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Ecological and Health Risk Assessment of Heavy Metal Contamination in Soil and Plants Around a Cement Factory in Ibese, Ogun State, Nigeria

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Abstract
The health and environmental risk assessment of metal contamination in soil and plants around a cement factory in Ogun State was the main thrust of this study. Topsoil and cassava leaf samples (18 each) were randomly collected from six communities around the factory and a control site farther away. The level of Cd, Zn, Cu, and Pb and Ni was analyzed using standard procedures, and compared against recommended standards. Higher metal concentration from the samples compared to the control site indicate that it is a main contributor to metal pollution in this study. Except for the soil Cd levels, soil and plant metal concentrations were below permissible limits. Mean (mg/kg) ± S.D concentrations for soil Cd, Zn, Cu, and Pb were 3.8±2.7, 6.0±1.9, 20.82±17.9, 0.75 and 58.65±4.4, 7.62±1.3, 6.7±3.9 for plants Zn, Cu, and Ni respectively. The metal potential ecological risk values indicated low to high risk. Cd was the most polluting metal, and Abule-Maria the most polluted site. The level of Zn and Cu in the plants posed no health hazard risk, unlike Ni which had a potentially high hazard index. These are important baseline data and relevant information for designing an environmental plan to manage cement production activity.
Keywords: Cement factory, Heavy metal concentration, Environmental pollution, Health hazard risk, Ecological risk

1. Introduction
The Cement factory is a major source of environmental pollution (Lamare and Singh, 2020). The processes involved in the manufacturing of cement are very dusty and energy consuming (Kholodov *et al*., 2020). These have resulted in the discharge of a high volume and concentration of various environmental pollutants (Etim *et al*., 2021). Dust particles of various sizes and volatile substances, which constitute primarily of alkaline and poisonous components are released into the environment (Etim *et al*., 2021). These substance includes trace elements, heavy metals, particulate matter, gaseous pollutants, and volatile organic compounds (Kholodov *et al*., 2020).

Soil an important part of the environment receives pollutants from different sources, and also serves as an active habitat for plants and interactions among biological organisms (Obaroh *et al*., 2016). Toxic and non-degradable pollutants including heavy metals from the cement manufacturing processes are deposited into it (Adebisi and Omoyeni, 2017). Once in the soil, these metals undergo chemical processes. Thereby causing soil alkalization and alteration of the physicochemical parameters of plants and soil (Lamare and Singh, 2020). Altered parameters in the soil include the level of toxic substances, pH, potassium, calcium, magnesium, soil texture, soil organic matter, electric conductivity, and soil organic carbon (Jadoon *et al*., 2016). Heavy metal is accumulated in plants by direct uptake from the air or indirect uptake from the soil through roots (Emetere and Dania, 2019). Distribution and rate of metal accumulation in plants is dependent on the plant species (Souri *et al.,* 2019). Permissible limit is the minimum degree of metal toxicity in agricultural soils (Amiri et al., 2022).

Metals are non-degradable in nature and therefore get easily accumulated in the soil and vital organs of crops (Silva *et al*., 2019). These vital organs are the stems, roots, and leaves of crops grown in polluted soil. Metals transported from the soil to plants, animals, and water bodies, eventually accumulate in the human body when they are consumed (Govil *et al*., 2018). Vegetables are said to be widely cultivated by the indigenes of Ibese (Olayinka *et al*., 2016. The ingestion of plants contaminated with heavy metals has been implicated as the cause of some health problems. It has been suspected in immune system function deficiency, fertility challenges, and increase in the rate of stomach cancers (Ahmad *et al*., 2016). There is need for assessment and remediation of metal polluted ecosystem in order to enhance their sustainability. Few studies have been undertaken to estimate the effect of cement factory activities on the ecosystem and living organisms, including humans (Laniyan and Adewumi, 2020 andAmiri *et al*., 2022). Previous works in Ibese have been devoted to determining the environmental implication of the cement factory processes (Olayinka *et al*., 2016; Adebisi and Omoyeni, 2017; Adeniran *et al*., 2018). Recently, Olatunde *et al.,* (2020) carried out a related study. They did not sample plants in their study, and soil from farmlands and other places where anthropogenic activities can affect their metal concentration were exempted. Many of these studies have revealed the negative impacts and risks that cement production has on the environment and health. The environmental quality evaluation and assessment that is proposed in this study is an effective scientific tool used by decision-makers to manage sites cost-effectively while preserving public and environmental health (Adebisi and Omoyeni, 2017). The objective of this study is to evaluate the potential ecological and health hazard risk of metal containation in the soil and plants at various locations in Ibese. The outcome of this will provide decision-makers with relevant information for sustainable development in preventing potential hazards.

