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Industrial Activities and Heavy Metal Pollution: Assessment of Concentration of Zn, Cu, Cd Cr and, Pb in Soil Samples around Dangote Cement Factory Kogi State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SDE and ESO designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MCA, AM and KIF managed the analyses of the study. Author MCA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study aims at determining the concentration of heavy metal contaminants in the soil around Dangote cement factory Kogi State, Nigeria. It also seeks to understand the relationship between the heavy metals and the level of concentration with respect to distance and direction as well as the ecological risk it poses. The monitoring and assessment of soil pollution have over the years become a very important area of study due to the significant threat it poses to the food web. A total of 33 soil samples were collected in the Northern, Eastern and Western axis within a radius of 4km of Dangote cement factory at a depth of 0-15cm using a stainless steel auger. The contamination

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factor indices for Cr and Cu show moderate pollution across all the samples collected from different axis at a different distance from the factory. Zn also pose a moderate pollution across the samples except for WK4 and NK4 where it is in a low level of contamination. The geo-accumulation indices for Pb and Cr show unpolluted to moderately polluted across all samples at different locations expect for sample location EK4. The results of the ecological risk assessment revealed that Cd poses the highest ecological risk of all the five heavy metals investigated.

Keywords: Ecological risk assessment; geo-accumulation indices; metal pollution; Nigeria.

1. INTRODUCTION

The monitoring and assessment of soil pollution have over the years become a very important area of study due to the significant threat it poses to the food web. In other words, soil contamination risks health, reduces soil fertility and productivity as well as cause other ecological problems. Soil pollution is the persistence of toxic compounds, salts, chemicals, radioactive material or disease causing agents, which has an adverse effect on plant development and animal health [1]. The most common soil pollutants are hydrocarbons, solvents, pesticides and heavy metals. Heavy metals are metals with a density greater than $5g/cm^3$ [2]. It is worthy to note that heavy metals are essential for plants and animals in trace amounts. In fact, they are widely distributed in the environment, soils (through weathering from parent materials), plants (root, leaves) and animals in their tissues. However, a significant increase from the essential concentration levels makes it very harmful and unsafe for both plants and animals. Often, the damages caused by toxic metals originates from the production of oxidative free radicals that results to lipids peroxidation and the disruption of metabolic processes [3]. The mutual problems associated with unauthorized management and discarding of wastes include; infections, disease transmission, and soil/water pollution [4]. Due to industrial expansion, large amounts of industrial wastes are gathering in the environment and cannot be disposed without prior special treatments [5]. In specific, waste products from the mining, tanneries, textiles and metal refining industries, sewage sledges, etc contain heavy metals at high concentrations. Generally, these heavy metals can be leaked from the soil to the surface water and underground water system [6] at concentrations higher beyond acceptance. Environmental pollution from heavy metals and minerals can arise from natural as well as anthropogenic sources. Natural sources are: seepage from rocks into water, volcanic activity, forest fires etc. In anthropogenic activity the pollution occurs both at the level of industrial production as well as end use of the products and run-off [4]. From the research conducted by Blacksmith Institute, it estimates that close to 125 million people are at risk from industrial pollution worldwide. The chief hazardous metals which are of great concern in the world today in terms of their environmental load and health effects are lead, mercury, chromium, cadmium, copper and aluminium. These metals exist in water and soil leading to severe threats and the need to treat and remove them from water and soil is paramount. Waste disposal into the environment generates adverse effects by changing the normal physiochemical properties of soil and water [7]. Heavy metal contamination has also been associated with an increased risk of; cancer and cardiovascular disease mortality in men due to cadmium [8], chronic kidney diseases due to lead [9], infertility and diabetes (due to cadmium) [10]. More recently, there is a recorded increase in the number of cases of some these diseases in Kogi State. Thus, this study aims at determining the concentration of heavy metal contaminants in the soil around Dangote cement factory Kogi State, Nigeria. It also seeks to understand the relationship between the heavy metals and the level of concentration with respect to distance and direction as well as the ecological risk it poses.

