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Environmental and Health Impact of Cement Factory Production in Ibese, Ogun state, Nigeria

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Abstract

This study investigated the effect of cement dust emitted from Dangote cement factory, Ibese, Ogun State, Nigeria on the environment and human health. Soil and plant samples were collected from six sampling points at different distances i.e. inside the factory kiln (IFK), the factory gate (TFG~50 m); Abule Oke (AOK~100 m), Maria (MAR~200 m), and Ibese (IBE~300m), based on the prevailing wind direction. Control samples were taken opposite the wind direction at ILA (Ilaro) about 1000 m. Cu, Zn, Mn, Pb, Ni and Cd were analyzed in the samples using atomic absorption spectrophotometer. Air quality and noise levels were monitored using standard methods. Sulphur dioxide, oxides of nitrogen (NO_x), total suspended particulate matter and noise concentrations ranged from 7-25 ppm, 0.1-0.2 ppm, 101-13056 ugm^{-3} and 72.1-98.2 dB respectively, which were higher than USEPA standard. Heavy metals in soils were in the order of: MAR> IFK>AOK>IBE>ILA>TFG for Cu, AOK>MAR>IFK>TFG>ILA>IBE for Zn, IBE>IFK> MAR>AOK>TFG>ILA for Cd, IBE>AOK>MAR>TFG>IFK>ILA for Mn, IBE>AOK> TFG>MAR>ILA>IFK>IBE for Pb and MAR>TFG>AOK>IBE>ILA>IFK for Ni. Health-related characteristics of the respondents also showed that 2.5% had allergies that hindered breathing, while 3.75% had difficulty in smelling. Health risk assessment showed that ingestion is the major pathway of exposure to heavy metals in soil samples for both children and adults. Cd, Mn, Ni and Pb pose non-cancer risks to children, while only Cd and Mn pose non-cancer risks to adults. Ni and Pb pose the greatest cancer risk to children. In cassava leaves and tubers Pb was the only metal found to pose cancer risk in both children and adults.

Keywords: Health hazard; Heavy metals; Cement pollution; Noise and suspended particulate matter

Introduction

Industrialization is a common phenomenon in developing countries such as Nigeria; the encouragement of industries has triggered the need for the development of a diversified economy that could propel the achievement of stable and sustainable economy [1]. The cement industry is a fast growing industrial sector and is a fundamental driver of industrial and infrastructural development in Nigeria [2]. The industry has grown rapidly to keep pace with increasing demand [3]. Air emissions in cement manufacturing are generated from the handling and storage of intermediate and final materials, and by the operation of kiln systems, clinker coolers, and mills [2, 4]. These processes release various pollutants into the environment, which may give rise to complaints of terrestrial or ambient air pollution. Air pollutants generated by the cement manufacturing process consist primarily of alkaline particulates from the raw and finished materials. The direct effects of cement dust pollution are the alkalization of the ecosystem [5] and changes to the chemical composition of soils, air, water and vegetation [6]. Emission of cement dust has increased alarmingly with the proliferation of cement plants around the country to meet domestic demand and reduce imports [7]. This in turn has contributed to environmental deterioration and impacts on human health caused by toxic metals and organic compounds released when industrial waste is burnt in cement kilns. The cement industry is one of the greatest environmental polluters, causing the spread of dust across large areas through wind, rain, and other dispersal processes. The main impacts of the cement activity on the environment are the broadcast of dust and gases; pollutant particles can enter into soil as dry, humid or occult deposits and can undermine its physicochemical properties [8].

Cement dust pollution has an adverse effect on soil physicochemical properties and biological activity. Deposition of cement dust causes many several biochemical and physiological effects [9] in plants; anatomical structure of plants are also distorted when pollutants in cement dust are absorbed by plants [10]. It may also alter the biodiversity of plants by directly covering the leaf surface and indirectly via the roots [11]. Bilen [12] suggested that cement dust accumulating in and on plants, animals, and soils also have very negative effects on human health. Health risks posed by inhaled dust particles are influenced by the deposition pattern of the particles in the various regions of the respiratory tract and by the biological responses exerted by the deposited dust particles causing a basic reaction leading to increased pH values that irritate exposed mucous membranes, which could lead to respiratory effects or failure [13]. Furthermore, Baby et al. [14] had reported that cement dust contains heavy metals including chromium, nickel, cobalt, lead, mercury and pollutants hazardous to the biotic environment with impacts on vegetation, human health, animal health and the overall ecosystem. Therefore, pollution triggered by industrialization is a worldwide menace because pollutants emitted are indestructible and most of them have toxic effects on living organisms, when they exceed a certain concentration [15]. In spite of multiple adverse impacts on the environment and health hazards in both developed and developing countries, cement remains the most popular material for building and infrastructural growth, attributable to its availability, durability, reliability and affordability. Hence, this study investigated the status of air quality, noise, soil physicochemical parameters and health risk of heavy metals contained in cement pollution.

Materials and methods

1) Study area

Ibese is located in Egbado (Yewa) North of Ogun state Southwestern Nigeria. It lies between latitudes 6° 58′ N to 6° 60′ N and longitudes 3° 2′ E to 3° 4′ E (Figure 1). The geology of Ibese and its environs consists of Ewekoro formation, which is marine and of the Paleocene Age. It consists of a limestone unit, several meters in thickness, which is overlain by a shale unit almost three times as thick as the limestone itself. The climate of the area falls directly under the generally hot and dry harmattan season (starting from November to March) and the warm and wet season (April to October). Precipitation ranges from 1270 to 1524 mm, and annual mean temperature is around 26.6 ºC. Vegetation in the area consists of the guinea savanna characterized by semi-deciduous trees. The Dangote Cement factory, which is a privately owned company, commenced production of cement in the vast limestone deposit in the area by the end of 2011. The inhabitants are mainly farmers and traders living in towns and villages such as Ibese, Abule-Oke, Maria and Ilaro located only a few kilometers from the cement factory.