2. Material and Methods

2.1 Study Area

Ibese is in the southwest Nigerian Ogun State region's Yewa North Local Government Area. It is located between longitude $3^{\circ}\ 2'$ and $3^{\circ}\ 4'$ E and latitude $6^{\circ}\ 58'$ and $6^{\circ}\ 60'$ N. The Paleocene-era marine Ewekoro formation makes up the geology of Ibese and its surroundings. The yearly mean temperature hovers around 26.6° C, and precipitation amounts between 1,270mm and 1,524mm. The guinea savanna, which is characterised by semi-deciduous trees, makes up the local vegetation. Cement manufacturing commenced in 2011 at the privately owned Dangote Cement mill in the large limestone deposit region. Only a few kilometres away from the cement factory are villages like Ibese, Abule Oke, Abule Maria, Ajibawo, and Afami, where the majority of the population consists of farmers and traders (Adeniran *et al.,* 2018).

2.2 Soil and Plants Sampling

Eighteen (18) topsoil and eighteen (18) cassava leaf (Cassava leaf; *Manihot esculenta*) samples were randomly collected from six (6) communities around the factory. Cassava plant was chosen because it is said to be readily available around Ibese and serves as a vegetable for human consumption (Olayinka *et al*., 2016). At each of the sampling locations, three subsamples were randomly collected at varying distances. Subsamples were obtained from farmlands, playgrounds, residential areas, and other sites where human exposure and contamination potential to the cement dust pollutants were likely to be high. The control site, Eggua is located 30km away from the cement plant at Ibese. Each of the soil samples was collected into a polythene sampling bag and labeled (Mumba, *et al*., 2008). Composite samples of the soil and plants were made. The control samples were also mixed to form a composite sample. They were then taken to the lab, air-dried for several days and grinded. Thereafter, they were passed through sieves of different mesh sizes to remove pebbles and stored for further analysis (Awofolu, 2005).

