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IMPACT ASSESSMENT OF ENVIRONMENTAL POLLUTION CAUSED BY CEMENT DUST ON VEGETATION AND SOIL OF OBAJANA COMMUNITY, KOGI STATE NIGERIA

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ABSTRACT

Heavy metals emanating from cement production activities are serious pollutants. The study assessed the level of metal contamination of topsoil and vegetables grown around Obajana Cement Factory. Soil and plant samples were collected at 1, 2 and 3 kilometers from the factory. Samples were digested using Aqua regia solution, metal concentrations were determined using Atomic Absorption Spectrophotometry. Data generated were subjected to basic statistics and ANOVA with significance level at $p<0.05$. The soil samples contained Zn (8.70-196.00 mg/kg), Cr (3.95-115.87 mg/kg), Pb (4.18-29.65 mg/kg), Cd (0.00-6.75 mg/kg) and Cu (5.70-34.00 mg/kg). The study discovered that: Heavy metal levels was highest at distances closest to the factory and Pb, Cr and Zn had peak concentrations in the northern, western and eastern axis of the factory respectively; Soil in the vicinity of the cement plant was slightly acidic to moderately alkaline while Soil organic matter was found to gradually increase in percentage as distance from factory increased; The soils of Obajana community has elevated levels of heavy metals, although Cr alone had concentrations higher than the WHO permissible limits. Vegetables grown around the factory bioaccumulated some heavy metal and portents hazard to its consumers. It is recommended that remediation process be put in place to reduce the Heavy Metal load in the soil of Obajana community.

Keywords; **Cement factory, soil, heavy metals, cement dust, plants**

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1.0 INTRODUCTION

Cement production is a vital emission route for heavy metals such as Cd, Cr, Cu, Pb and Zn (Al–Khashman and Shawabkeh, 2006). The contamination of soil by heavy metals can pose challenges at several levels because they are not biodegradable (Emmanuel *et al*., 2009) and this causes several soil dysfunctions leading to concerns about the environmental quality. Soil properties such as pH, organic matter (OM) and electrical conductivity (EC) are known to influence the interactions, adsorption and desorption process of heavy metals within the soil matrix (Aloysius *et al*., 2013). Vegetables grown on polluted soils picks up heavy metals from the polluted soil and is of great health concern to humansOgunkunle*et al.*, 2013a. Obajana cement factory has a production capacity of 16.5 million metric tons of cement per annum as at 2020 (OCP, 2020). Particles of dust that escapes from this factory during the blasting of raw materials, grinding of cement clinkers and the packaging or loading of finished cement are often transported by wind and deposited in areas close to and far from the factory (Bankole, 2003). This is evident by the impact of cement dust on leaf anatomical features of selected plant species grown around this mega factory as reported by Owoleke *et al*., 2020. Owing to the vastness of the factory and its massive production capacity, it is pertinent to investigate the impact of cement dust emanating from Obajana cement factory on the physicochemical properties and heavy metal levels of soil and vegetables grown on the vast arable land around Obajana cement factory.

2.0 Materials and Methods

2.1 Study Area

Obajana cement factory is located between Latitudes $6^0$24'N – $7^0$34′N, Longitudes $7^0$49′E – $8^0$59′E of the Greenwich meridian. Limestone, quartzite, pegmatite, Schist, granite and granulites are some of the region's most common rock types (Afeni *et al*., 2008). The limestone deposit in the study area is projected to be about 647 million metric tonnes, which should make limestone sufficiently available to the factory for about 45 years. Obajana has an average maximum temperature of 33 degrees Celsius and is hot almost all year. There are rainy and dry seasons in the region. The predominant wind direction in June/July and December/January is south to southwesterly and northesterly, respectively (Afeni *et al.*, 2008). Obajana cement factory began producing cement in 2007 with two production lines and a capacity of 5 million metric tonnes per year (Vetiva, 2010). It currently has five production lines with a combined capacity of 16.25 million metric tonnes per year (OCP, 2020).