2) Sampling site procedure

Samples were collected from six sampling points at different distances from the kiln which include: inside the factory kiln (IFK), the factory gate (TFG~50 m), Abule Oke (AOK~100 m), Maria (MAR~200 m), and Ibese (IBE~300m) based on the prevailing wind direction where the cement dust are blown. Control samples were taken opposite the wind direction at ILA (Ilaro) about 1,000 m from the cement factory. All soil samples were taken using a stainless steel soil auger. Plants growing in the soil such as young cassava leaves (used as vegetable and cassava tubers) normally processed to cassava powder and flakes for cooking, were also collected.

3) Sample treatment

Soil samples were randomly collected at each sampling location in triplicate and were air-dried for several days. They were then homogenized and sieved through a 2 mm sieve. The plant samples were then washed and air dried before grinding in a ceramic mortar with a pestle, then stored in plastic bottles prior to analysis [16].

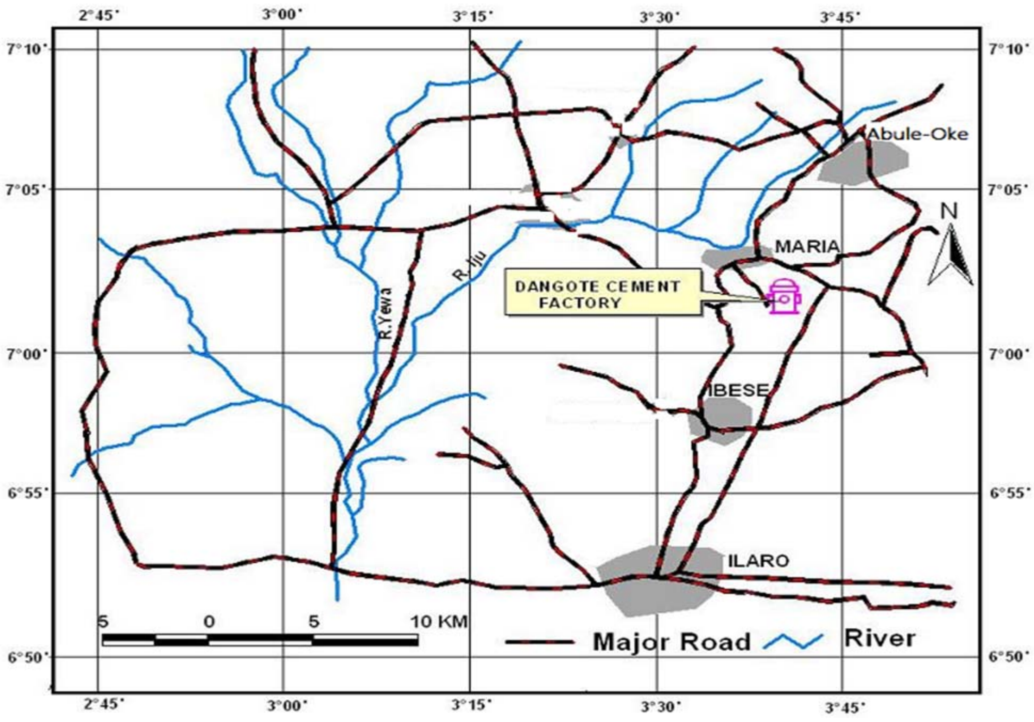

Figure 1 Map of the study area

4) Determination of soil pH

Soil pH was determined using a Philips pH meter model PW9418 after mixing 5.0 g of the sieved soil with 10 ml distilled water in a beaker. After stirring with the electrode probe which has been first standardized with buffer solutions, readings were then taken after 30 minutes.

5) Determination of organic carbon

The Walkey- Black and digestion method as described by [17] was used to determine the organic carbon content of soils. About 1 g of soil sample was placed into a block digester tube (sample weight) after which 5 ml of potassium dichromate solution and 7.5 ml of concentrated H_2SO_4 were added. The tube was then placed in a pre-heated block at 145-155 ^oC for 30 minutes, then removed and allowed to cool. The digest was quantitatively transferred into a 100 ml conical flask and then 0.3 ml of O-phenan threne-ferrous complex (ferroin) indicator solution added. The solution was then stirred and mixed using a magnetic stirrer. The digest was titrated with ferrous ammonium sulphate solution with end point indicating a change from greenish to brown colouration. The organic carbon content was expressed as a percentage as follows, based on a 77% recovery factor.

$$\%\ \text{Organic C} = \frac{N\ (T-B)}{W} \times 0.390$$

where;

N = Normality of $K_2Cr_2O_7$

T = Volume of $K_2Cr_2O_7$ used in titration of soils

B = Volume of $K_2Cr_2O_7$ used in titration of blank

W = Weight of soil in gram

6) Determination of organic matter

Soil organic matter content was determined by multiplying the organic carbon content from the procedure above by 1.724 using the assumption that organic matter content is approximately 58 % carbon [17].

7) Determination of trace elements (Cu, Zn and Mn)

5 g of the dried sieved soil was digested with HNO_3-HCl according to USEPA method 3050B to extract the metals. The concentrations of Cu, Zn and Mn were measured by Buck Scientific 210/211VGP with an air-acetylene flame atomic absorption spectrophotometer.

8) Determination of soil Pb, Ni and Cd

Pb, Ni and Cd in the soil were determined according to the method of [18]. Exactly 0.2 g of the soil sample was weighed and 6ml freshly prepared aqua-regia (1:3) HNO_3:HCl respecttively was added and allowed to stand overnight and placed in a digestion block for about 30 mins. It was allowed to cool and then filtered into a 100 ml volumetric flask with distilled water. The filtrate was analyzed for selected heavy metals using Buck Scientific model 210 /211VGP Atomic Absorption Spectrophotometer (AAS).