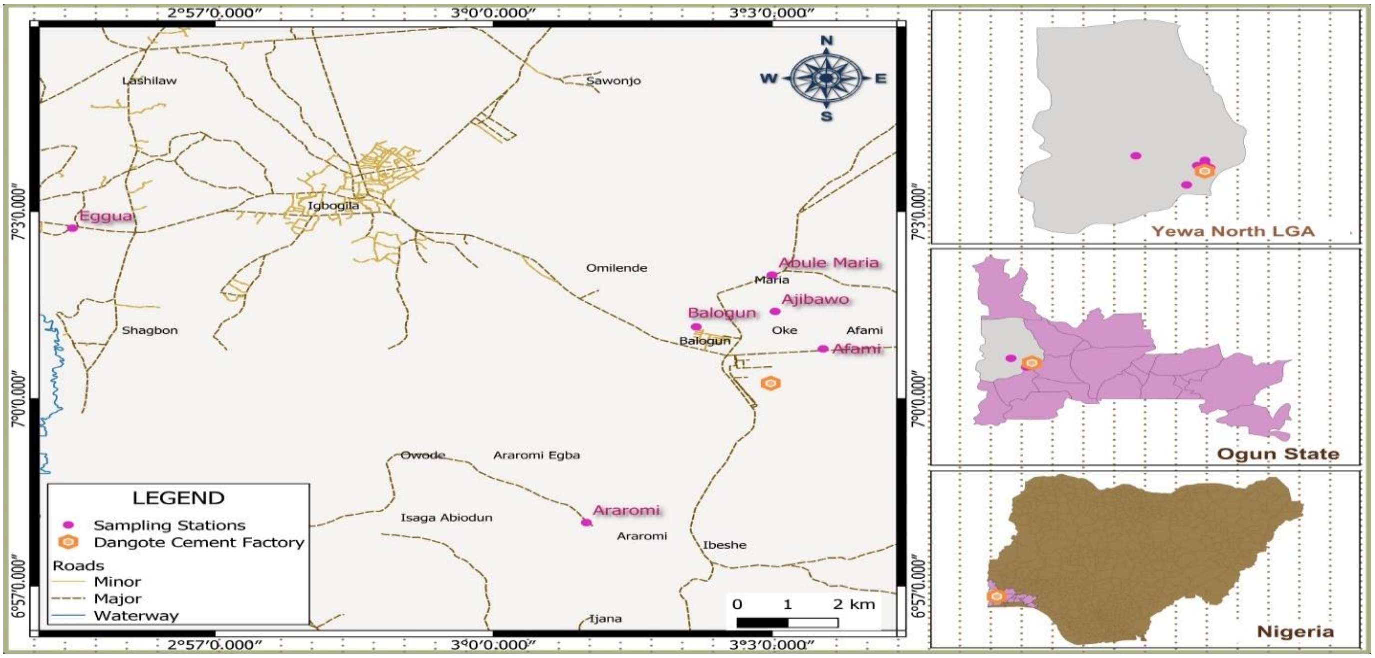

Figure 1: Study area map with sampling points.

2.3 Metal Concentration and Physicochemical Properties

The soil physicochemical properties that were determined in this study include organic matter content, electrical conductivity, organic carbon content, and pH. Soil and plant metal (Ni, Cu, Cd, Zn, and Pb) contents were also analyzed.

2.3.1 pH

The level of pH in the sampled soil was determined with a Philips pH meter. Approximately 10g of the 2mm sieved sample was mixed with 10 ml distilled water in a beaker. Mechanical shaker was used to mix up the solution for 10minutes before taking the reading (Olayinka et al., 2016).

2.3.2 Organic Carbon Content

This was determined by using the Walkey-Black and digestion method (Anderson and Ingram, 1989). Samples were digested with sulphuric acid and potassium dichromate (2:1) and allowed to cool. A change occurred in the color of the digest from green to brown when it was titrated with ferrous ammonium sulphate solution, signifying an endpoint.

2.3.3 Level of Organic Matter

This was calculated by multiplying the organic carbon content value by 1.724 (Anderson and Ingram, 1989).

2.3.4 Electrical Conductivity (EC)

Soil electrical conductivity was measured using a Digital Conductivity meter model No. PT360.

2.3.5 Soil and Plants Metal Contents

Metal contents in the soil and plants were analyzed using standard method. The samples were digested with nitric acid and perchloric acid (2:1) solution. This was heated up at 70 ˚C under a fume cupboard until it turned milky white. After cooling the digest was filtered and kept for further analysis. Buck Scientific Atomic Absorption Spectrophotometer was used for the metals analysis (Amani *et al*., 2018).

2.4 Ecological Risk Assessment

Assessment of contamination level and risk was done using the geoaccumulation (*Igeo*), contamination factor (*Cf*), and ecological risk (*Ri*) index.

2.4.1 Contaminant Factor *(Cf)*

This was calculated by dividing the level of metal in the soil by the control (Maanan *et al*., 2014).
Cf = 1.1 - 3.0 signifies moderate pollution
Cf = 3.1 - 6.0 signifies considerable amount of pollution
Cf > 6.0 signifies high amount of pollution (Maanan *et al*., 2014).

2.4.2 Geo-accumulation (*Igeo*) Index

$Igeo = Log2\ (Ci/1.5Bn)$

Ci is the level of the metal in the contaminated sampled soil ; 1.5 is the correction value; *Log*2 = 0.3010; *Bn* is the metal level in the control sample.
0 < *Igeo* < 1: unpolluted
Igeo = 1-3: moderately polluted
Igeo = 3-5: strongly polluted
Igeo ≥ 5: very strong pollution (Buccolieri *et al*., 2016).

2.4.3 Ecological Risk Factor (*Ri*)

$Ri = \sum Ei$; $Ei = Tr \times Cf$
Ei is the risk factor of each metal; *Cf* is the contamination factor, and *Tr* is the toxic response factor for each of the metals (Zn, Pb, Cu, Cd, and Ni and are 1, 5, 5 30, and 5 respectively) (Hakanson, 1990).
Ri < 95 indicates a low potential ecological risk
95- 190 connotes moderate ecological risk
190 - 380 connotes considerable ecological risk
Ri ≥ 380 connotes high ecological risk (Maanan *et al*., 2014).

