, copper, cobalt, phosphorus, and boron become limiting.

According to the guidelines of Scianna (2002), the pH value of soils which were treated either with the white CKD or the black CKD is within the range of 7.9-8.4 under the pH class of “moderately alkaline” (Table 6). Scianna (2002) demonstrated that soil pH is an important indication of the chemical status of soils. Since soluble salts affect the soil pH and vice versa, it is often included in evaluations and discussions of soil saltiness.

Table 6. Guidelines for soil pH classes (Scianna, 2002).

pH class	pH
Ultra acid	< 3.5
Extremely acid	3.5 - 4.4
Very strongly acid	4.5 - 5.0
Strongly acid	5.1 - 5.5
Moderately acid	5.6 - 6.0
Slightly acid	6.1 - 6.5
Neutral	6.6 - 7.3
Slightly alkaline	7.4 - 7.8
Moderately alkaline	7.9 - 8.4
Strongly alkaline	8.5 - 9.0
Very strongly alkaline	> 9.0

Accumulation and spatial distribution of lead, nickel, and cadmium in the soil

It is clear from the results presented in Table 4 that addition of the white and black CKDs at all application rates resulted in an increase in the concentration of lead, nickel, and cadmium in the soil at the harvest of wheat and fodder sorghum plants when compared control. Increasing the application rate of white and black CKDs from 0.0 up to 20 Mg $feddan^{-1}$ significantly increased the lead, nickel, and cadmium concentration in the soil ($p = 0.05$) at the harvest. The increase in the concentration of lead, nickel, and cadmium in the soil may be attributed to: (1) addition of the white and black CKDs to the soil, (2) the continued release of lead, nickel, and cadmium due to the dissolution of white and black CKDs, (3) addition of the pesticides and chemical fertilizers especially the phosphate fertilizers, and (4) heavy metals content in the ground water used for irrigation in the investigated site. Bhalerao *et al*. (2015) reported that high Ni concentrations in soil have left some farmland unsuitable for growing crops, fruits, and vegetables. In addition, Siti Norbaya *et al*. (2014) pointed out that heavy metals in soils have been considered as powerful tracers for monitoring impact of anthropogenic activity such as industrial emission (cement plant) and atmospheric deposited. Moreover, Kloke *et al*. (1984) revealed that some of the heavy metals are present in agricultural chemicals such as fertilizers in the form of impurities. Currently being debated are especially the cadmium contents of phosphate fertilizers and the mercury in seed treatment agents. Rock phosphate used in Europe contain from 0.1 ppm (Kola-Phosphate) up to more than 75.0 ppm cadmium (phosphates from Western Africa). Nevertheless, Wanninayake *et al*. (2021) indicated that phosphorus fertilizers contain cadmium as a contaminant at levels varying from trace amounts to high levels and therefore can be a major source of cadmium to agricultural systems.

Considering the effect of white and black CKDs on the spatial distribution of lead, nickel, and cadmium in the soil; the values of lead, nickel, and cadmium concentration in treated soils with white CKD ranged from 3.42 - 4.64, 1.90 - 2.37, and 0.59 - 1.13 mg kg^{-1}; respectively; at wheat harvest. Whereas, values ranged from 3.96 - 5.23, 2.12 - 2.67, and 0.76 - 1.25 mg kg^{-1}; respectively; at fodder sorghum harvest (Table 4). Whereas, the values of lead, nickel, and cadmium concentration in soil treated soil with the black CKD ranged from 4.02 - 4.86, 2.10 - 2.48, and 0.82 - 1.20 mg kg^{-1}; respectively; at wheat harvest. While, values ranged from 4.61 - 5.57, 2.35 - 2.78, and 0.90 - 1.34 mg kg^{-1}; respectively; at fodder sorghum harvest. It is clear from these results that the soils contained low concentrations of lead and nickel as well as they contained relatively high concentrations of cadmium. Lead, nickel, and cadmium are spatially distributed in the soils of investigated site. Moreover, Kloke *et al*. (1984) showed that the lead content of soils is normally in the range of 0.1 - 20.0 ppm. In South Africa, Olowoyo *et al*. (2015) observed that the concentration of Cd obtained from the soil of sites at about 50 m from a cement factory in Pretoria, ranged from 0.12 ± 0.01 mg/g - 0.86 ± 0.12 mg/g.

The heavy metals concentrations in the soils of investigated site was in the following descending order: Lead > Nickel > Cadmium. This result is evident in the chemical analysis of the white and black CKDs (Table 2) in which heavy metals concentration in white and black CKDs was in the same descending order. In Malaysia, Siti Norbaya *et al*. (2014) found that the concentration of heavy metals in the soil display the following decreasing trend: Cu > Pb > Cr > Ni > Cd.

It is shown from the results in Table 4 that at the harvest of wheat and fodder sorghum plants, the values of lead, nickel, and cadmium concentration in the soil which was treated with black CKD were higher than those in the soil which was treated with white CKD. This result may be interpreted by that the values of lead, nickel, and cadmium concentration of black CKD were higher than that of white CKD (Table 2). Kloke *et al.* (1984) indicated that so far, critically high concentrations of heavy metals covering large areas have not been ascertained.