9) Determination of heavy metals in leaves and tuber

Heavy metals were analyzed in the leaves and tuber according to the method of [19]. Leaves and tuber samples of cassava were dried at 105^0C in an oven until constant weight was obtained. It was then ground and sieved through a 2 mm sieve. About 0.2 g of the sample was placed in a crucible and transferred into a furnace to ash for 24 hrs at 550^oC. The ash was dissolved with 10ml of 10% HNO_3 solution and left overnight. The final extract was filtered into a 100 ml volumetric flask and made-up to mark with dilute acid, and the digests were analyzed for heavy metal concentrations using Atomic Absorption Spectrophotometer (AAS).

10) Collection of ambient air quality and noise data

Six sampling sites were selected for this study: Parking plant-recycling unit, parking plant – Roto parker unit, parking plant – loading Bay, cement mill, raw mill and crusher. Air quality determination was carried out using portable gas analyzers as described by [2]. The ambient air was monitored to determine sulphur (IV) oxide (SO_2), nitrogen oxides (NOx) and carbon monoxide (CO) using Qrae II. A PPM 1055 Handheld Aerosol Monitor was used to determine suspended particulate matter (SPM) while an Extech Sound Level Meter was used for noise level measurement.

11) Survey of worker health status

Sampling was limited to workers and was carried out through distribution of structured questionnaires to 80 respondents. The workers were selected as the target respondents because they are the primary recipients in contact with the cement dust due to the nature of their work and due to the fact that many of them live near the factory.

12) Contamination assessment methods

A number of methods have been reported in the literature for estimating pollution in soils, sediments and dusts. In this study, the degree of heavy metals contamination in the dust was characterized by geoaccumulation index (Igeo).

$$Igeo = \log2\ (Cn/1.5\ Bn) \qquad (Eq.1)$$

where;

Cn = the measured concentration (μg g^{-1}) of element n

Bn = the geochemical background concentration (μg g^{-1}) of the element in fossil argillaceous sediment (average shale)

Here, Bn is the background content of element n in the continental crust [20-22]. The following classification is given for geoaccumulation index: <0 = practically unpolluted, 0–1 = unpolluted to moderately polluted, 1– 2 = moderately polluted, 2–3 = moderately to strongly polluted, 3–4 = strongly polluted, 4–5 = strongly to extremely polluted and >5 = extremely polluted.

13) Health risk assessment model

13.1) Daily exposure dose and exposure point concentration

The health risk assessment equations used were based on the method developed by the United State Environmental Protection Agency (EPA) [23-30]. The subjects considered were divided into two groups: children and adults. Exposure to metals can occur via three main pathways: (a) inhalation of soil particles from the air; b) dermal contact with soil particles; and (c) direct ingestion of soil particles and diet through the food chain. Exposure calculation for daily estimation was made using the following equations:

$$D_{ing} = C \times \frac{(IngR \times EF \times ED)}{BW \times AT} \times 10^{-6} \qquad (Eq.2)$$

$$D_{inh} = C \times \frac{(InhR \times EF \times ED)}{PEF \times BW \times AT} \times 10^{-6} \qquad (Eq.3)$$

$$D_{dermal} = C \times \frac{(SL \times SA \times ABS \times EF \times ED)}{BW \times AT} \times 10^{-6} \qquad (Eq.4)$$

$$Diet = C \times \frac{(IRv \times EF \times ED)}{BW \times AT} \times 10^{-6} \qquad (Eq.5)$$

where;

D (mg kg^{-1} day^{-1}) = the combined dose contacted through ingestion (Ding), inhalation (Dinh) and dermal contact (Ddermal).

For this study, ingestion rate (IngR) is 200 mg day^{-1} for children and 100 mg day^{-1} for adults [31]. InhR: ingestion rate is 7.6 m^3 for children and 20 m^3 for adults [32]. EF: exposure frequency is 180 days $year^{-1}$ [24, 25, 28]. ED: exposure duration is 6 years for children and 24 years for adults [31] BW: the average body weight is 15 kg for children and 70 kg for adults [23]. AT: averaging time for non-carcinogens is ED×365 days; for carcinogens, 70×365 = 25,550 days. SA: the skin surface area; 2,800 cm^{-2} for children and 3300 cm^{-2} for adults [27]. SL: skin adherence factor is 0.2 mg cm^{-2} d^{-1} for children and 0.7 mg cm^{-2} d^{-1} for adult); ABS: dermal absorption factor (0.03 for arsenic and 0.001 for other metals). $IR_{vegetable}$ = ingestion rate 0.345 kg d^{-1} [33]. PEF: particle emission factor is 1.36 ×109 m^3 kg^-1. C (exposure-point concentration, lg g^{-1}) in Eq.2 to Eq.5 was an estimate of reasonable maximum exposure [24-28] and was calculated as the upper limit of the 95% confidence limit for the mean. The value was calculated as shown in Eq. 6 below:

$$C_{95}\% = \exp\left\{X + 0.5 \times s^2 + \frac{S \times H}{\sqrt{n-1}}\right\} \quad \text{(Eq.6)}$$

In this formula, X is the arithmetic mean of the log-transformed data, s represents the standard deviation of the log-transformed data, H is the H-statistic [34] and n is the number of samples.