2. MATERIALS AND METHODS

2.1 Study Area

Dangote cement factory lies between 7.9104° N and 6.4399° E. It is situated in Obajana community, an area underlain by basement complex rocks, predominantly composed of folded gneisses and metal sediments. The commonly found rock types in the study area include: granite, quartzite, limestone, schist, pegmatite, and granulites. An overburden of 2m and 8m thickness of soil overlies the limestone. The area is characterized by two types of landforms; river valleys and domed shaped residual hills [11].

Dangote has an average maximum and minimum temperature of 33-22.8°C, respectively. While average rainfall is between 1,100 and 1,320mm. Rainfall lasts from May through October with dry season (harmattan) dominant in between [12]. The soil types in the area range from sand to loam with the sand fraction varying from 68.3-95%. The percentage content generally decreases with increasing depth at any particular point while the percentage silt content varies from 2.3 – 20.7% and clay content are between 2.3- 20.0% [13].

2.2 Sampling Protocol

A total of 33 soil samples were collected in the Northern, Eastern and Western axis within a radius of 4km of Dangote cement factory at a depth of 0-15cm using a stainless steel auger. Three subsamples of soil were collected at each sampling location. Composite samples were collected at the control site (5 kilometers away from the factory) which served as the less contaminated/reference area [14]. Each soil sample collected was transfered into a polythene bag which was labelled and transported to the laboratory. Soil samples were then air-dried for 2 weeks to constant weight. Dried soil samples were pulverized using a ceramic mortar and pestle, and sieved through a 2mm sieve. All heavy metal determination from soil samples was based on the fine particles obtained.

Digestion of soil samples for determination of Zn, Cu, Cr, Pb and Cd content of soil samples was carried out according to the conventional Nitric-Perchloric acid digestion method. One gram of the soil sample was measured (Mettler Toledo mb-8310) and transferred into a 250 ml conical flask, and 10 ml of concentrated nitric acid was added. The mixture was boiled gently for 30–45 min to oxidize all easily oxidizable matter and then allowed to cool for 12hrs. After cooling, 5 ml of 70% $HClO_4$ was added and the mixture was boiled gently until dense white fumes appeared. After cooling, 20 ml of distilled water was added and the mixture was boiled further to release any fumes. The solution was cooled, further filtered using a Whattman filter paper No. 42 and transferred into a 50ml volumetric flask and was topped up to 25ml with deionized water. Finally, the solution was analyzed for total Zn, Cu, Cr, Pb and Cd using atomic absorption spectrophotometer (A.A.S) which can detect heavy metals from samples through emissions from their corresponding wavelength after excitation into a higher energy level from a light source. Quality assurance and control were assessed using the duplicates and blanks method [15].

2.3 Data Analysis

Data were subjected to Descriptive statistics and Levene's test using an IBM SPSS Statistics Version 23.0.

3. CONTAMINATION AND RISK ASSESSMENT

3.1 Contamination Factor

A contamination factor is used to determine the contamination of a given toxic substance in a lake, or a sub-basin [16]. Contamination factor (Cf) is calculated with the formula Cf= Ci/Cn. Where Ci is the mean concentration of the heavy metal, Cn is the Concentration of the heavy metal in the REF (Control). The contamination factor is categorized as follows:

Cf ≤ 1 is low pollution
1 ≤ Cf ≤ 3 is moderate pollution
3 ≤ Cf ≤ 6 is considerable pollution
Cf > 6 is very high pollution [17].

3.2 Geo Accumulation Index

The index describes the degree of pollution in soils posed by the element by balancing it with the background concentrations (REF). It can be calculated as Igeo=Log2(Ci/1.5Cn)

Where Ci is the mean concentration of the heavy metal
Cn is the Concentration of heavy metal in the REF (Control)

The factor 1.5 is used because of man's influences or possible variations in the background values.

The geo accumulation index is grouped into seven classes according to [18] as follows:

Igeo < 0: unpolluted
1 <Igeo <2: moderately polluted
2 < Igeo < 3: moderately to strongly polluted
3 < Igeo < 4: strongly polluted
4 < Igeo < 5: strongly to very strongly polluted
Igeo ≥ 5: very strongly polluted

3.3 Ecological Risk Factor

Ecological risk factor is the product of the contamination factor and the toxicity of individual

metal. It expresses the potential ecological risk of each given contaminant [16]. It can be expressed as: E=Tr x Cf. R=∑E

Where E is the individual potential risk factor, Cf is the contamination factor, Tr is the toxic response factor and the toxic response factor for Zn, Cr, Pb, Cd, and Cu is 1, 2, 5, 30 and 5 respectively [19].