For the risk assessment of lead, nickel, and cadmium concentration in the soil, all the values of lead, nickel, and cadmium concentration in the soil shown in Table 4 were compared with the guidelines of Maclean *et al.* (1987) for the permissible limit of DTPA-extractable heavy metals in soils as presented in Table 7.

Table 7. Guidelines for the permissible limit of DTPA-extractable heavy metals in soils [Adapted from Maclean *et al*. (1987)].

Heavy metal		Soil (mg/kg)
Lead	Pb	13.00
Nickel	Ni	8.10
Cadmium	Cd	0.31

The values of lead and nickel concentration in the soil are below the permissible limit of DTPA-extractable of lead and nickel concentration in soils, however, the values of cadmium concentration in the soil are above the permissible limit of DTPA-extractable of cadmium concentration in soils according to the guidelines of Maclean *et al.* (1987); implying that there is no obvious pollution of lead and nickel in the soil. Therefore, the soils of investigated site are still in a safe lead and nickel level, while, they are still in a potentially unsafe cadmium level. In the case of cadmium level in the soil, it could be observed that the cadmium concentration in the soil of investigated site before addition of both CKDs was 0.61 mg kg^{-1}, which is above the permissible limit of DTPA-extractable of cadmium concentration in soils according to the guidelines of Maclean *et al*. (1987). The results of our study are in agreement with the findings of Siti Norbaya *et al*. (2014). In addition, Lafond and Simard (1999) showed that cement kiln dust is an effective source of K and Ca for the potato production without short term loss in the tuber quality or soil contamination by heavy metals. Furthermore, Kloke *et al*. (1984) showed that the suggested guidelines value in Germany for cadmium in agricultural soils is at present 3.0 ppm.

The results of risk assessment of lead, nickel, and cadmium pollution in the soil can be used as a basis for improving the situation and guide environmental planners and government in preventing and reducing the soil pollution in El-Minia Goverorate, Egypt, so as to keep the surrounding environment healthy and safe for humans, animals, plants, and all living organisms.

Initial and residual effect of applying white and black CKDs on wheat and fodder sorghum crops

Growth of wheat and fodder sorghum

Growth of wheat and fodder sorghum was enhanced due to addition of white and black CKDs to sandy loam soil as it resulted in an increase in the plant height of wheat and fodder sorghum. Increasing the application rate of white CKD from 0.0 up to 16 Mg $feddan^{-1}$ and increasing the application rate of black CKD from 0.0 up to 12 Mg $feddan^{-1}$ significantly increased wheat plant height and fodder sorghum plant height of first and second cuts (p = 0.05) when compared to those of untreated soil (control treatment). In contrary; when the application rate of white CKD was increased from 16 to 20 Mg $feddan^{-1}$ and when the application rate of black CKD was increased from 12 up to 20 Mg $feddan^{-1}$, wheat plant height and fodder sorghum plant height of first and second cuts were significantly decreased (p = 0.05) as summarized in Tables 8 and 9. The enhancement in plant height of wheat and fodder sorghum when the soil was treated with white CKD was better than that when soil was treated with black CKD. In addition, the enhancement in fodder sorghum plant height of second cut was better than that of the first cut. One explanation for this result is that white CKD was approximately in the neutral pH (pH 6.89) (Table 2).

Table 8. Initial effect of applying white and black CKDs on growth and yield of wheat.

CKD treatments (Mg $feddan^{-1}$)		Wheat plant height (cm)	Wheat Yield: Wheat grains (Mg $fed.^{-1}$)	Wheat Yield: Dry weight of grains (Mg $fed.^{-1}$)*	Wheat Yield: Wheat straw (Mg $fed.^{-1}$)	Wheat biological yield (Mg $fed.^{-1}$)	Wheat harvest index (%)
Control		96.0	2.10	1.81	2.15	4.25	49.4
White CKD	4	109.8	2.34	2.01	2.12	4.46	52.5
	8	122.8	2.43	2.09	2.15	4.58	53.1
	12	124.2	2.64	2.27	2.34	4.98	53.0
	16	130.7	2.77	2.38	2.34	5.11	54.2
	20	117.7	2.61	2.24	2.24	4.85	53.8
	Mean	121.0	2.56	2.20	2.24	4.80	53.32
Black CKD	4	105.8	2.29	1.96	2.20	4.49	50.9
	8	115.7	2.38	2.05	2.22	4.60	51.7
	12	122.2	2.54	2.18	2.30	4.84	52.5
	16	104.3	2.50	2.15	2.31	4.81	51.9
	20	102.9	2.47	2.12	2.34	4 81	51. 3
	Mean	110.2	2.44	2.09	2.27	4.71	51.66
LSD at 5% level		1.91	0.30	0.20	0.34	-----	-----

***Moisture in the wheat grains = 14% and the dry weight = 86 %.**

Table 9. Residual effect of applying the white and black CKDs to the soil on the growth and yield of fodder sorghum.