13.2) Risk characterization

Risk characterization was quantified separately for non-carcinogenic and carcinogenic effects, for soil, cassava leaves and cassava tuber. The non-carcinogenic risk was evaluated by the hazard quotient (HQ). HQ and carcinogenic risks (CR) were calculated from Eq.7 and Eq.8:

As can be referred to Eq.7, hazard index (HI) is equal to the sum of HQ and is used to assess the overall potential for non-carcinogenic effects posed by more than one chemical. An HI below 1.0 indicates no significant risk of non-carcinogenic effects. Conversely, an HI above 1.0 indicates an elevated risk of non-carcino genic effects, with a probability that tends to increase with the value of HI [37]. While carcinogenic risk (CR) is the probability of an individual developing any type of cancer from lifetime exposure to carcinogenic hazards. The acceptable or tolerable risk for regulatory purposes is 1×10^{-6} to 1×10^{-4}.

14) Statistical analysis

Data obtained were subjected to descriptive (mean ± standard deviation) analysis using SPSS (Statistical package for social sciences) version 19.0.

$$HQ = \frac{D_{ing}}{RfD_{o}} = \frac{D_{dermal}}{RfD_{o} \times GIABS} = \frac{D_{inh}}{RFC_i \times 100\ \mu g\ mg^{-1}} \quad \text{(Eq.7)}$$

$$CR = D_{ing} \times SF_{o} = D_{dermal} \times {}^{SF_{o}}\!/_{GIABS} = IUR \times D_{inh} \quad \text{(Eq.8)}$$

where;

RfDo = the oral reference dose (mg kg^{-1} day^{-1})

RfCi = the inhalation reference concentrations (mg m^{-3})

SFo = the oral slope factor ((mg $kg^{-1}day^{-1})^{-1}$)

GIABS = the gastrointestinal absorption factor

IUR = the inhalation unit risk ($(mgm^{-3})^{-1}$) as obtained from the USEPA website [35-36]

Results and discussion

Soil physical and chemical properties are presented in Table 1. The soil organic carbon content ranged from 1.50±0.10 (Location IFK) to 4.86±1.90 % (Location TFG). Soil pH was highest (8.09±0.00) in Location IFK and lowest (5.76±0.40) in Location ILA while organic matter in the soil varied between 2.58±0.10 to 8.37±3.30 %. It was observed that deposition of cement kiln dust emerging from the cement plant affected the physical and chemical properties of the soil. Soil pH was alkaline, varying over a narrow range except in location ILA (control) where the soil pH was acidic. This indicated that cement factory emissions could alter soil pH when they settle on soil. Buba el al. [16] reported a soil pH range of 6.5 to 8.6 in Ashaka Cement Company, Gombe State, Nigeria, which was in line with the findings of this study but disagreed with the moderately acidic (mean of 5.8) pH recorded by Ibanga et al. [38]. However, acidic pH in location ILA (control) may have been due to the partial neutralization of the soil by high acidic gas emissions that may have been produced at the cement plant [39].

Organic matter content (2.58% to 8.37%) recorded in this study disagreed with the findings of Ibanga et al. [38] in Calabar cement factory where a moderate value (mean of 2.54%) was observed. Meanwhile, the observation in this study was above the range of 2.01 to 3.33% in a cement factory in Karachi, Pakistan recorded by Iqbal et al. [40]. In this study it was observed that the soil in the cement kiln had the highest organic matter content which agreed with the assertion of Ogunkunle et al. [41] who found that cement-polluted soil was significantly high in organic matter as a result of the synergistic deposition effects from cement production operations. In addition, organic matter was higher in the cement kiln than at other locations. Similar observations were reported by Khamparia et al. [39], at the Hirmi cement plant, Raipur district (India) where a decreasing trend was observed from 4.53 to 3.95 g kg^{-1} at 5,000 m and 50 m distance, respectively. The highest (2.98± 0.50 mg kg^{-1}) concentration of copper was found in location MAR, with the lowest (1.55±0.40 mg kg^{-1}) in location TFG, with geoaccumulation (I_{geo}) index and contamination factors of -0.71 and 0.90, respectively. Mean concentration of zinc varied between 139.00±25.00 to 141.00± 45.00 mg kg^{-1} in locations AOK and MAR, respectively, with I_{geo} index and contamination factor of 2.07 and 6.31, respectively. Meanwhile, cadmium had the highest (15.00±7.00 mg kg^{-1}) concentration in location IBE and the lowest in locations TFG and ILA (2.50±3.50 mg kg^{-1}). The I_{geo} index and contamination factors were 1.06 and 0.05, respectively, at these locations. In addition, manganese, lead and nickel had their highest concentrations in locations AOK (159.00 ±6.70), (30.00±21.00) and MAR (32.50± 11.00) with the lowest in location ILA (30.30±7.40), (10.00±4.50) and (7.50±3.50), respectively. The I_{geo} indices for manganese, lead and nickel were -0.06, -0.05 and -0.10, respectively, while the contamination factor was 1.44, 1.35 and 1.40.

Levels of copper, zinc, cadmium and manganese were higher in soil samples from around the cement factory than from control samples, except for lead and nickel, which were not detected around the cement kiln. The results of the heavy metal concentration obtained in this study were higher than the findings in a study around a cement factory in the Volta Region of Ghana reported by Addo et al. [42]. It is also important to note that transportation of the cement dust was aided by wind direction and velocity, which accounted for the high concentration of some heavy metals in soil samples some distance away from the factory. In a similar study [43] working around Ashaka Cement Factory in Gombe State, Nigeria reported an increase in soil enrichment of heavy metals with distance away from the cement factory as maximum values between 50 and 700 m distance along the wind direction. It was also discovered that zinc and manganese levels were significantly high in location AOK that was close to the cement kiln. Al-Khashman et al. [44] reported that cement production is an important emission source of heavy metals such as Cd, Cr, Cu, Pb and Zn, which supported the observation in this study. These heavy metals are deposited into the soil at various distances [45] depending on wind velocity and particle size [46] which also accounts for the varying values recorded in each station. Concentration of Cd in the soil can be attributed to the ferralitic nature of some of the raw materials used in the cement production, which is usually in low concentrations as observed in this study [44] and its significantly high concentration in the soil could not evidently be linked to the operation of the cement factory. Higher concentrations of Zn were observed in the soil in this study, compared with other similar studies [44-47]. Based on [48] classification, contamination factor showed a clearer picture of contamination in the studied soils. All metals examined showed low level of contamination in the soil except for zinc, for which high levels of soil contamination was found.