The following terminologies are used to describe the risk factor.

E < 40: low potential ecological risk
40 < E < 80: Moderate potential ecological risk
80 < E < 160: Considerable ecological risk
160 < E < 320: High potential ecological risk and
E ≥ 320: very high ecological risk.
The following terminologies are also used to describe the Ri.
Ri < 95 indicates a low potential ecological risk
95 < Ri < 190 is a moderate ecological risk
190 < Ri < 380 is a considerable ecological risk
Ri ≥ 380 is a very high ecological risk [17].

4. RESULTS

4.1 Descriptive Statistics

Results were subjected to a descriptive statistical analysis to further justify frequencies of occurrences of each heavy metal in relation to the directions they were taken from. Since three soil samples were collected at each kilometre in each direction the mean of the triplicate results was recorded as the final value.

The same descriptive analysis was used for all the other heavy metals which include Zinc, Chromium, Lead, Cadmium and Copper. Their tables are shown below respectively.

Table 1. A multivariate descriptive statistics table showing more profound view of the total metal contents of the soil in the study area

Descriptive statistics					
	Distance (Km)	**Direction**	**Mean**	**Std. deviation**	**N**
Zn	One Kilometre	West (7°55'36N 6°24'48" E)	154.1933	1.09203	3
		North (7°56'15"N 6°25'28" E)	145.1667	1.69730	3
		East (7°55'37" N 6°25'53")	173.4833	1.83053	3
		Total	157.6144	12.60093	9
	Two Kilometre	West (7°55'35" N 6°24'15" E)	134.0533	4.99770	3
		North (7°56'38" N 6°25'35" E)	139.8367	1.60936	3
		East (7°55'37" N 6°28'28" E)	165.1133	2.48325	3
		Total	146.3344	14.59686	9
	Three Kilometre	West (7°55'38" N 6°23'43" E)	121.8067	4.01399	3
		North (7°57'14" N 6°25'42" E)	123.8033	4.23510	3
		East (7°55'44" N 6°37'00" E)	151.4533	1.41952	3
		Total	132.3544	14.66100	9

Descriptive statistics					
	Distance (Km)	**Direction**	**Mean**	**Std. deviation**	**N**
	Four Kilometre	West 7°55'36" N 6°23'08" E	109.4200	1.90502	3
		North (7°57'41" N 6°25'52" E)	116.3133	3.09742	3
		East (7°55'34" N 6°27'32" E)	157.4067	2.54168	3
		Total	127.7133	22.57838	9
	Total	West	129.8683	17.50027	12
		North	131.2800	12.44579	12
		East	161.8642	8.82886	12
		Total	141.0042	19.83837	36
Cd	One Kilometre	West	.4200	.18358	3
		North	.5900	.07211	3
		East	.8067	.02082	3
		Total	.6056	.19494	9
	Two Kilometre	West	.4567	.11930	3
		North	.5233	.01528	3
		East	.5067	.04933	3
		Total	.4956	.07161	9
	Three Kilometre	West	.4067	.07506	3
		North	.4200	.04583	3
		East	.2700	.07000	3
		Total	.3656	.09126	9
	Four Kilometre	West	.2867	.17616	3
		North	.4600	.04359	3
		East	.2300	.04359	3
		Total	.3256	.13956	9
	Total	West	.3925	.14079	12
		North	.4983	.07907	12
		East	.4533	.24362	12
		Total	.4481	.16965	36
Cr	One Kilometre	West	64.9100	6.63885	3
		North	64.3600	3.46451	3
		East	63.9033	1.39429	3
		Total	64.3911	3.83351	9
	Two Kilometre	West	53.8333	3.54730	3
		North	57.5967	5.82320	3
		East	62.5733	1.60815	3
		Total	58.0011	5.16570	9
	Three Kilometre	West	57.2567	3.16443	3
		North	55.5433	2.89706	3
		East	52.9400	1.49342	3
		Total	55.2467	2.95000	9
	Four Kilometre	West	51.2267	2.83495	3
		North	51.4333	1.53324	3
		East	46.6333	3.39644	3
		Total	49.7644	3.31716	9
	Total	West	56.8067	6.51535	12
		North	57.2333	5.84314	12
		East	56.5125	7.63812	12
		Total	56.8508	6.51901	36