CKD treatments ($Mg\ feddan^{-1}$)		First cut of fodder sorghum: Plant height (cm)	First cut: Yield ($Mg\ fed.^{-1}$)	First cut: Dry weight ($Mg\ fed.^{-1}$)	Second cut of fodder sorghum: Plant height (cm)	Second cut: Yield ($Mg\ fed.^{-1}$)	Second cut: Dry weight ($Mg\ fed.^{-1}$)	Total yield of fodder sorghum ($Mg\ fed.^{-1}$)
Control		97.2	4.1	0.8	106.9	4.8	1.0	8.9
White CKD	4	113.7	5.5	1.1	125.1	6.6	1.3	12.1
	8	120.0	6.3	1.3	132.0	7.6	1.5	13.9
	12	117.2	6.5	1.4	133.9	7.8	1.6	14.3
	16	125.3	7.3	1.5	137.4	8.8	1.8	16.1
	20	119.4	6.3	1.3	130.3	7.6	1.5	13.9
	Mean	115.3	6.4	1.3	127.5	7.7	1.5	----
Black CKD	4	111.2	4.9	1.0	122.3	5.9	1.2	10.8
	8	114.1	5.2	1.1	125.5	6.2	1.2	11.4
	12	116.2	6.2	1.2	127.8	7.4	1.5	13.6
	16	110.7	4. 6	1.1	121.8	5.5	1.1	10.1
	20	110.2	4.4	1.0	121.2	5.3	1.1	9.7
	Mean	112.5	5.1	1.1	123.7	6.1	1.2	----
LSD at 5% level		2.2	0.4	0.2	2.8	0.6	0.3	----

This improvement in the growth of wheat and fodder sorghum may be illustrated by the beneficial effects of white and black CKDs which may be useful as: (1) a soil amendment; in which they improve the physical, chemical, and biological properties of the studied sandy loam soil and (2) a fertilizer material, in which they are a source of macro and micro nutrients necessary for the growth and development of wheat and fodder sorghum plants. From the view point of this concern, the results of our study are in agreement with those reported by many authors (Dollhopf and Mehlenbacher, 2002; Rahman *et al.*, 2011; and Uysal *et al*. 2012). Moreover, Dollhopf and Mehlenbacher (2002) indicated that alkaline by-products with enriched metals and/or soluble salts may provide the means for good plant growth when applied at low soil application rates, but a threshold dosage rate may exist that impairs plant growth.

The decrease in the plant height of wheat and fodder sorghum may be attributed to: (1) the high value of electrical conductivity of white CKD (7.99 dS m^{-1}) and black CKD (14.28 dS m^{-1}) and (2) the concentration of lead, nickel, and cadmium in white and black CKDs. This indicates that the use of white and black CKDs in the agricultural applications such as a soil amendment and a fertilizer material may cause a soil salinity hazard and may affect the surrounding ecosystem. Similar results were reported by Dollhopf and Mehlenbacher (2002) who found that for every alkaline product; the loss in the plant growth was in part attributed to both elevated pH and soluble salts in the soil matrix. In addition, Pourrut *et al*. (2011) concluded that excessive lead accumulation in plant tissue is toxic to most plants, leading to a decrease in seed germination, inhabitation of chlorophyll biosynthesis, mineral nutrition and enzymatic reactions, as well as a number of other physiological effects. Moreover, Dollhopf and Mehlenbacher (2002) suggested that the mechanisms causing loss in plant growth may have been: (1) lower availability of N, P, and K as pH was increased and (2) greater expenditure of energy by the plant root to uptake water due to soluble salt induced increase in the osmotic potential.

Yield of wheat and fodder sorghum

Yield of wheat and fodder sorghum were enhanced as a result of addition of white and black CKDs to the sandy loam soil. Wheat grain yield and fodder sorghum yield of first and second cuts were significantly increased with increasing the application rate of white CKD from 0.0 up to 16 Mg $feddan^{-1}$ and increasing the application rate of black CKD from 0.0 up to 12 Mg $feddan^{-1}$ when compared to that of the untreated soil. Wheat straw yield was increased by increasing the application rate of white CKD from 0.0 up to 16 Mg $feddan^{-1}$ and increasing the application rate of black CKD from 0.0 up to 20 Mg $feddan^{-1}$ when compared to that of the untreated soil.

Conversely; when the application rate of white CKD was increased from 16 to 20 Mg $feddan^{-1}$, wheat yield of grains and straw and fodder sorghum yield of first and second cuts were decreased. While, when the application rate of black CKD was increased from 12 up to 20 Mg $feddan^{-1}$, wheat grain yield and fodder sorghum yield of the first and second cuts were decreased as listed in Tables 8 and 9. The enhancement in wheat grain yield and fodder sorghum yield of first and second cuts when the soil was treated with white CKD was better than that when soil was treated with black CKD. Whereas, the enhancement in wheat straw yield when the soil was treated with black CKD was better than when the soil was treated with white CKD. Furthermore, the enhancement in fodder sorghum yield of second cut was better than that of first cut. This improvement in the yield of wheat and fodder sorghum may be explained by the beneficial effects of white and black cement kiln dusts which may be useful as: (1) a soil amendment; in which they improve the physical, chemical, and biological properties of the studied sandy loam soil and (2) a fertilizer material, in which they are a source of macro and micro nutrients necessary for the growth and development of the wheat and fodder sorghum plants.