1) Concentration of heavy metals in cassava leaves and tuber

Concentrations of heavy metals in cassava leaves and tuber are shown in Figure 2. Cassava tubers had higher concentrations of Cu (40.00 mg kg^{-1}) than the leaves (25.00 mg kg^{-1}). Concentration of Zn in the cassava tuber was 55.00 mg kg^{-1} while it was below the detection limit in the leaves. Cd was found at 5.00 mg kg^{-1} in both leaves and tubers. Mn concentration in the leaves was 240.00 mg kg^{-1}compared to 70.00 mg kg^{-1} found in the tuber. Amongst all metals detected in the tuber, Pb had the highest concentrations (280.00 mg kg^{-1}). The lowest concentration of Pb found in the leaves was 105.00 mg kg^{-1}. The highest concentration of Ni was found in the leaves (Figure 2). The concentration of heavy metals in cassava leaves were ranked in the order Ni>Mg>Pb>Cu>Cd>Zn. Although concentrations of all metals analyzed in the environment samples were low, accumulation may lead to serious health problems. Deposition of these metals from cement kilns on herbaceous plants and fruit crops could block stomata, reduce the number of leaves, stunt vegetative growth and inhibit reproduction [49].

According to Semhi et al., high levels of heavy metals such as manganese might result from contributions from other sources such as agricultural run-off and local geological formations [50]. However, Iqbal et al. [40] suggested that depending on the dust load, duration and tolerance of the plants, particulates might cause negative changes in the leaf surface ultra-structures, inhibit growth of the plants, reduce the area of leaves, and hence reduce total biomass.

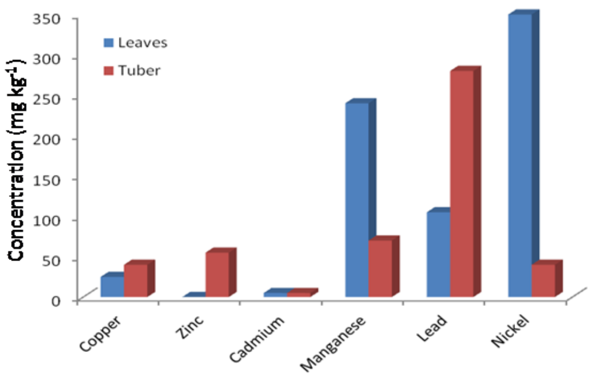

Figure 2 Heavy metal concentration in the leaves and tuber of cassava

Table 1 Mean of physical and chemical properties of soil (mg kg^{-1})

Parameter	Sampling Locations						I_{geo}	C_f
	IFK	TFG	AOK	MAR	IBE	ILA		
Cu	2.36±1.20	1.55±0.40	2.35±0.10	2.98±0.50	2.50±0.10	2.00±0.60	-0.71	0.90
Zn	15.40±8.6	9.75±1.60	141.00±45.0	139.00±60.0	5.50±2.10	6.93±1.30	2.07	6.31
Cd	12.60±11.0	2.50±3.50	7.50±3.50	12.50±3.5	15.0±7.0	2.40±3.50	1.06	0.50
Mn	57.00±15.0	67.80±0.4	159.00±6.7	101.00±29.0	141.00±51.0	30.30±7.40	-0.06	1.44
Pb	0.00±0.00	15.00±21.0	30.00±21.0	12.50±18.0	0.00±0.00	10.00±14.0	-0.15	1.35
Ni	0.00±0.00	17.50±3.5	12.50±18.0	32.50±11.0	10.00±0.00	7.50±11.0	-0.10	1.40
pH	8.09±0.00	7.80±0.10	7.22±0.10	7.16±0.50	7.34±0.50	5.76±0.40		
Organic Carbon (%)	4.86±1.90	1.50±0.10	2.82±1.20	2.33±0.70	3.03±0.90	3.67±0.30		
Organic Matter (%)	8.37±3.30	2.58±0.10	4.86±2.10	4.01±1.30	5.21±1.70	6.32±0.50		

Note:

- Cf is contamination factor
- IFK = inside the factory kiln, TFG = the factory gate, AOK = Abule Oke, MAR = Maria, IBE = Ibese and ILA = Ilaro

2) Air Quality parameters in Dangote cement factory, Ibese

Air quality around the cement factory is presented in Table 2. The concentration of carbon monoxide (CO) ranged from 2.00 to 8.00 ppm with a mean concentration of 4.18±2.04. These values were below standard as reported by Gbadebo and Bankole [49] who found low CO concentration in Benue Cement Company, Nigeria. Levels of nitrogen oxides (NOx) ranged from 0.10 to 0.20 ppm with a mean concentration of 0.14±0.05 ppm. Mean concentration of SO_2 14.75±6.37 ppm and it varied between 7.00 and 25.00 ppm. Total suspended particulate matter (TSPM) in the cement factory ranged from 101.00 to 13,056.00 µg m^{-3} with a mean of 3,782.40±40.15 µg m^{-3}, while noise levels varied between 72.10 and 98.20 dB. Concentrations of SO_2, TSPM and NO_X exceeded the national standard, while total suspended particulate matter in this study also exceeded the FEPA acceptable limit. This indicated that workers in the cement plant are susceptible to skin infections, respiratory ailments such as asthma, reduction and distortion of visibility [52] under prolonged exposure to cement dust [4]. The concentration of TSPM recorded in this study was double that reported by Bada et al. [2] from a cement company in Ewekoro, Nigeria. The higher concentration of SO_2 recorded in this study was corroborated by Zeyde et al. [51] who noted that higher SO_2 emissions from rotary kiln systems in the cement industry are often attributable to the sulfides contained in the raw material, which become oxidized to form SO_2 and SO_3 at prevailing kiln preheater temperatures of 370 °C to 420 °C.