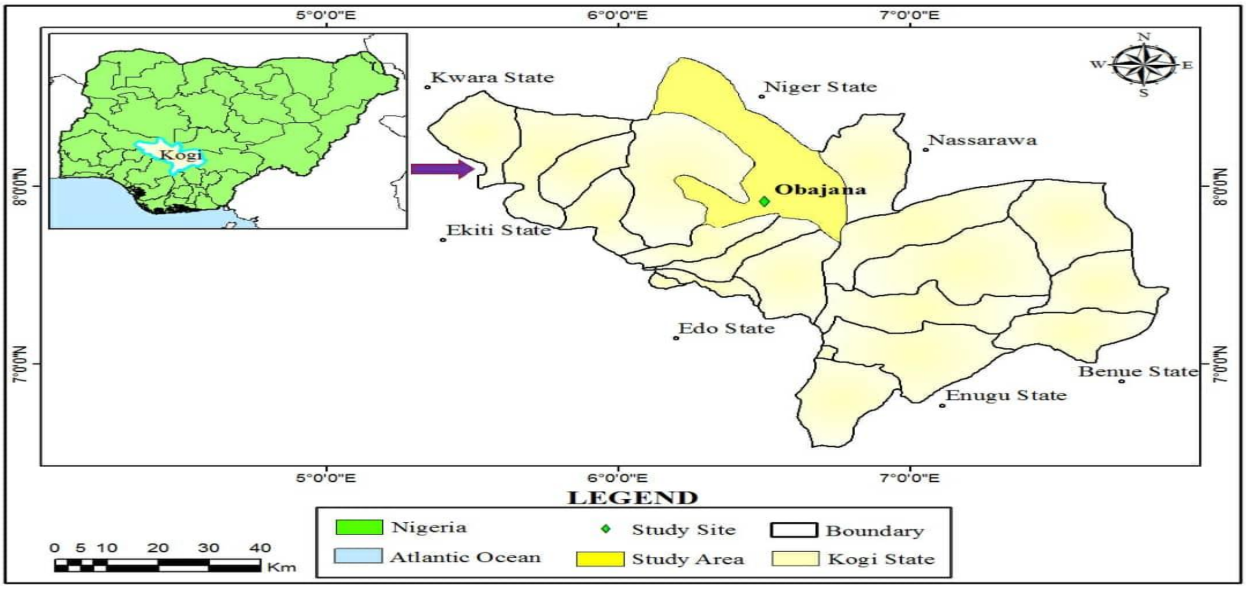

Fig. 1: Map of Obajana showing sample collection points
Source, Owoleke *et al*., 2020

2.2 Samples Collection

Sampling was carried out in the rainy and dry seasons of the year 2022 from farms in the north, east and west axis of the factory. Samples were not collected from the south of the factory as it is a rocky terrene. Sampling was done at distances 1, 2 and 3 kilometers from the factory. A total of 84 composite soil samples were collected in both seasons. Vegetables were also sampled at the points where soil samples were collected. The coordinates of every sampling point was taken by a handheld GPS (Garmin Montana 700). The soil samples were collected at depth (0 – 20cm) using a soil auger, while plant samples were collected with a stainless steel knife. Soil and plant samples were processed according to Awofolu (2005).

2.3 Determination of soil physicochemical parameters

Soil samples were air–dried, sieved through a 2–mm sieve mesh to remove coarse particles and pulverized into powder. The pH was determined in a soil solution (1:2) using CrisonMicropH meter 2000 (Vogel, 1994). Organic matter content was determined using loss on ignition method of Reddy *et al*. (2009) based on 1 g of the soil sample. Electrical conductivity of soil samples were measured with a soil:water ratio 1:2 (w/v) using Digital Conductivity meter model No PT360. Before use, the electrical conductivity meter was calibrated using 0.1M KCl.

2.4 Determination of Total Zn, Cr, Pb, Cd and Cu, content of soil and plant samples.

Digestion of the samples was done following the method of (Jaing *et al.*, 2011). One (1) gram of each sample was weighed using electric weighing balance (Mettler Toledo mb-8310) into a 250 ml glass conical flask and 10ml of concentrated HNO_3 (70% Sigma-Aldrich Corp, Germany) was added. The mixture was boiled gently in a fume chamber for 45minutes. It was then allowed to cool for 12hours. After cooling, 5ml of 70% HCl (Sigma Aldrich Corp Germany) was added and the mixture was again boiled gently until dense white fumes appeared. All the digests were cooled and filtered through a whatman filter paper No. 42 and diluted to 50ml by adding double distilled water. Each digest was transferred into acid-washed stoppered glass bottle, appropriately labeled for metal analysis. The Zn, Cr, Pb, Cd and Cu, content of samples was determined using FAAS (Buck Scientific 210 VGP). The detection limits of the FAAS used was 0.005mg/l , 0.04mg/l, 0.08mg/l, 0.001mg/l and 0.005mg for Zn, Cr, Pb, Cd, and Cu respectively.