From the view point of this concern, the results are in consistent with those reported by several researchers in many parts of the world. Some authors have suggested the use of CKD as a soil amendment and a source of nutrients necessary for the growth and development of plants as well as for enhancing the crop yield because of the high lime content and potassium concentration in the CKD (Adaska and Taubert, 2008 and Rahman *et al.*, 2011). Furthermore, Rahman *et al*. (2011) concluded that CKD may be used as a soil conditioner and a source of nutrient to enhance the crop yield. In contrast, Khader and Abu-Rub (1986) studied the possibility of using CKD as a fertilizer. They found that CKD did not show any significant effect on the dry matter yield of barely when planted in sand and soil mixed with CKD. Therefore, one should remember that these beneficial usages critically depend on the chemical and physical properties of the CKD.

The decrease in the yield of wheat and fodder sorghum may be due to: (1) the high value of electrical conductivity of white CKD (7.99 dS m^{-1}) and black CKD (14.28 dS m^{-1}) and (2) the concentration of lead, nickel, and cadmium in the white and black CKDs as shown in Table 2. The results are in harmony with that reported by Sharma and Agrawal (2005) who pointed out that heavy metals are persistent in nature, therefore get accumulated in soils and plants. Heavy metals interfere with physiological activities of plants such as photosynthesis, gaseous exchange and nutrient absorption, and cause reductions in the plant growth, dry matter accumulation and yield.

The highest value of wheat grain yield (2.77 Mg $fed.^{-1}$) and fodder sorghum yield of first and second cuts (7.3 and 8.8 Mg $fed.^{-1}$, respectively) was recorded when the soil was treated with 16 Mg $feddan^{-1}$ of white CKD. While, the highest value of wheat straw yield (2.34 Mg $fed.^{-1}$) was attained when the soil was treated either with 16 Mg $feddan^{-1}$ of white CKD or with 20 Mg $feddan^{-1}$ of black CKD.

It can be noticed from the results presented in Tables 8 and 9 that the wheat biological yield, wheat harvest index, and total yield of fodder sorghum were enhanced when white and black CKDs were added to the sandy loam soil. Wheat biological yield, wheat harvest index, and total yield of fodder sorghum were increased with increasing the application rate of white CKD from 0.0 up to 16 Mg $feddan^{-1}$ and increasing the application rate of black CKD from 0.0 up to 12 Mg $feddan^{-1}$ when compared to those of the untreated soil. In contrary; when the application rate of white CKD was increased from 16 to 20 Mg $feddan^{-1}$ and when the application rate of black CKD was increased from 12 up to 20 Mg $feddan^{-1}$, wheat biological yield, wheat harvest index, and total yield of fodder sorghum were decreased.

Concentration and uptake of lead, nickel and cadmium by wheat and fodder sorghum plants

It is evident from the results in Table 10 that increasing the application rate of either the white CKD or the black CKD from 0.0 up to 20 Mg $feddan^{-1}$ significantly increased the concentration of lead, nickel, and cadmium in wheat grains and in fodder sorghum plants of first and second cuts ($p = 0.05$) when compared to those of untreated soil. Similar observations were reported by many authors. Sharma and Agrawal (2005) showed that the general population is exposed to Pb from air and food. Cadmium is of particular concern in plants since it accumulates in leaves at very high levels, which may be consumed by animals or human being. Heavy metals pose a number of hazards to human health. Therefore, their concentration in the environment and their effects on human health must be regularly monitored. In addition, Waly *et al.* (2007) reported that heavy metals can pose health hazards if their concentrations exceed allowable limits. Even when the concentrations of metals do not exceed these limits, there is still a potential for long-term contamination, since heavy metals are known to be accumulated within biological systems. Cadmium causes intoxication of liver, kidneys, brain, lungs, heart and testicles. It is a carcinogen. Moreover, Bhalerao *et al*. (2015) pointed out that Ni is essential for plants, but the concentration in the majority of plant species is very low (0.05 - 10 mg/kg dry weight). Further, with increasing Ni pollution, excess Ni rather than a deficiency, is more commonly found in plants. Toxic effects of high concentrations of Ni in plants have been frequently reported. For example, adverse effects on fruit yield and quality of wheat (*Triticum aestivum* L.).

Table 10. Initial and residual effect of applying white and black CKDs on accumulation of lead, nickel, and cadmium in wheat grains and fodder sorghum plants.