The mean noise level measured at the cement plant was 86.03±8.21 dB, which exceeded the maximum permitted noise level of 85 dB as reported by Umunnakwe [53]. Noise levels at Parking Plant-recycling Unit, Parking Plant-Roto Parker Unit, Cement mill, and Raw-mill all exceeded the standard. Oyedepo and Saadu [54] reported that only 17% of the measurements in the parking, clay crusher and red soil silo had acceptable noise levels below 80 dB, while 83% of measurements for those sections had noise levels between 80-90 dB. About 50% of measurements at the limestone crusher had noise levels between 80-90 dB, with 50% were above 90dB. However, in this study, the highest noise levels were observed in the compressor room, raw mill, cement mill and power plant, where all measurements showed noise levels above 90 dB. Since exposure to continuous excessive noise at levels above 85 dB may lead to hearing loss [55], workers at the factory are highly prone to long-term hearing losses as observed in this study.

3) Health related characteristics

Health related characteristics of workers in Dangote Cement Factory, Ibese are presented in Table 3. It should be noted that most of workers were young and single males working as causal workers.

The study also revealed that presently, most respondents rarely suffered from any major health issues; only a few cases were reported with suspected breathing problems and difficulties in smelling. This may be due to the fact that the factory has been in operation for only 5 years, and most workers have had insufficient long term exposure to factory dust for other symptoms to manifest themselves. Longer exposure would be expected to reveal more cases especially of gastrointestinal inflammation. Hence, this study showed that cement dust could cause respiratory and non-respiratory diseases if exposed over a long working period. This study also showed that wheezing was commonly experienced by workers in the factory both during work and outside working hours. Wheezing is likely to be due to dust accumulation in the respiratory tract of affected individuals [56]. In a previous study, Zeleke et al. [13] stated that total cement dust deposits along the whole respiratory tract might be associated with respiratory symptoms from the upper and lower airways. A total of 2.5% of respondents reported breathing problems, while 3.75% had difficulty in smelling. In terms of the pulmonary system, 12.5% of respondents experienced wheezing. None of the respondents experienced cardiovascular problems or lung problems. However, in the long-term, workers exposed to fine particulate dust are known to be at high risk of pneumoconiosis, emphysema, bronchitis, and fibrosis.

Table 2 Concentration of air quality parameters in Dangote cement plant

Location		CO (ppm)	NO_X (ppm)	SO_2 (ppm)	TSPM ($\mu g/m^3$)	Noise
Parking Plant-recycling Unit	Entrance	6	-	-	448	86.7
	Mid-way	8	0.2	-	1,817	89.1
	End	6	0.2	-	5,684	78.2
Parking Plant-Roto Parker Unit	Entrance	4	0.1	-	7,014	89.9
	Mid-way	3	-	-	9,292	90.5
	End	3	0.2	-	1,863	79.1
Parking Plant-Loading Bay	Grand floor Entrance	-	0.1	7	708	73.2
	Grand floor Mid-way	2	0.1	11	971	79.9
	Grand floor End	4	0.2	9	182	95.2
	First floor Entrance	-	-	12	2,945	75.7
	First floor Mid-way	-	-	15	6,207	76.3
	First floor End	-	-	7	2,648	89.9
	Silo1	-	-	-	7,194	92.6
	Silo 2	-	-	-	13,056	89.0
	Silo 3	-	-	-	11,660	90.6
	Silo 4	-	-	-	1619	98.2

Table 2 Concentration of air quality parameters in Dangote cement plant *(continued)*

Location		CO (ppm)	NO_X (ppm)	SO_2 (ppm)	TSPM (µg/m^3)	Noise
Parking Plant-Loading Bay *(continued)*	Silo 5	-	-	-	10,147	72.1
	Silo 6	-	-	-	7,771	86.7
Cement mill	Entrance	-	0.1	25	754	92.1
	End	-	0.1	21	398	88.6
Raw mill	Milling Plant A	-	-	20	357	98.2
	Milling Plant B	-	-	24	471	97.7
Crusher	Plant A	2	0.1	11	934	74.9
	Plant B	2	-	15	101	77.2
	Ambient by the gate	6	0.1	-	842	85.8
	Ambient by the admin. Block	-	-	-	185	76.5
Mean±S.D		4.18±2.0	0.14±0.1	14.75±6.4	3782.4±40.2	86.03±8.2

Note: "-" means not detected

Table 3 Health related characteristics of respondents (workers) in Dangote cement factory, Ibese

	Percentage Yes	Percentage No
Suspected health conditions		
Seizures	0.00	100.00
Diabetes	-	100.00
Breathing allergies	2.50	98.50
Trouble smelling odours	3.75	96.25
Pulmonary problem	0.00	100.00
Asbestosis	0.00	100.00
Chronic bronchitis	0.00	100.00
Emphysema	0.00	100.00
Lung cancer	0.00	100.00
Silicosis	0.00	100.00
Chest injury	0.00	100.00
Asthma	0.00	100.00
Pneumonia	0.00	100.00
Tuberculosis	0.00	100.00
Others	0.00	100.00
Pulmonary Symptoms		
Shortness of breath	0.00	100.00
Shortness of breath with light activity	0.00	100.00
Cough with thick sputum or blood	0.00	100.00
Cough lasting for weeks	0.00	100.00
Wheezing	12.50	87.50
Wheezing that interferes with work	6.25	93.75
Others	0.00	100.00
Cardiovascular problems		
Heart attack	0.00	100.00
Stroke	0.00	100.00
Angina	0.00	100.00
Heart failure	0.00	100.00
Irregular heart beat	0.00	100.00
Swelling of leg	0.00	100.00
High blood pressure	0.00	100.00
Others	0.00	100.00