Quality validation

Reagent blanks were used to validate the purity of chemicals used for digestion; Certified reference material IAEA-SL-1 (lake sediment) and certified reference material IAEA-Cabbage-359 was subjected to the same digestion procedure as the soil and plant samples and analyzed to evaluate the accuracy of the analytical procedure; The detection limit of the FAAS used was also noted to help ascertain the limit of detection of heavy metals in the samples.

Data analysis

Data obtained from heavy metal analysis were subjected to statistical analysis using SPSS 23.0 (SPSS Inc., USA) software. The means of the replicates and the evaluation of significant differences among sampling sites, sampling distances were determined using descriptive statistics and analysis of variance (ANOVA) and significant means were separated by Duncan Multiple range test at 0.05 probability level.

3.0 Results and Discussion

3.1 Physicochemical properties of top soil around the factory

Table 1, shows the pH, organic matter and electrical conductivity of soil around the factory in the rainy and dry seasons. The pH values in the polluted site ranged from slightly acidic (5.1) to slightly alkaline (9.3). Soil of the western axis was the most alkaline of the 3 axis investigated. The prevailing wind direction which lead to the deposition of more cement dust in the west axis of the factory could have accounted for the recorded peak alkalinity in the west. This was corroborated by the report of Afeni *et al*., 2008 on the prevailing wind direction in Obajana to be North westerly and the findings of Ogunkunle *et al.*, 2013a which states that the higher the amount of cement dust pollution of soil the more alkaline the soil will be since cement itself is alkaline in nature. Owoleke *et al.*, 2020 reported acidic soil pH in soil of some communities that were about 40Km distance from Obajana cement factory.

Organic matter content of soil of the study area ranged from 6.2% to 12.0%, with the highest (12.0%) occurring at E3 and the least (6.2%) at N2. There was slight variations in soil organic matter from season to season, distances from the factory and the three axes of the factory that were assessed. The relatively higher organic matter content in the dry season could be due to lower soil moisture in the soil during the dry season. Thus, microbial decompositions of organic matter was retarded during the dry season. The soil organic matter content for the three axis was in the order of North > West > East in the dry season and West > East > North in the rainy season. The relatively higher organic matter content in the Northern axis could be attributed to less cement dust, occasioned by the prevailing north-westerly wind direction (Afeni *et al.,* 2008) in the dry season. Similar trend has been reported around cement factories (Oludoye and Ogunyebi 2017).

Electrical conductivity ranged from 100.5 us/cm to 119.7 us/cm. In the rainy season, electrical conductivity values were slightly lower than in the dry season. This may be attributed to rainfall and weathering intensities as well as to leaching and lateral translocations which is capable of lowering EC in the rainy season. This was attested to by the report of (Fatoba and Iyeh, 2012). Electrical conductivity decreased with increasing distances from the factory with few exceptions in the rainy season. This can be attributed to the significant amount of cement dust deposited on the soil surface around the vicinity of the cement factory.

Table 1: Soil physicochemical parameters of the study sites in the rainy and dry seasons