Descriptive statistics					
	Distance (Km)	**Direction**	**Mean**	**Std. deviation**	**N**
Pb	One Kilometre	West	63.8667	3.10286	3
		North	45.0233	2.76666	3
		East	42.4300	1.19578	3
		Total	50.4400	10.36069	9
	Two Kilometre	West	67.6833	1.21006	3
		North	44.3000	2.47314	3
		East	44.5833	8.31359	3
		Total	52.1889	12.41906	9
	Three Kilometre	West	64.6267	4.98412	3
		North	37.7533	1.16363	3
		East	34.7633	3.15120	3
		Total	45.7144	14.55672	9
	Four Kilometre	West	60.4533	.80903	3
		North	37.6000	2.36432	3
		East	27.1200	3.33173	3
		Total	41.7244	14.90766	9
	Total	West	64.1575	3.72396	12
		North	41.1692	4.14093	12
		East	37.2242	8.26480	12
		Total	47.5169	13.27755	36
Cu	One Kilometre	West	31.7833	2.78852	3
		North	41.8967	1.38551	3
		East	37.3167	.55752	3
		Total	36.9989	4.66217	9
	Two Kilometre	West	31.1667	.66395	3
		North	36.8233	4.27259	3
		East	32.5867	.59003	3
		Total	33.5256	3.35506	9
	Three Kilometre	West	25.4467	1.44417	3
		North	31.7033	.77184	3
		East	24.6467	1.68512	3
		Total	27.2656	3.54656	9
	Four Kilometre	West	24.8233	1.10618	3
		North	28.3067	2.84282	3
		East	20.0167	.88081	3
		Total	24.3822	3.93897	9
	Total	West	28.3050	3.62807	12
		North	34.6825	5.84781	12
		East	28.6417	7.08428	12
		Total	30.5431	6.28405	36

A graphical representation of the total metal contents of the soil in the study area is depicted below as Figs. 1a to 1e respectively.

Fig. 1 (a-e): A graphical representation of the total metal contents of the soil in the study area is depicted

A Levene's test of equality of variances is a test to check whether the variances of two samples or groups are approximately equal or homogeneous. A Levene's test starts with a null hypothesis, in this case a null hypothesis is that there is no difference between the variance of the first group and the variance of the second group. A Levene's test is an F test and we could interpret the significant value the same as we would for any hypothesis test. If the significance value is greater than 0.05, Levene's test is non-significant so equal variances are assumed and if the significance value is less than 0.05, Levene's test is significant so equal variances are not assumed.

In a two-way ANOVA one of the assumptions is that the variances should be homogenous in a case where the value of significance is below

0.05 and Levene's test is significant it should be declared as a limitation in the manuscript since a two-way ANOVA is robust to violate the assumption of homogenous of variances.

4.2 Levene's Test

Using a multivariate test, the Levene's test was calculated for all the heavy metals. Table 2

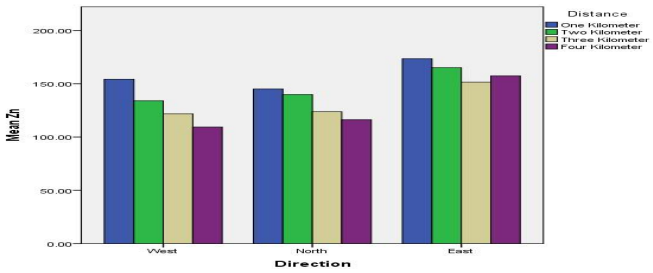

Fig. 1a. Shows (Zinc)