CKD treatments (Mg $feddan^{-1}$)		Pb concentration (mg kg^{-1})			Ni concentration (mg kg^{-1})			Cd concentration (mg kg^{-1})		
		Wheat	Fodder sorghum		Wheat	Fodder sorghum		Wheat	Fodder sorghum	
			First cut	Second cut		First cut	Second cut		First cut	Second cut
	Control	0.43	0.44	0.42	0.24	0.23	0.21	0.08	0.05	0.05
White CKD	4	0.44	0.50	0.44	0.24	0.27	0.26	0.09	0.09	0.10
	8	0.49	0.52	0.46	0.26	0.29	0.28	0.10	0.11	0.11
	12	0.54	0.56	0.47	0.28	0.31	0.30	0.12	0.13	0.12
	16	0.60	0.58	0.49	0.31	0.34	0.32	0.14	0.14	0.14
	20	0.67	0.61	0.51	0.32	0.36	0.34	0.15	0.15	0.15
	Mean	0.55	0.55	0.47	0.28	0.31	0.30	0.12	0.12	0.12
Black CKD	4	0.51	0.62	0.54	0.27	0.37	0.30	0.11	0.15	0.12
	8	0.54	0.65	0.56	0.29	0.39	0.32	0.12	0.16	0.14
	12	0.60	0.69	0.57	0.32	0.40	0.34	0.14	0.18	0.15
	16	0.64	0.73	0.59	0.34	0.40	0.36	0.15	0.19	0.16
	20	0.69	0.77	0.60	0.36	0.41	0.35	0.17	0.19	0.17
	Mean	0.60	0.69	0.57	0.32	0.39	0.33	0.14	0.17	0.15
LSD at 5% level		0.05	0.05	0.07	0.03	0.02	0.02	0.01	0.01	0.01

The concentration of lead, nickel, and cadmium in wheat grains and in fodder sorghum plants of first and second cuts as a result of treating soil with black CKD was higher than that in wheat grains and in fodder sorghum plants of first and second cuts when soil was treated with white CKD. These results may be elucidated by that the lead, nickel, and cadmium concentration of black CKD was higher than that of white CKD (Table 2).

It is prominent from the results in Table 11 that increasing the application rate of either white CKD or black CKD from 0.0 up to 20 Mg $feddan^{-1}$ significantly increased uptake of lead, nickel, and cadmium by wheat grains ($p = 0.05$) when compared to that of untreated soil. Kloke *et al.* (1984) indicated that when discussing the behavior of heavy metals in soil, the central question is the uptake of these element by plants, for in the interests of the health of man and animals only a certain level of heavy metals in plants can be tolerated.

The uptake of lead, nickel, and cadmium by the fodder sorghum plants of the first and second cuts was significantly increased (p = 0.05) by increasing the application rate of white CKD from 0.0 up to 16 Mg feddan^{-1} and increasing the application rate of black CKD from 0.0 up to 12 Mg feddan^{-1} when compared to that of the untreated soil as presented in Table 11. On the other hand; when the application rate of white CKD was increased from 16 to 20 Mg feddan^{-1} and when the application rate of black CKD was increased from 12 up to 20 Mg feddan^{-1}, the uptake of lead, nickel, and cadmium by the fodder sorghum plants of first and second cuts was significantly decreased (p = 0.05).

Table 11. Initial and residual effect of applying white and black CKDs on uptake of lead, nickel, and cadmium by wheat grains and fodder sorghum plants.

CKD treatments (Mg feddan^{-1})		Pb uptake (g fed.$^{-1}$)				Ni uptake (g fed.$^{-1}$)				Cd uptake (g fed.$^{-1}$)			
		Wheat	Fodder sorghum			Wheat	Fodder sorghum			Wheat	Fodder sorghum		
			First cut	Second cut	Total uptake		First cut	Second cut	Total uptake		First cut	Second cut	Total uptake
Control		0.78	0.35	0.42	0.77	0.43	0.18	0.21	0.39	0.14	0.04	0.05	0.09
White CKD	4	0.88	0.55	0.57	1.12	0.48	0.30	0.34	0.64	0.18	0.10	0.13	0.23
	8	1.02	0.68	0.69	1.37	0.54	0.38	0.42	0.80	0.21	0.14	0.17	0.31
	12	1.23	0.78	0.75	1.53	0.64	0.43	0.48	0.91	0.27	0.18	0.19	0.37
	16	1.43	0.87	0.88	1.75	0.74	0.51	0.58	1.09	0.33	0.21	0.25	0.46
	20	1.50	0.79	0.77	1.56	0.72	0.47	0.51	0.98	0.34	0.20	0.23	0.43
	Mean	1.21	0.73	0.73	-----	0.62	0.42	0.47	-----	0.27	0.16	0.19	-----
Black CKD	4	1.01	0.62	0.65	1.27	0.53	0.37	0.36	0.73	0.22	0.15	0.14	0.29
	8	1.11	0.72	0.67	1.39	0.59	0.43	0.38	0.81	0.25	0.18	0.17	0.35
	12	1.31	0.83	0.86	1.69	0.70	0.48	0.51	0.99	0.31	0.22	0.23	0.45
	16	1.38	0.80	0.65	1.45	0.73	0.44	0.40	0.84	0.32	0.21	0.18	0.39
	20	1.46	0.77	0.66	1.43	0.76	0.41	0.39	0.80	0.36	0.19	0.19	0.38
	Mean	1.26	0.75	0.70	-----	0.66	0.42	0.41	-----	0.29	0.19	0.18	-----
LSD at 5% level		0.10	0.04	0.06	-----	0.06	0.02	0.03	-----	0.04	0.01	0.02	-----

Regarding the health risk assessment of lead, nickel, and cadmium concentration in the wheat grains and in the fodder sorghum plants of first and second cuts; all the values of lead, nickel, and cadmium concentration in the wheat grains and in the fodder sorghum plants illustrated in Table 10 were compared with the guidelines of WHO/FAO (1976) and the guidelines of Awashthi (2000) as shown in Tables 12 and 13, respectively. The values of lead, nickel, and cadmium concentration in the wheat grains and in the fodder sorghum plants are below the permissible levels recommended by the guidelines of WHO/FAO (1976) and the guidelines of Awashthi (2000). The values of lead, nickel, and cadmium concentration are within the normal range of lead, nickel, and cadmium concentration in foods and vegetables according to the guidelines of WHO/FAO (1976).