Location	pH		Organic matter (%)		EC(µS/Cm)	
	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry Season
N1	8.8±0.7[a]	10.5±1.5[a]	9.0±1.0[b]	10.7±1.4[a]	115.4±14.3[a]	123.5±12.5[a]
N2	7.4±0.8[ab]	9.4±1.4[a]	6.2±0.8[bc]	12.6±2.3[a]	100.7±11.6[c]	118.2±10.6[a]
N3	5.1±0.5[bc]	5.2±0.2[c]	10.2±1.0[a]	15.3±2.1[a]	118.6±20.5[a]	112.4±15.3[ac]
W1	9.3±1.0[a]	10.1±1.5[a]	10.2±2.5[a]	8.6±1.5[b]	119.7±16.3[a]	116.8±12.6[b]
W2	9.0±0.8[a]	9.2±0.7[a]	11.2±2.1[a]	10.0±1.2[a]	110.5±10.4[ab]	105.3±10.3[c]
W3	6.8±0.7[b]	4.3±0.2[c]	13.1±2.3[a]	12.4±2.0[a]	112.8±10.8[ab]	102.4±12.6[c]
E1	9.0±1.3[a]	11.5±1.4[a]	8.5±0.7[b]	9.3±0.4[b]	116.5±12.5[a]	120.0±13.7[a]
E2	8.8±1.0[a]	10.5±1.7[a]	10.2±1.2[a]	6.4±0.2[c]	111.4±12.8[bc]	118.4±10.4[a]
E3	7.4±0.8[ab]	10.7±1.2[a]	12.0±2.5[a]	10.5±1.0[a]	112.1±10.7[ab]	115.2±14.3[a]
Control	4.7±0.5[c]	4.4±0.5[c]	10.0±0.5[a]	8.5±0.6[b]	95.0±10.0[cd]	96.4±10.5[c]

Values with the same superscript along the column are not significantly different at $p<0.05$
N-north, W-west, E-east, 1, 2, 3 implies one, two, three Kilometers from OCF

3.2 Soil heavy metal levels in both seasons, varying distances and axes of the cement factory

As shown on table 2, in the dry season, the concentrations of the studied heavy metals were higher in the soils around the cement factory than in the rainy season. This could be as a result of their association with the raw materials (limestone, clay, laterite, sandstone and gypsum) used for cement production (Ogunkunle *et al.,* 2013). The elemental concentrations were slightly lower in the rainy season than values obtained in the same location during the dry seasons probably due to rain induced heavy metals dilutions and leaching into the sub-soil layers as researchers have indicated these heavy metals have the potential of being leached out when weakly adsorbed to topsoil (Zanders, 1999). Imray and Langley (2001) also reported that changes in concentration of heavy metals overtime in soil stratum may occur as a result of factors such as breakdown and leaching.

The average concentrations of the metals varied along the sampling distances. Average concentrations decreased with increase in distance from the factory. This decrease in metal concentrations as distance from the factory increases is an indication that the metals were being discharged from the activities of the factory. In cement industries, the linings for the rotaries contains Cr, Co and Cu which could be liberated to the environment by wears and frictions (Banat *et al*., 2005). Generally, higher concentrations of heavy metals were observed in the 1km distance than in the 3km distance. The heavy metals analysis inculpates cement dust originating from the cement facility for being partly or wholly responsible for metal contamination of soil around the factory. The decrease in the quantity of the metal concentrations as distance from the factory increases could indicate a link between the cement production and soil metal concentrations around the factory. Metals originating from industrial activities are distributed in soils by the atmosphere within a distance that depends on the size of particles (Mandal and Voutchkov, 2011).

The quarry is in the eastern axis while a high traffic density road transverses the north, through the west to the southern axes of the factory. Chromium, cadmium and copper levels of the sampled soil was high in the eastern axis, where the quarry is located. The quarrying activity must have accounted for their peak concentrations in the eastern axis. This finding is in agreement with the results reported by Al-Omran *et al.*, 2011 who reported a similar trend in metal concentrations in the direction of the quarry relative to a cement factory. The peak Zn and Pb concentrations recorded in the North and West axis of the factory could have resulted from a synergistic deposition effects from cement production operations, loading of trucks for distribution and traffic activities. This could be attributed to the high traffic density road that transverses from the north through to the western axis of the factory as Farmaki and Thomaidis, 2008; Wang *et al*., 2009 has attributed substantially high soil Pb and Zn levels to vehicular activities. Also, the truck loading site is also located in the North-west axis of the factory. Pb and Cu are known to be part of heavy metals released during cement production (Carreras and Pignata, 2002; Banat *et al*., 2005; Kakareka and Kukharchyk, 2011). High concentration of Pb in the north/western part of the factory was expected because of the synergy of depositions from cement production with the release from vehicular activities (Carerras and Pignata, 2002; Al-Khashman and Shawabkeh, 2006). Cd is derived from the mechanical abrasion of vehicles and is associated with tyre wear Kakareka and Kukharchyk (2011).