2.5 Health Risk Assessment

$$HQ = \frac{E_F \times E_D \times F_{IR} \times C\ 10^{-3}}{RfD \times W_{AB} \times T_A}$$ (Atikpo *et al.,* 2021)

HQ – Hazard quotient (unit less); E_F is exposure frequency (350 days/year); E_D is exposure duration (54 years); F_{IR} is the ingestion rate of vegetables (187g/p/d); C – metal level in food (mg/kg) (Atikpo *et al.,* 2021); RfD – Reference oral dose of metal (mg/kg of body weight/day). The values of RfD are: Cd (0.001), Ni (0.02); Pb (0.0035), Zn (0.3) and Cu (0.04) (USEPA, 2006); W_{AB} denotes mean body weights (70 kg) (WHO, 2019); T_A denotes non – carcinogens mean time of exposure (E_D x 365 days/year). (Atikpo *et al.,* 2021).

HQ = 1.1-10 indicates moderate hazard risk while HQ>10 indicates high hazard risk
Hazard Indices (HI)
$HI = \sum HQi$
HI = åHQPb + HQCd + HQCu + HQNi + HQZn. HI <1 indicates no hazard; HI = 1 – 3, represents probability of hazard from consumption of the plant. HI = 3-10, indicates probability of fatal health risk (Atikpo *et al.,* 2021).

2.6 Data Analysis

The degree and source of metal contamination in this study was measured by comparing samples close to the cement factory with those from the control site, and against recommended standards (permissible limits). The Canadian Council of Ministers for Environment (CCME) standards were used for soil metals, while the Food Additives and Contamination (FAO) standards were used for the heavy metal in plants. Ecological and health risk posed as a result of the heavy metal contaminations were assessed using ecological risk (*Ri)* index, contamination factor (*Cf*), and geoaccumulation (*Igeo*) index. Statistical analysis was done using statistical package for social science (SPSS) version

23. Comparison of mean heavy metal values with the CCME/FAO standard value was done using one sample t-test. Significant results were accepted at $p < 0.05$.

3. Results

Soil and plants from six sampling points around a cement industry in Ibese were analyzed for metal pollution in this study. Soil and plants metal level were more in the samples near the factory than that of the control site (Eggua). Ni was not detected in the soils collected; Pb and Cd were not detected in any of the plant samples. The soil and plants heavy metal concentration varied across the sampling sites. The comparison of the soil and plants heavy metal concentration with CCME/FAO standard values revealed that all except the soil Cd concentration were below permissible limits. Ecological risk assessment indices showed that there was moderate contamination and ecological risk from Cd and Zn in Eggua, Afami, Ajibawo, Araromi, and Balogun. High pollution from Cd and Cu was observed in Abule Maria. Health hazard index (HI) in all the sampling sites was greater than one (>1); Balogun showing the highest hazard risk and Ni the highest hazard quotient (HQ).