Table 12. WHO/FAO guidelines for metals in foods and vegetables [Adapted from FAO/WHO (1976)].

Heavy metal		WHO/ FAO	Normal range in plant (mg/kg)
Lead	Pb	2.00	0.50 – 30.00
Nickel	Ni	-----	0.02– 50.00
Cadmium	Cd	1.00	< 2.40

Table 13. Guidelines for the Indian standards for heavy metals in the soil, food, and drinking water [Adapted from Awashthi (2000)].

Heavy metal	Soil (mg/kg)	Food (mg/kg)	Water (mg/l)
Pb	250 – 500	2.5	0.10
Ni	75 – 150	1.5	-----
Cd	3.0 – 6.0	1.5	0.01

This result indicates that there is no obvious accumulation of lead, nickel, and cadmium in the wheat grains and in the fodder sorghum plants; implying that these metals have no risk, does not make a concern, and could not affect the human and animal health through the three primary routes namely inhalation, ingestion, and skin absorption. The results of our study are in consistent with that reported by Pourrut *et al.* (2011) who concluded that lead enters plants mainly through the roots via the apoplast pathway or calcium ion channels. Lead can also enter plants in small amounts through leaves. Once in the roots, lead tends to sequester in root cells. Only a limited amount of lead is translocated from roots to shoot tissues, because there are natural plant barriers in the root endodermis (e.g., Casparian strips).

The results of our study revealed that the source of lead, nickel, and cadmium present in wheat grains and in fodder sorghum plants may be as a result of (1) applying white and black CKDs to soil and (2) other contaminants in the investigated site.

CONCLUSIONS

Addition of both white and black CKDs to the investigated soil resulted in a significant increase in the concentration of lead, nickel, and cadmium in the soil at harvesting of wheat and fodder sorghum plants. The investigated soils remain at safe levels of lead and nickel, while, soils are in a potential level of unsafe cadmium. The highest value of wheat yield and fodder sorghum yield was recorded when white CKD was applied to soil at the rate of 16 Mg feddan^{-1}. The health risk assessment of lead, nickel, and cadmium concentrations in wheat grains and fodder sorghum plants were below the permissible levels in the food recommended by international guidelines. Consequently; these metals have no risk on human, plant and animal health. Subsequently, it could be recommended to apply white CKD at the application rate of 16 Mg feddan^{-1} just one time for staple crops grown in sandy soils under the conditions of El-Minia Governorate, Egypt.

REFERENCES

Abd El-Aleem, S.; Abd El-Aziz, M. A.; Heikal, M.; and El-Diadmony, H. (2005). Effect of cement kiln dust substitution on chemical and physical properties and compressive strength of Portland and slag cements. The Arabian Journal for Science and Engineering, Vol. 30, No. 2B, pp. 263-273.

Abd El-Azeim M. M. ; Sherif M. A.; Hussien M. S.; Haddad S. A. (2020). Temporal Impacts of Different Fertilization Systems on Soil Health under Arid Conditions of Potato Monocropping. https://doi.org/10.1007/s42729-019-00110-2.

Abd El-Azeim, M. M.; W. S. Mohamed and A. A. Hammam (2016). Soil Physiochemical Properties In Relation To Heavy Metals Status of Agricultural Soils In El-Minia Governorate, Egypt. J. SOIL SCI. AND AGRIC. ENGINEERING, MANSOURA UNIV., VOL. 7 (6): 423 – 431, 2016. DOI: 10.21608/jssae.2016.39676

Adaska, W. S. and Taubert, D. H. (2008). Beneficial uses of cement kiln dust. Presented at 2008 IEEE/PCA 50th Cement Industry Technical Conf., Miami, FL, May 19-22, 2008, pp. 1-19.

Awashthi, S. K. (2000). Prevention of food adulteration Act No. 37 of 1954. Central and State Rules as Amendment for 1999. IWD Edition. Ashoka Law House, New Delhi [Cited from: Sharma and Agrawal (2005). Journal of Environmental Biology, 26 (2 supp1), pp. 301-313].

Bhalerao, S. A.; Sharma, A. S.; and Poojari, A. C. (2015). Toxicity of nickel in plants. International Journal of Pure and Applied Bioscience, 3 (2), pp. 345-355.

Dollhopf, D. J. and Mehlenbacher, J. T. (2002). Alkaline industrial by-product effects on plant growth in acidic-contaminated soil system. National Meeting of the American Society for Surface Mining and Reclamation, Lexington, KY June 9-13, 2002, pp. 568-581.