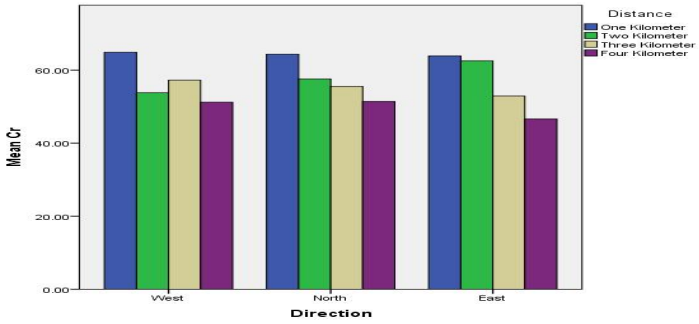

Fig. 1b. Shows (Chromium)

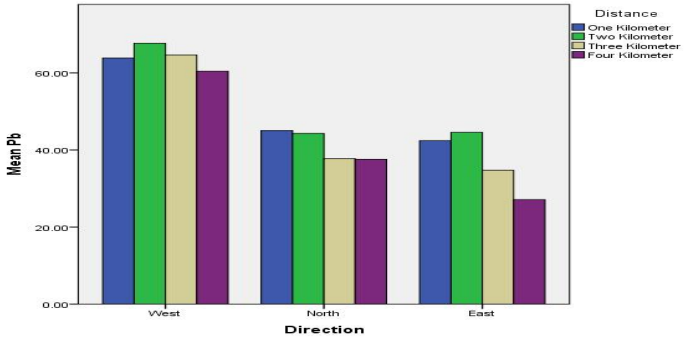

Fig. 1c. Shows (Lead)

Table 2. Levene's test of equality of error variancesa

	F	df1	df2	Sig.
Zn	1.488	11	24	0.200
Cr	2.154	11	24	0.056
Pb	3.668	11	24	0.004
Cd	3.128	11	24	0.009
Cu	3.286	11	24	0.007

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
df-standard deviation
sig-significant value
*a. Design: Intercept + Direction + Distance + Direction * Distance*

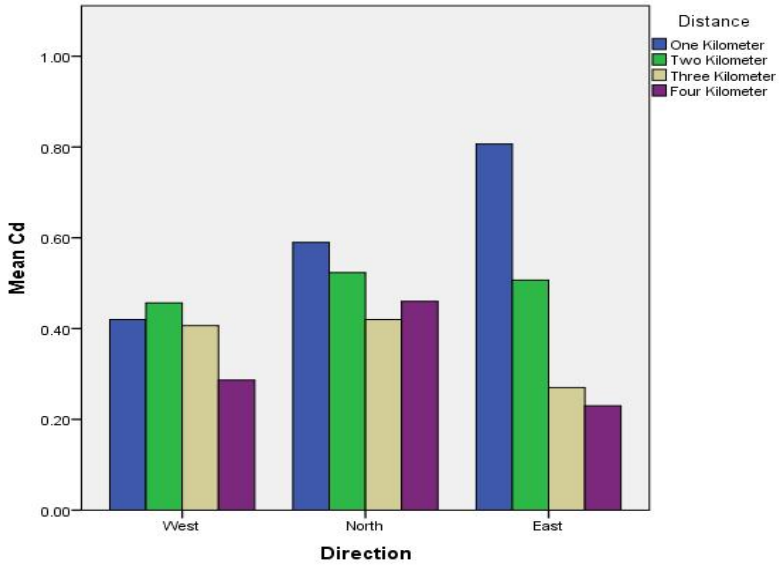

Fig. 1d. Shows (Cadmium)