Table 3 Health related characteristics of respondents (workers) in Dangote cement factory, Ibese *(continued)*

	Percentage Yes	Percentage No
Cardiovascular symptoms		
Chest pain or tightness	0.00	100.00
Over time heart skipping	0.00	100.00
Heart burn on ingestion	0.00	100.00
Others	0.00	100.00
Current medication	0.00	100.00
Breathing or lung problems	0.00	100.00
heart trouble	0.00	100.00
blood pressure	0.00	100.00
Seizures	0.00	100.00

4) Health risk assessment

The results of health risk for carcinogenic and non-carcinogenic effects on children and adults are presented in Tables 4 and 5.

4.1) Carcinogenic and non-carcinogenic risk to children

Soil-laden air may deposit metals on food, drink and on the surfaces of crops, resulting in elevated health risks to residents, especially children with non-fully developed respiratory systems [28; 58]. For non-carcinogenic effects, ingestion appeared to be the main pathway of children exposure to soil particles. This pathway was followed sequentially by dermal absorption and inhalation. However, inhalation of Mn (8.38E-02) and Ni (3.31E-01) raises risks for children because these values exceed the acceptable maximum of 1×10^{-4}. For non-car cinogenic effects in the soil, the order of magnitude for ingestion effects was Cd>Ni>Mn >Zn>Pb>Cu, while the order for dermal exposure was Cd>Ni>Pb>Mn>Zn>Cu (Table 5). The HI values for all heavy metals for children decreased in the order: Pb>Cu>Zn>Ni>Cd> Mn for the soil. The HQ and HI values for all soil pathways were within the safe limit of 1.0, indicating that soils pose no non-carcinogenic effects to the children. $\sum HI$ for all the heavy metals (1.05) exceeded the safe limit of 1.0, indicating a higher probability of non-carcino genic effects [24, 37]. The non-carcinogenic effects reported for most of the heavy metals in this study corroborated with studies in China [26-27]. According to the classification by the International Agency for Research on Cancer (IARC), Cd, Ni and Pb are classified as carcino gens.

The carcinogenic risk (CR) to children from Cd, Ni and Pb were found to range from 5.16 E-04 to 3.72E-03 (Table 4) in soil for Cd and Pb, respectively, which exceeded the range of 1×10^{-4} to 1×10^{-6}, indicating a potential carcinogenic risk to children. The non-carcinogenic risks (HQ) and (HI) for all heavy metals through dietary exposure in children were within the safe limit of 1.0. CR from Pb for the diet pathway for both cassava leaves and cassava tuber which were 7.79E-06 and 1.60E-05, respectively, were also within the range of no probable cancer effect of 1×10^{-4} to 1×10^{-6} (Table 5).

4.2) Carcinogenic and non-carcinogenic risk to adult

The major pathways for non-carcinogenic risks to adults is ingestion, followed by dermal and inhalation pathways, as for children. Mn (2.18E-01) and Cd (6.16E-03) for HQ_{ing} (Table 4) were the major contributors to non-cancer effects in soil and exceeded the acceptable limit of 1×10^{-4} to 1×10^{-6}, indicating a potential carcinogenic risk to adults. The dermal pathway followed the same trend. The order of contribution through ingestion to non-carcinogenic effects is Mn>Cd>Ni>Zn>Cu> Pb in soil (Table 4). The HQ, HI and ∑ HI values were lower than 1.0 in this study, showing that adults are not at elevated risk from heavy metals in the soil. Carcinogenic effect for all metals was slightly higher than the no probable cancer effect level of 1×10^{-4} to 1×10^{-6}. The non-carcinogenic risks (HQ) and (HI) for all heavy metals through dietary exposure in adults were within the acceptable safe limit of 1.0, showing that there is no significant risk of non-carcino genic effects from (cassava leaves and cassava tuber) to adults (Table 5). The CR calculated for Pb in cassava leaves (2.38E-07) was lower, while in the tuber, CR was 1.25E-04, slightly exceeding the no probable cancer effects (1×10^{-4} to 1×10^{-6}).