FAO/WHO (1976). List of maximum levels recommended for contaminants by the joint FAO/WHO codex Alimentarias Commission. 2nd series, CAC/FAL, 1976, 3, pp. 1- 8 [Cited from: Opaluwa *et al*. (2012). Advances in Applied Science Research, Pelagia Research Library, 2012, 3 (2), pp. 780-784. Online: available at the website: www. pelagiaresearchlibrary. com].

Haddad, S. A.; J. Lemanowicz, And M. M. Abd El-Azeim, (2019). Cellulose Decomposition in Clay and Sandy Soils Contaminated with Heavy Metals. International Journal Environmental Science and Technology16:3275–3290. Https://Doi.Org/ 10.1007/ S13762-018-1918-1.

Jackson, M. L. (1973). Methods of chemical analysis. Prentic Hall, Englewood Cliffs, N. T. J.

Khader, S. and Abu-Rub, N. (1986). The potential use of cement dust as a fertilizer. Dirasat, Vol. 13, No. 5,pp. 51-60 [Cited from: Rahman *et al*. (2011). IJRRAS, Vol. 7, Issue 1, April 2011, pp. 77-87].

Kloke, A.; Sauerbeck, D. R.; and Vetter, H. (1984). The contamination of plants and soils with heavy metals and the transport of metals in terrestrial food chains. Changing metal cycles and human health (editor: I. O. Nriagu), pp. 113-141. Dahlem Konferenzen 1984. Berlin, Heidelberg, New York, Tokyo: Springer Verlag.

Kumpulainen, I.; Raittila, A. M.; Lehto, I.; and Koiristoinen, P. (1983). Electrothermal Atomic Absorption Spectrometric determination of heavy metals in foods and diets. J. Associ. Off. Anal. Chem., 66, pp. 1129-1135.

Kunal; Siddique, R.; and Rajor, A. (2012). Use of cement kiln dust in cement concrete and its leachate characteristics: Review. Resources, Conservation and Recycling 61, pp. 59-68, Elsevier. Contents lists available at SciVerse Science Direct. Journal homepage: www.elsevier.com/locate/resconrec.

Maclean, K. S.; Polunson, A, R.; and MacConnell, H. M. (1987). The effect of sewage sludge on the heavy metals content of soils and plant tissue. Commun. Soil Sci. Plant Anal. 18, pp. 1303-1316.

Mathieu, C. and Pieltain, F. (2003). Chemical analysis of soils. Selected methods, France, pp. 387.

Naik, T. R.; Canpolat, F.; and Chun, Y. (2003). Uses of CKD other than for flue gas desulfurization. Center for by-products utilization, a CBU Report for Holcim (US), report No. CBU-2003-35, REP-529, September 2003, College of Engineering and Applied Science, the University of Wisconsin, Milwaukee, pp. 1-33.

Olowoyo, J. O.; Mugivhsa, L. L.; and Busa, N. G. (2015). Trace metals in soil and plants around a cement factory in Pretoria, South Africa. Pol. J. Environ. Siud. Vol. 24, No. 5, pp. 2087-2093.

Page, A. L.; Miller, R. H.; and Keeney, D. R. (eds.) (1982). Methods of soil analysis. Part 2: Chemical and biological properties. Agronomy 9, 2nd edition, Am. Soc. Agron., Madison, Wisconsin, USA.

Pourrut, B.; Shahid, M.; Dumat, C.; Winterton, P.; and Pinelli, E. (2011). Lead uptake, toxicity, and detoxification in plants. Reviews of Environmental Contamination and Toxicology, Springer Verlag, Vol. 213, pp. 113-136. ISSN 0179-5953. Online: available at: https://hal.archives-ouvertes.fr/hal-00717188.

Rahman, M. K.; Rehman, S.; and Al-Amoudi, O. S. B. (2011). Literature review on cement kiln dust usage in soil and waste stabilization and experimental investigation. IJRRAS, Vol. 7, Issue 1, April 2011, pp. 77-87. Web Site: www.arpapress.com/ Volumes/Vol7Issue1/IJJRAS_ 7_1_12.pdf.

Scianna, J. (2002). Salt-affected soils: Their causes, measure, and classification. Hort. Note No. 5, Plant Materials Program, pp. 1-3.

Sehgal, J. L.; Sohanlal; and Pofalii, R. M. (1992). Sandy soils of India. Agropedology, Volume 2, pp. 1-16,October, 1992.

Sharma, R. K. and Agrawal, M. (2005). Biological effects of heavy metals: An overview. Journal of Environmental Biology, 26 (2 supp1), pp. 301-313. Online: available at the website: http://www.geocities. com/Lenviron_biol/. Access date: 11 September 2019.

Siti Norbaya, M. R.; Hasan, S.; Kamal, M. L.; and Hashim, N. S. M. (2014). Analysis and pollution assessment of heavy metal in soil, Perlis. The Malaysian Journal of Analytical Sciences, Vol. 18, No. 1, pp. 155-161.