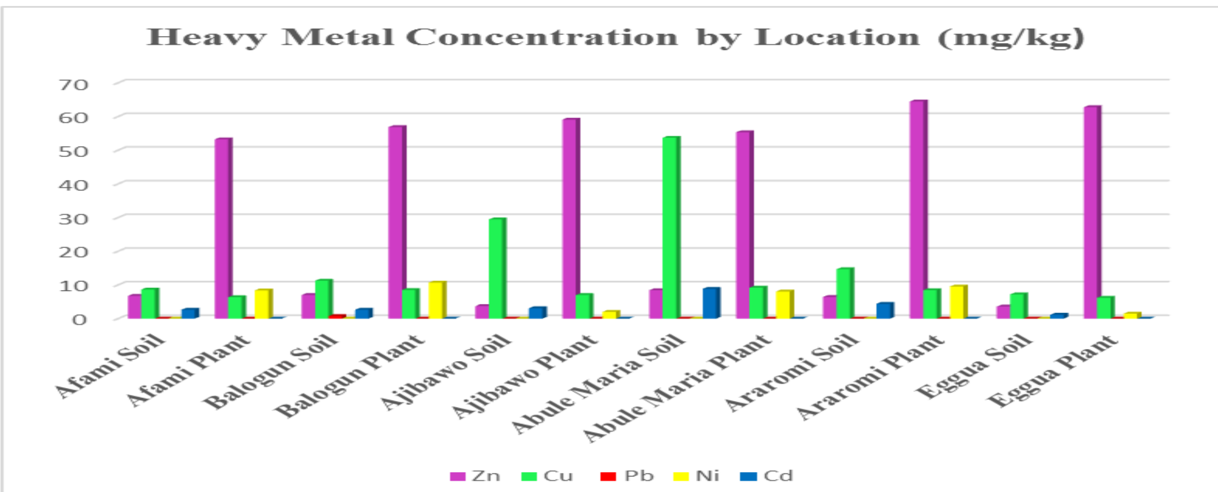

Figure 2: Soil and Plant Heavy Metals Concentration by Location

Figure 2 presents the total metal concentration of the plants and soil across the sampling sites. The soil Zn concentrations were between 3.60mg/kg in Eggua to 8.45mg/kg in Abule Maria. Soil Cu is the highest, ranging between 7.20mg/kg in Eggua to 53.70mg/kg in Abule Maria. Cd ranged between 1.15mg/kg in Eggua to 8.85mg/kg in Abule Maria. Pb was detected only in Balogun with a concentration of 0.75mg/kg. The plants Zn had the highest concentrations ranging between 53.25mg/kg in Afami to 64.50mg/kg in Araromi. Cu ranged between 6.20mg/kg in Eggua to 9.20mg/kg in Abule Maria. Ni ranged between 1.50mg/kg in Eggua to 10.70mg/kg in Balogun.

Table 1: Soil and Plants Heavy metal Concentration in Comparison with Standard Values

	Average conc. from sites (mg/kg) ± sd	**CCME/ FAO standard value**	**Difference**	**t-value**	**df**	**p-value**
SOIL						
Zinc	6.0 ± 1.9	200	194	246.447	5	**0.000**
Copper	20.82 ± 17.9	63	42.18	-5.742	5	**0.002**
Lead	0.75	70	69.88	-559	5	**0.000**
Cadmium	3.8 ± 2.7	1.4	2.4	2.19	5	**0.08**
PLANT						
Zinc	58.65 ± 4.4	60	1.35	-0.760	5	**0.08**
Copper	7.62 ± 1.3	40	32.38	62.815	5	**0.000**
Nickel	6.7 ± 3.9	67.9	61.2	37.963	5	**0.000**

In this table (1), soil Cd level was higher than the permissible limit. The Cd concentration obtained in soils from the areas around the production site was not significantly different in value to the CCME standard value. There is a significant difference in average soil Pb, Zn, and Cu concentrations between the production site and the CCME standard values.

For plants, table 1 shows that there is a significant difference between average concentration of Cu and Ni obtained in plant samples around the production sites and the FAO standard value. Significant differences in Zn concentration among the villages was not observed. Although the Zn concentration in plants around the cement production site appeared slightly lower, it was not significantly different in value to the FAO standard value.

Table 2: Soil Physicochemical Properties by Location

Locations	**Distance (km)**	**pH**	**EC (μS/Cm)**	**% Organic Carbon**	**% Organic Matter**
Afami	4.00	7.00	508	1.218	2.099
Balogun	5.00	6.4	468	0.714	1.231
Ajibawo	6.00	7.2	605	1.26	2.172
Abule Maria	8.00	6.6	460	0.813	1.402
Araromi	12.00	6.8	745	0.852	1.469
Eggua	30.00	6.2	145	0.624	1.076

The pH of the soil in the vicinity factory is from neutral to slightly alkaline, and slightly acidic with increasing distance. Soil EC content did not follow a regular pattern, but it was more in the factory surrounding sites than in the control samples. Soil organic carbon and organic matter concentrations decreased with increase in distance (Table 2).