Table 4 Cancer and Non cancer Risks for children and adults in soil

	Metal in soil (for child case)					
	Cu	Zn	Cd	Mn	Ni	Pb
Concentration (95%UCL) mg kg^{-1}	2.97	658.3	78.23	637.17	297.87	565.52
Ding	1.95E-05	4.33E-03	5.14E-04	4.19E-03	1.96E-03	3.72E-03
Dinh	5.30E-10	1.17E-07	1.40E-08	1.14E-07	5.32E-08	1.01E-07
Dder	5.47E-08	1.21E-05	1.44E-06	1.17E-05	5.48E-06	1.04E-05
derRfd	4.00E-02	3.00E-01	2.50E-01	2.10E-05	4.40E-04	3.50E-03
ingRfd	4.00E-02	3.00E-01	1.00E-03	3.00E-04	1.10E-02	3.00E-01
inhRfd	-	-	1.00E-02	8.75E-05	5.95E-05	-
HQ_{ing}	4.88E-04	1.44E-02	5.14E-01	2.99E-02	1.78E-01	1.24E-02
HQinh	-	-	9.31E-07	8.38E-02	3.31E-01	-
HQ_{der}	1.37E-06	4.04E-05	5.76E-02	8.38E-05	1.25E-02	2.97E-03
HI	4.90E-04	1.45E-02	5.72E-01	1.14E-01	3.33E-01	1.54E-02
CR	-	-	5.16E-04	-	1.96E-03	3.72E-03
	Metal in soil (for adult case)					
Concentration (95%UCL) mg kg^{-1}	2.8	657.89	78.23	637.18	144.78	458.56
Ding	1.61E-06	3.67E-05	6.16E-06	6.53E-05	9.14E-06	7.93E-06
Dinh	2.73E-10	5.54E-09	9.07E-10	9.60E-09	1.38E-09	1.17E-09
Dder	3.78E-08	8.70E-07	1.42E-07	1.51E-06	2.17E-07	1.83E-07
derRfd	4.00E-02	3.00E-01	2.50E-01	2.10E-05	4.40E-04	3.50E-03
ingRfd	4.00E-02	3.00E-01	1.00E-03	3.00E-04	1.10E-02	3.00E-01
inhRfd	-	-	1.00E-02	8.75E-05	5.95E-05	-
HQ_{ing}	4.03E-05	1.25E-04	6.16E-03	2.18E-01	8.55E-04	2.64E-05
HQinh	-	-	9.07E-08	1.12E-04	2.34E-05	-
HQ_{der}	9.32E-07	2.90E-06	5.70E-03	7.18E-02	4.94E-04	5.23E-05
HI	4.03E-05	1.28E-04	1.19E-02	2.90E-01	1.37E-03	7.87E-05
CR	-	-	6.31E-06	-	9.62E-06	8.11E-06

Table 5 Cancer and non-cancer risks for children and adults in cassava leaves and tuber

Metals	Concentration (95%UCL) mg kg-1	Ddiet	ingRfd	HQdiet	CR
Cassava leaves (Children)					
Cu	64.38	7.30E-07	4.00E-02	1.83E-05	
Zn	-	0.00E+00	3.00E-01	0.00E+00	
Cd	5.24	5.90E-08	1.00E-03	5.90E-05	
Mn	1247.74	1.42E-05	1.40E-01	1.01E-04	
Ni	286.77	3.25E-06	1.10E-02	2.96E-04	
Pb	736.09	8.35E-06	3.00E-01	2.78E-05	7.79E-06
Cassava leaves (Adult)					
Cu	64.38	6.08E-08	4.00E-02	1.52E-06	
Zn	-	0.00E+00	3.00E-01	0.00E+00	
Cd	5.24	1.22E-08	1.00E-03	1.22E-05	
Mn	1247.74	5.83E-07	1.40E-01	4.17E-06	
Ni	286.77	9.72E-08	1.10E-02	8.84E-06	
Pb	736.09	2.55E-07	3.00E-01	8.51E-07	2.38E-07
Cassava tuber (Children)					
Cu	129.87	1.47E-06	4.00E-02	3.68E-05	
Zn	263.02	2.98E-06	3.00E-01	9.94E-06	
Cd	5.49	6.22E-08	1.00E-03	6.22E-05	
Mn	870.61	9.87E-06	1.40E-01	7.05E-05	
Ni	1784.14	2.02E-05	1.10E-02	1.84E-03	
Pb	1514.25	1.72E-05	3.00E-01	5.73E-05	1.60E-05
Cassava tuber (Adult)					
Cu	129.87	3.16E-07	4.00E-02	7.89E-06	
Zn	263.02	6.39E-07	3.00E-01	2.13E-06	
Cd	5.49	1.33E-08	1.00E-03	1.33E-05	
Mn	870.61	2.12E-06	1.40E-01	1.51E-05	
Ni	1784.14	4.34E-06	1.10E-02	0.000394	
Pb	1514.25	3.68E-06	3.00E-01	1.23E-05	1.25E-04

Conclusion

The deposition of cement kiln dust emerging from Dangote cement plant has affected soil physicochemical properties in the adjacent area, with accumulation of heavy metals in soil and plants around the factory. Cement manufacturing can generate significant emissions of heavy metals such as Pb and Cd, deriving mainly from feedstocks, fossil fuels, and waste fuel. They are often bound to particulates such as dust. Cement dust laden with heavy metals emitted from the factory is dispersed by air and over time, deposited widely on soils and crops.

Heavy metals concentrations in soils at sampling locations around the factory were ranked in the order of MAR>IFK>AOK>IBE>ILA>TFG for copper, AOK>MAR>IFK>TFG>ILA > IBE for zinc, IBE>IFK>MAR>AOK>TFG > ILA for cadmium, IBE>AOK>MAR>TFG>IFK>ILA for manganese, IBE>AOK>TFG>MAR>ILA>IFK>IBE for lead and MAR>TFG >AOK>IBE>ILA>IFK for nickel.

Furthermore, high concentrations of sulfur dioxide, nitrogen oxides (NO_x), total suspended particulate matter and noise concentrations were found at levels ranging from 7-25 ppm, 0.1-0.2 ppm, 101-13,056 µg m^{-3} and 72.1-98.2 dB, respectively, all exceeding the respective USEPA standards. Health risk assessment showed that ingestion is the major pathway of exposure to heavy metals in soil samples for both children and adults. Cd, Mn, Ni and Pb pose a non-cancer risk to children, while only Cd and Mn pose non-cancer risk to adults. Ni and Pb posed the greatest cancer risk to children. In the cassava leaves and tuber Pb is the only metal that poses a cancer risk for both children and adults. For all the heavy metals examined except Cu, exposure through dermal contact is also a major pathway in adults, posing a non-cancer risk to those exposed. The findings highlight the importance of monitoring cement industry operations. This study also underlines the need for replicating studies periodically to prevent chronic health hazards. Generally, the company should ensure strict compliance with existing environmental pollution guidelines which are achievable under normal operating conditions in appropriately designed and operated facilities through application of pollution prevention and control techniques.

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