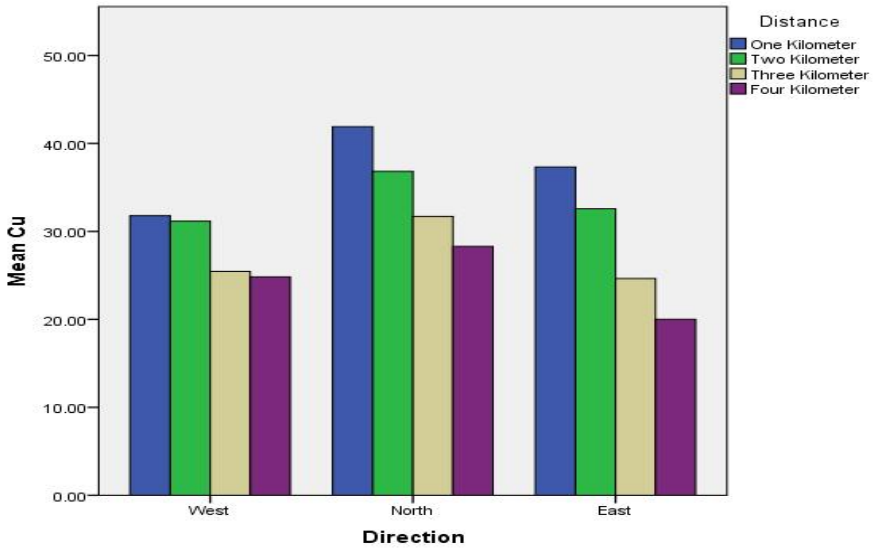

Fig. 1e. Shows (Copper)

Table 2 shows the significant value of each heavy metal. In the case of Lead, Cadmium and Copper we reject the null hypotheses since their significant values are below 0.05 being 0.004, 0.009 and 0.007 respectively. Hence, the error variance of the dependent variables is not equal across groups. Zinc and Chromium accept the null hypothesis since their significance value is greater than 0.05.

Table 3 above shows the mean concentration and standard deviation of heavy metals obtained from different axis at different distances from the Dangote factory**.** All the soil samples analyzed for Zn showed a high level of concentration than the normal permissible limit with WHO standard [20]. The concentration of Zn ranged from 109.42mg/kg to 173.48mg/kg at all sampling locations with EK1 having the highest level of concentration. Zn is higher in soil than the detection limit which is 50mg/kg [20].

The values of Cr and Pb in all the soil samples ranged from 46.63mg/kg to 64.91mg/kg and

27.12mg/kg to 67.68mg/kg respectively. The highest level of concentration for Cr and Pb were obtained at WK1 and WK2 respectively. The observed values of Cr and Pb are within the WHO permissible limit of soil which is 100mg/kg and 85mg/kg respectively [20].

The concentrations of Cd in soil samples ranged from 0.23mg/kg to 0.81mg/kg. All the values of Cd in soil are within the permissible limit except for EK1 with a value above the permissible limit as shown in Table 3.

The values of Cu in soil samples varied from 20.02mg/kg to 41.90 mg/kg. Cu is higher in soil at NK1 and NK2 than the permissible limit which is 36mg/kg [20]. The values of Cu in other samples were within the permissible limit. The highest level of concentration of Cu was observed in WK1.

The mean concentration, contamination factor, geoaccumulation index and ecological risk factor of heavy metals are shown in Table 4. The contamination factor indices for Cr and Cu show moderate pollution across all the samples collected from different axis at different distance from the factory. Zn also poses moderate pollution across the samples except for WK4 and NK4 where it is in a low level of contamination. There is a considerable pollution for Cd in samples NK1 and EK1. Pb shows a considerable pollution in WK2 and moderate pollution in rest samples as shown in Table 4. The order of pollution of heavy metals was Cd> Pb> Cr> Cu>Zn.

The geo-accumulation indices for Pb and Cr show unpolluted to moderately polluted across all samples at different locations expect for sample location EK4. Soils were moderately polluted with Cd at NK1 and EK1, and unpolluted at EK3 and EK4. Cu shows unpolluted to moderately polluted at sampling points WK1, NK1, EK1, WK2, NK2, EK2, and WK3. Soils were unpolluted with Zn at all sampling locations. The order of geo-accumulation indices value of heavy metals was EK1>NKI>EK1>WK2>WK3>WK1> WK4>NK2>EK2>WK2and NK4>NK3>EK3.

The results of the ecological risk assessment show Cd posing the highest ecological risk of all the five heavy metals investigated. It shows a considerable risk at NK1, EK1, NK2, EK2 and moderate ecological risk at WK1, WK2, WK3, NK3, EK3, WK4, NK4 and EK4. Zn, Cr, Pb and Cu shows low potential ecological risk (do not pose any potential risk).