Table 3: Ecological Risk Assessment of Soil Metal Contamination

		Balogun	**Ajibawo**	**Afami**	**Abule-Maria**	**Araromi**	**Eggua (control)**
Zn	Conc.	7.00	3.75	6.75	8.45	6.45	3.60
	Cf	**1.94**	**1.042**	**1.88**	**2.35**	**1.79**	1.00
	Igeo	0.37	-0.53	0.32	0.65	0.26	-0.59
	Ei	1.9	1.04	1.88	2.35	1.79	1.00
	Ri	78.89					
Cu	Conc.	11.25	29.45	8.65	53.70	14.65	7.20
	Cf	**1.56**	**4.09**	**1.20**	**7.46**	**2.04**	1.00
	Igeo	0.06	**1.45**	-0.32	**2.31**	0.44	-0.59
	Ei	7.81	20.45	6.01	37.29	10.17	5.00
	Ri		**102.36**				
Pb	Conc.	0.75	0	0	0	0	0
	Cf	0	0	0	0	0	0
	Igeo	0	0	0	0	0	0
	Ei	0	0	0	0	0	0
	Ri			77.01			
Ni	Conc.	0	0	0	0	0	0
	Cf	0	0	0	0	0	0
	Igeo	0	0	0	0	0	0
	Ei	0	0	0	0	0	0
	Ri				**270.51**		
Cd	Conc.	2.65	3.10	2.65	8.85	4.40	1.15
	Cf	**2.30**	**2.70**	**2.30**	**7.70**	**3.83**	1.00
	Igeo	0.62	0.85	0.62	**2.36**	**1.35**	-0.59
	Ei	**69.13**	**80.87**	**69.13**	**230.87**	**114.78**	30.00
	Ri					**126.748**	36.00

Emboldened figures signify a degree of ecological risk from metal pollution.

Metal contamination indices and concentration for the soil in each sampling location are presented in Table 3. The *Cf* and *Igeo* indices show that the surrounding soil is not contaminated with Ni and Pb. The *Cf* index indicates moderate pollution across locations for Zn. Moderate pollution was indicated for Cu in Eggua, Balogun, Araromi, and Afami. However, considerate to very high pollution was indicated for Cu in Ajibawo and Abule Maria respectively. Moderate pollution was indicated for Cd in all the locations except for Araromi and Abule Maria which was shown to have considerate to very high pollution respectively.

Table 4: Health Hazard Risk Assessment

		Balogun	Ajibawo	Afami	Abule-maria	Araromi	Eggua (control)
Zinc	HQ	0.49	0.51	0.46	0.47	0.55	0.54
	HI	**2.40**					
Copper	HQ	0.54	0.45	0.41	0.59	0.54	0.40
	HI		**1.21**				
Lead	HQ	-	-	-	-	-	-
	HI			**1.94**			
Nickel	HQ	**1.37**	0.26	**1.08**	**1.03**	**1.22**	0.19
	HI				**2.09**		
Cadmium	HQ	-	-	-	-	-	-
	HI					**2.32**	**1.13**

Emboldened figures signify a degree of hazard from the consumption of the cassava leaf.

The health hazard risk of the metal contamination in the plants is presented in Table 4. Hazard index (HI) in all sampling sites were greater than one (>1). Zn and Cu have Hazard Quotients (HQ) less than one (<1). Ni however has HQ > 1.

4. Discussion

The cement manufacturing industry has been a key contributor to environmental pollution through the release of various toxic components (Lamare and Singh, 2020). Heavy metals are part of these toxic components which interact with the environment to produce various effects. Some metals exist naturally in the soil. However, elevation in their concentration above recommended limit is an of anthropogenic contribution (Olatunde *et al.,* 2020). In this study, we have attempted an ecological and health risk assessment study on the plants and soil of areas close to the Dangote cement industry in Ibese.

4.1 Soil Metal Concentration

In this study, variation in the concentration of metals across sampling points can be attributed to variation in distances, prevailing wind direction, and various anthropogenic activities (e.g application of fertilizer) taking place in the various sampling locations. High contents of Zn, Cd, and Cu were detected in Abule Maria which is approximately 8km away from the cement plant. This particular site is a residential area and many activities such as farming, movement of cement transporting vehicles, and other anthropogenic activities that have been suspected in the introduction of metal to the soil are taking place there. Higher concentration of all the metals in the soil samples closer to the cement factory than in the control obtained approximately 30 km from the factory indicates that the cement production processes are suspected as the major source of metal pollution in the study area. These findings are consistent with those of Laniyan and Adewumi, (2020); Amiri *et al*., (2022). They noted in their studies that high metal concentrations were detected in locations along the prevailing direction, and that average metal level in the locations close to the cement factory were more than the ones in the reference samples. High soil Cu and Zn contents can be justified with the fact that the cement industry is a key contributor of these metals to the environment through its ingredients and processes (Olayinka *et al*., 2016). Application of fertilizer by farmers on the farmlands can also be a contributing factor to their high concentrations..