U. S. Environmental Protection Agency (1993). Report to Congress on cement kiln dust. Volume II: Methods and findings, December 1993, U. S. Environmental Protection Agency, Office of Solid Waste, Washington, D.C. [Cited from: Naik *et al.* (2003). Center for by-products utilization, A CBU Report for Holcim (US), report No. CBU-2003-35, REP-529, College of Engineering and Applied Science, the University of Wisconsin, Milwaukee, pp. 1-33].

USDA, United States Department of Agriculture (2000). Heavy metal soil contamination. United States Department of Agriculture, Natural Resources Conservation Service (NRCS), Soil Quality-Urban Technical Note No. 3, September 2000, pp. 1-7.

Uysal, I.; Ozdilek, H. G., and Ozturk, M. (2012). Effect of kiln dust from a cement factory on growth of

Vicia faba L. Journal of Environmental Biology, 32, April 2012, pp. 525-530.

Waly, T. A.; Dakroury, A. M.; Sayed, G. E.; and El-Salam, S. A. (2007). Assessment removal of heavy metals ions from wastewater by cement kiln dust (CKD). Eleventh International Water Technology Conference, IWTC11 2007 Sharm El-Sheikh, Egypt, pp. 879-893.

Wanninayake, P. C. U.; Malaviarachchi, M. A. P. W. K.; Hettiarachchi, R. P.; and Yapa, P. N. (2021).Different sources of phosphorus fertilizers and soil amendments affected the phosphorus and cadmium content in soil, roots and seeds of maize (Zea mays L.). Turkish Journal of Agriculture - Food Science and Technology, 9 (4), pp. 640-645. Online: available at the website: www.agrifoodscience.com.

تأثير تراب فرن الاسمنت على بعض الخواص الكيميائية للتربة والنمو والمحصول للقمح وذرة العلف

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يؤدى الاستخدام الزراعي لتراب فرن الأسمنت الناتج من مخلفات مصانع الاسمنت إلى تحسين خواص التربة الرملية وزيادة النمو والمحصول النامي بالتربة المعاملة به. أجريت تجارب حقلية بمزرعة خاصة في الأراضي المستصلحة حديثا في المنطقة الغربية من وادي النيل بمحافظة المنيا - مصر .وتهدف هذه الدراسة إلى بحث تأثير إضافة كل من تراب فرن الأسمنت الأبيض و الأسود بستة معدلات إضافة (صفر، 4، 8 ،12 ، 16 ، 20 طن/فدان) للتربة الرملية على بعض الخواص الكيميائية للتربة و النمو و المصول و التركيب الكيميائي لنباتات القمح و ذرة العلف النامية بها. تشير النتائج إلى أن تراب فرن الأسمنت الأبيض أو الأسود يعتبر مادة امنة كمنتج ثانوي عند إضافتها إلى التربة الرملية من حيث رقم الحموضة ومحتوى عناصر الرصاص والنيكل والكادميوم، بينما قد تسبب خطرا محتملا من حيث تراكم الاملاح بالتربة. أدت إضافة أي من تراب فرن الأسمنت الأبيض أو الأسود إلى التربة إلى زيادة التوصيل الكهربي للتربة ونقص قليل فى رقم الحموضة وزيادة فى تركيز كل من الرصاص والنيكل والكادميوم بالتربة عند حصاد نباتات القمح او ذرة العلف النامية بها. وقد توزعت عناصر الرصاص والنيكل والكادميوم مكانيا بالتربة في موقع الدراسة. وكانت تركيزات هذه العناصر الثقيلة في أراضي موقع الدراسة بالترتيب التنازلي التالي: الرصاص > النيكل > الكادميوم. بعد انتهاء التجربة لا تزال أراضي موقع الدراسة آمنة من حيث مستوى الرصاص والنيكل بها، بينما لا تزال التربة غير آمنه احتماليا من حيث مستوى الكادميوم بها.حدث تحسن في نمو ومحصول القمح وذرة العلف نتيجة إضافة كل من تراب فرن الأسمنت الأبيض والأسود للتربة الرملية. وهذا التحسن نتيجة اضافة معاملات تراب فرن الاسمنت الأبيض كان أفضل من ذلك عند اضافة معاملات تراب فرن الأسمنت الأسود. وقد سجلت أعلى قيمة لمحصول القمح ومحصول ذرة العلف عند معاملة التربة بتراب فرن الأسمنت الأبيض بمعدل 16 طن/فدان. وقد بين تقييم المخاطر الصحية لتركيز العناصر تحت الدراسة فى حبوب القمح (كغذاء للإنسان) ونباتات ذرة العلف (كغذاء للحيوان) ان قيم تركيز الرصاص والنيكل والكادميوم اقل من المستويات المسموح بها في الغذاء والتي اوصت بها اثنتين من الدلائل العالمية. وبالتالي، فان هذه العناصر لا تسبب خطرا ولا تؤثر على صحة الانسان او الحيوان. ويمكن التوصية بإضافة تراب فرن الاسمنت الأبيض بمعدل 16 طن/فدان مرة واحدة فقط للمحاصيل الشائعة والنامية في الأراضي الرملية تحت ظروف محافظة المنيا - مصر.