Based on the Ri indices, the results show a moderately potential ecological risk across NK1, EK1, WK2, NK2, EK2 from Zn, Cr, Pb, Cd, Cu and low potential risk at WK1, WK3, NK3, EK3, WK4, NK4 and EK4.

However, on the overall pollution indices, soil samples collected from a distance closest to the Dangote factory are the most contaminated. The overall degree of contamination is in the order (WK1, NK1, and EK1) > (WK2, NK2 and EK2) > (WK3, NK3 and EK3) > (WK4, NK4 and EK4).

5. DISCUSSION AND CONCLUSION

In this section, we will discuss the objectives of the study which are; determining the concentration of heavy metal contaminants in the soil, the relationship between the heavy metals and the level of concentration with respect to distance and direction and the ecological risk it poses.

Table 3. Concentration (mean ± sd) mg/kg

Samples	Zn	Cr	Pb	Cd	Cu
WK1	154.19±1.90	64.59±6.64	63.87±3.10	0.42±0.18	33.12±2.79
NK1	145.17±1.70	64.36±3.47	45.02±2.77	0.59±0.07	41.90±1.39
EK1	173.48±1.23	63.90±1.39	42.43±1.20	0.81±0.02	37.32±0.56
WK2	134.05±4.50	53.83±3.55	67.68±1.21	0.46±0.12	31.17±0.66
NK2	139.97±1.61	57.60±5.82	44.30±2.47	0.52±0.02	36.82±4.29
EK2	165.11±2.48	62.57±1.61	44.58±8.31	0.51±0.05	32.59±0.59
WK3	122.02±4.01	57.26±3.16	64.63±4.98	0.41±0.08	25.45±1.44
NK3	123.92±4.24	55.54±2.90	37.75±1.16	0.42±0.05	37.70±0.77
EK3	151.45±1.42	52.94±1.61	34.76±3.15	0.27±0.07	26.98±1.68
WK4	109±1.19	60.45±0.81	60.45±0.81	0.29±0.18	24.82±1.12
NK4	116.31±3.10	51.43±1.53	37.60±2.36	0.46±0.04	28.31±2.84
EK4	157.41±2.54	46.63±3.40	27.12±3.33	0.23±0.04	20.02± 0.88
Permissible Limits	50.00	100.00	85.00	0.80	36.00 (Rf)

Table 4. Metal Concentration (mg/kg), Contamination Factor (Cf), Geoaccumulation Index (Igeo), Ecological Risk Factor (Ri)