The average concentration of soil metals below the CCME standard values in this study implies that even though there is metal contamination in the study site, most of them do not exceed the threshold limit set down by regulating agencies. Cd on the other hand was detected to be above the permissible limit, although its concentrations were lower than that of Cu and Zn across the sampling sites. It is not an essential element for plant growth, relatively low concentration of it is needed in the soil because of its high toxic effect. Therefore, Cd can be regarded as hazardous in this study area. This finding corroborates the report of Olatunde *et al*., (2020) and Safari and Karimi, (2019) where all soil metal levels were below the standard values except for Cd. There is a need to properly monitor the soil Cd content in this study area to avoid health hazards due to poisoning through inhalation, dermal absorption, or ingestion. There might also be need for bioremediation.

4.2 Heavy Metal Concentration in Plants

In the plant samples, Zn was detected to have a high concentration in all the sampling sites. Although high Zn concentration was observed in the soil samples, it was not as high as the level observed in these plant samples. There is no doubt that the cement factory is an important contributor of Zn to the environment. However, the high Zn content in plants in this study could be attributed to some other factors. Zn is an essential element for plants. Therefore, farmers apply fertilizers containing Zn to the plants to enhance their growth and development. This explains the reason for its relatively high level in the sampled plants as opposed to that in the soil. It is therefore safe to say that its high concentration in the plant samples is not just due to cement factory processes, but also because it is an important nutrient. The findings in this study are similar to that of Makanjuola and Aderinboye, (2019) Zn was found to have the highest concentration across the sampling locations. High level of Zn found in the plants as compared to levels in soil samples can be also a result of additional uptake of the metal from the air. In this study, Cassava plant is suspected to be a good accumulator of Zn, due to its high concentration in the plant samples. High Zn concentration detected in this study is quite unexpected, but currently in Eggua there is a concerted commercial rice farming effort - anthropogenic activities and fertilizer application might have impacted the Zn level of these plant samples.

Higher plants metal concentrations in areas close to the production site compared to that of the control site that was observed in this study is a pointer that the cement manufacturing processes might be major contributor to metal content in this research. Olayinka *et al*., (2016) also observed in their research that the average level of metals in the plant samples close to the cement factory were greater than the ones in the control samples. Just as in the soil, the metal distribution and concentration in the plant samples varied. High concentration of Zn was found in Araromi which is approximately 12 km far from the cement industry. The highest Cu concentration was also found in Abule Maria which is about 8 km away from the cement plant. This shows that apart from proximity in distance from the production sites other factors such as the various anthropogenic activities taking place in the environment may also affect the abundance and distribution of metals in the ecosystem.

4.3 Physicochemical Properties

Soil alkalinity that was detected in this study is typical of a metal contaminated soil. Cement dust has been proved to be alkaline in nature. Soil alkalinity can be due to the liming effect of cement production emissions (Olayinka *et al*., 2016). However, Balogun has an acidic pH of 6.4 despite the fact that it is near the cement factory. This may be as a result of the other components from which the soil of the study area is formed. Although we do not have enough evidence to back up this claim, the nature of parent material is a key factor that determines the pH of soil (Etim *et al*., 2021). Other factors that could have impacted the soil pH level include the type of fertilizer, type of vegetation in the environment, and run-off (Zhang *et al.,* 2018). However, the pH of the Eggua (control) was detected to be the lowest. The studies of Adebisi and Omoyeni, (2017); Lamare and Singh, (2020); Akpambang *et al*., (2022) revealed similar findings. The pH value of the soil obtained from the control site was found to be lower than that of communities closer to the cement factory.

The EC of the sites around the factory ranged from 460 to 745. However, the EC of the control site was found to be 145. The high EC level in the sampling sites is an indication of high availability of nutrients in the study area. Although the soil EC level does not follow a regular pattern, they were found to be higher in value as compared with that of the control site (Eggua). Similar findings have also been reported by other researchers. Sites close to the cement factory have been discovered to have higher SEC than the control sites (Lamare and Singh, 2020; Akpambang *et al*., 2022).

The decrease in soil organic carbon (SOC) and organic matter (SOM) concentrations with increasing distance observed in this study can be due to the synergistic deposition effect from cement production operations which must have enhanced the decomposition processes of microorganisms in the soil samples. This is very good for agricultural soil has it signifies the abundance and availability of nutrients that are important for plants health. Even though this finding corroborates that of Olayinka *et al*., (2016) where cement contaminated soil were significantly higher in organic matter than the unpolluted ones, it is in contrast with the findings of Adebisi and Omoyeni, (2017) and Lamare and Singh, (2020) and, where the SOC and SOM levels of contamination-receiving sites was always low.

4.4 Ecological Risk Assessment

The assessment values for Cd > Cu > Zn were higher than 1 and therefore suggest some level of metal contamination in the sampling sites which were likely of anthropogenic origin. There is another cement industrial facility much farther away from the Dangote cement factory. However, the latter factory can be regarded as the main source of metal contamination in the areas near it from which we sampled. The *Cf* and *Igeo* indices indicate that Cd is the most polluting metal across all the sampling sites, except in Ajibawo where Cu is the most polluting metal. Based on this, Cd can be said to have a higher pollution load and potentially more adverse ecological effects in comparison to Zn, Cu, and Pb in the study area. While the topsoil around the factory was unpolluted to moderately polluted in terms of *Igeo*, the index of *Cf* showed that the effects of anthropogenic activities are considerable in the study area. The ecological risk (*Ri*) posed by the individual metal concentration is presented in Table 4. *Ri* values of the metals across all the sampling locations ranges from low (36) to considerate potential ecological risk (270.5). Cd posed the highest potential risk across all the sampling sites. This finding agrees with that of Olatunde *et al*., (2020). Cd posed the highest ecological risk of all heavy metals measured in their study. It is also consistent with Amiri *et al*., (2021). In their studies Cd had greater contamination factor and more ecological risk in comparison to other metals. The potential ecological risk posed across the sampling locations was highest in Abule Maria and lowest in Afami among the villages close to the cement production site. Naturally there was very little probability of ecological risk from the cement plant in soils from Eggua.

4.5 Health Risk Assessment of Metal Contamination

Zn and Cu did not pose the probability of health hazard across all the sampling locations although Ni posed the probability of health hazard in all the sampling locations with the exception of Ajibawo. HI value above 1 in the sampling sites implies that there is a probability of occurrence of some health disorders in all the sampling sites from the consumption of Cassava leaf that is contaminated with Ni. The HI index indicated that Balogun is the most potentially hazardous site as far as Ni contamination is concerned in this study. There is need for remediation plans to prevent health hazards.

5. Conclusion

The comparison of the soil and plants samples close to the cement facility with that of a control site showed that the cement factory in the study area is a key contributor of metal pollution. Other factor such as the application of fertilizers to crops was also suspected to have some level of impacts.. The comparison of the soil and plant samples with CCME/FAO values has shown that all the metals in this study except soil Cd were below standard values and are therefore within safe limits. The health hazard index revealed a higher probability of occurrence of some health disorders from the consumption of the cassava plants contaminated with Ni. However, constant discharge of these heavy metals to this study area might result in bioaccumulation which can be further hazardous to man and the environment overtime. Considerable contamination from Ni, Cu, Pb and Zn were observed in soils of the study area as indicated by the ecological indices. High pollution from Cd was observed in Abule Maria. Cd had a high toxic response factor, and its presence above permissible limits in this study is of great concern. There is a need for decision makers to design an environmental plan to continue to monitor and manage the production activity in this environment. The use of some improved technologies which can reduce the level of metal discharge to the environment can also be explored.

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List of abbreviations

Ei - Potential risk factor of each metal
Cu - Copper
Igeo - Geo-accumulation index
Pb - Lead
HI - Hazard Index
Ri - Potential risk index of all the metals
F_{IR} - Ingestion rate of food
SOC - Soil organic carbon
Tr - Toxic response factor for each of the metals
HQ - Hazard quotient
Zn- Zinc
E_D - exposure duration
Cd- Cadmium
SOM - Soil organic matter
RfD - Reference oral dose of metal
Cf - Contaminant factor
Ni- Nickel
W_{AB} - Mean body weights
$K_2Cr_2O_7$ - Potassium dichromate
T_A - Non – carcinogens mean time of exposure
CCME - The Canadian Council of Ministers for Environment
E_F - Exposure frequency
FAO - Food Additives and Contamination
SPSS - Statistical package for social science
EC - Electrical Conductivity
C - Concentration of metal in food

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