E/M	C	WK1	NKI	EKI	WK2	NK2	EK2	WK3	NK3	EK3	WK4	NK4	EK4
Zn conc.	120.37	154.19	145.17	173.48	134.05	139.97	165.11	122.02	123.92	151.45	109.42	116.31	157.41
Cf	1.00	1.28	1.24	1.44	1.11	1.16	1.37	1.01	1.03	1.26	0.91	0.97	1.31
Igeo	-0.57	-0.23	-0.33	-0.07	-0.43	-0.04	-0.13	-0.57	-0.53	-0.27	-0.70	-0.63	-0.10
Ri	1.00	1.28	1.21	1.44	1.11	1.16	1.37	1.01	1.03	1.26	0.19	0.97	1.31
Conc. Cr	33.41	64.91	64.36	63.90	53.83	57.60	62.57	57.26	55.54	52.94	51.23	51.43	46.63
Cf	1.00	1.94	1.93	1.91	1.61	1.72	1.87	1.71	1.66	1.58	1.53	1.54	1.40
Igeo	-0.57	0.37	0.37	0.33	0.10	0.20	0.33	0.20	0.17	0.10	0.03	0.03	-0.10
Ri	2.00	3.88	3.88	3.82	3.22	3.44	3.74	3.42	3.32	3.16	3.06	3.08	2.80
Conc. Pb	22.08	63.87	45.02	42.43	67.68	44.30	44.58	64.63	37.75	34.76	60.45	37.60	27.12
Cf	1.00	2.89	2.04	1.92	3.07	2.01	2.02	2.93	1.71	1.57	2.74	1.70	1.23
Igeo	-0.57	0.97	0.43	0.37	1.03	0.43	0.43	0.97	0.20	0.07	0.87	0.20	-0.30
Ri	5.00	14.45	10.20	9.60	15.35	10.05	10.10	14.65	8.55	7.85	13.70	8.50	6.15
Conc. Cd	0.19	0.42	0.59	0.81	0.46	0.52	0.51	0.41	0.42	0.27	0.29	0.46	0.33
Cf	1.00	2.21	3.12	4.26	2.42	2.74	2.68	2.16	2.21	1.42	1.53	2.42	1.21
Igeo	-0.57	0.53	1.03	1.50	0.67	0.83	0.83	0.50	0.53	-0.10	0.00	0.67	-0.33
Ri	30.00	66.30	93.60	127.80	72.60	82.20	80.40	64.80	66.30	42.60	45.90	72.60	36.30
Conc. Cu	20.13	33.12	41.90	37.32	31.17	36.82	32.59	45.45	31.90	26.98	24.82	28.31	20.02
Cf	1.00	1.65	2.08	1.85	1.55	1.83	1.62	1.26	1.57	1.33	1.23	1.40	1.00
Igeo	-0.57	0.13	0.47	0.30	0.03	0.27	0.10	-0.27	0.07	-0.17	-0.47	-0.10	-0.60
Ri	5.00	8.25	10.40	9.25	7.75	9.15	8.10	6.30	7.85	6.65	6.15	7.00	5.00
R		94.16	119.27	151.91	100.03	106.00	103.71	90.18	87.05	61.52	69.72	92.15	51.5

The metal concentration (mean) was highlighted in Table 3. All the soil samples analysed for Zn showed a high level of concentration than the normal permissible limit of 50mg/kg [20]. The high level of concentration of Zn in all soil samples analysed can be attributed to the deposition of pollution dust. Thus, of all the heavy metal pollution caused by cement dust, Zn has the highest mobility in soil profile which explains the high level of concentration all through [21]. This is similar with the findings of the study conducted by Ogunkunle with Fatoba [14] and Ogundele [22], analysis of soil and plant sample which revealed a high concentration of Zn in the soil and contrary to the result of the study conducted by Olatunde et al [23] on distribution and ecological risk assessment of heavy metals in soils around a cement factory. On the other hand, the values of Cr and Pb in all the soil samples observed are within the WHO permissible limit of soil which is 100mg/kg and 85mg/kg respectively [20]. Although the values for Cr and Pb are permissible, their observed increase (WK1 and WK2) could be as a result of liberation of Cr from the lining of the rotary machine due to wears and tears [24] and the emission of Pb from cars and trucks (around 2km away) respectively. This tallies with the study conducted by Olatunde et.al [22] for Cr and Pb at permissible concentrations. Whereas the concentrations of Cd in soil are within the permissible limit except for EK1 with a value above the permissible limit which may be due to the incineration of municipal waste which contains and emits Cd. The values of Cu are higher in soil at NK1 and NK2 than the permission limit which is 36mg/kg [20] as a result of industrial waste. However, the values of Cu in other samples were within the detection limit.

The highest level of concentration for Zn, Cr, Pb, Cd and Cu was observed in EK1, WK1, WK2, EK1 and WK1 respectively. The disparity in the level of concentration in relation to direction and distance confirms the assertion in the study. Except for Pb (WK2) all other heavy metals have their highest concentration 1 kilometre from the cement factory. This confirms the conclusion of the studies conducted by Okoro et al [25] and Omar and Shawabkeh [26] –the concentration is higher in locations closer to the cement factory and closer to the surface of the soil. In other words, the concentration of heavy metals in soil usually decreases with distance and depth. The highly concentrated directions are the East and West which means that they may be the more active locations were disposal, incineration and traffic occur.

The results of the ecological risk assessment revealed that Cd poses the highest ecological risk of all the five heavy metals investigated. This result reflects in the study conducted by Olatunde et.al [23], Ogunkunle and Fatoba [14] and Omar and Shawabkeh [26] revealing that Cd poses the most ecological risk factor.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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