Table 2: Total heavy metal contents (mg/kg) at different axis and distances in the rainy and dry seasons

	Zn		Cr		Pb		Cd		Cu	
Location	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**	**Dry**
N1	86.65	90.24	100.57	103.57	26.87	34.35	0.50	0.05	22.00	20.50
N2	89.87	94.93	104.25	107.25	28.15	38.15	0.00	0.05	34.00	30.00
N3	86.82	88.80	105.85	108.85	26.20	26.20	0.00	0.00	19.25	14.15
W1	72.90	82.90	108.35	110.35	19.77	25.45	.000	0.05	20.25	18.25
W2	77.55	71.59	111.70	112.70	29.65	28.45	2.75	1.15	15.75	14.75
W3	59.77	49.36	76.32	86.32	12.47	18.47	0.00	0.05	8.75	10.75
E1	30.90	47.90	115.87	119.49	27.92	26.52	2.25	1.05	21.50	17.50
E2	66.10	48.10	77.95	100.95	14.10	24.10	0.500	0.50	11.25	10.25
E3	8.72	12.78	58.57	86.57	9.60	19.60	0.00	0.00	10.25	10.00
SC	8.42	8.11	46.42	47.42	6.77	8.37	0.00	0.00	8.00	6.00

Values with the same superscript along the column are not significantly different at $p<0.05$
(N- North, W-West, E-East, SC-Control sample. 1Km, 2Km, 3Km from factory)

3.3 Heavy metal levels in plants sampled from farms around the cement factory

The accumulation of metals has been described as their content or concentration in different parts on the basis of their amount per unit dry weight of tissues (mg/kg dry weight). Heavy metals are mobile and easily taken up by plants grown in metal contaminated environments. Since the plants have high ability to accumulate metals in their different parts from the environment, metals taken up by the crop plants may pose risks to human health when they are grown on or near contaminated areas through various food chains. The heavy metal levels in the plant samples is as presented on table 3 below.

Table 3: Heavy metal levels in plants sampled from farms around the cement factory

Location	Zn	Cr	Pb	Cd	Cu
N1	51.40	3.20	0.40	0.07	9.00
W1	61.25	4.37	0.20	0.04	7.00
E1	52.00	2.65	0.20	0.06	4.50
FAO	60	2.3	0.3	0.2	20

3.4 Bioaccumulation factor of heavy metals from soil to plant root.

The values of bioaccumulation factor of heavy metals from soil to plant root was used to assess the mobility of metals from the soil on which the plant grows. It was determined as;

$$\text{Bioaccumulation factor (BF)} = \frac{\text{Concentration of metal in plant root}}{\text{Concentration of metal in soil}}$$

Transfer of metals from soil to the root of was higher than 1 across the locations for Zn and Cu indicating that Zn and Cu had high transfer rate from soil to root. Zn and Cu are essential elements needed for plant growth. The capacity of accumulating different heavy metals by different plant species is related to the heavy metal content in soil and the alternative absorptivity to heavy metals (Sajjad*et al.*, 2010). In this case, *Mangifera indica* being a perennial plant is more likely to have high absorptivity for the essential metals. Moreover, trees absorb less metal than fast growing plants like maize and okra according to Smical *et al.* (2008). This can be attributed to activities of the woody root, which seems to act as a barrier for uptake of metals (Khan *et al.*, 2009).

Table 4: Bioaccumulation Factor (BF) of Heavy metals in the root of the sampled plants

Location	Zn	Cr	Pb	Cd	Cu
North	1.93±0.13	0.04±0.01	0.08±0.02	0.19±0.06	1.11±0.01
West	1.29±0.42	0.04±0.01	0.15±0.03	0.25±0.03	1.18±0.02
East	2.42±0.34	0.03±0.00	0.31±0.01	0.01±0.00	1.08±0.01
Control	0.69±0.05	0.01±0.02	0.09±0.02	0.03±0.00	0.50±0.04

Values given are means ± standard deviation

3.5 Human health implications from ingestion of heavy metal laden vegetables growing around OCF

From the computed HQ values as presented on Figure 1, Zn and Cr portends adverse toxicological effects on humans through the consumption of crops grown around OCF. This is because the daily oral ingestion estimated was less than the oral chronic reference dose (RFD) for Pb, Cd and Cu (USEPA, 2010). This translates into non-carcinogenic hazard quotient (HQ) that was less than unity which poses low-non carcinogenic risk.

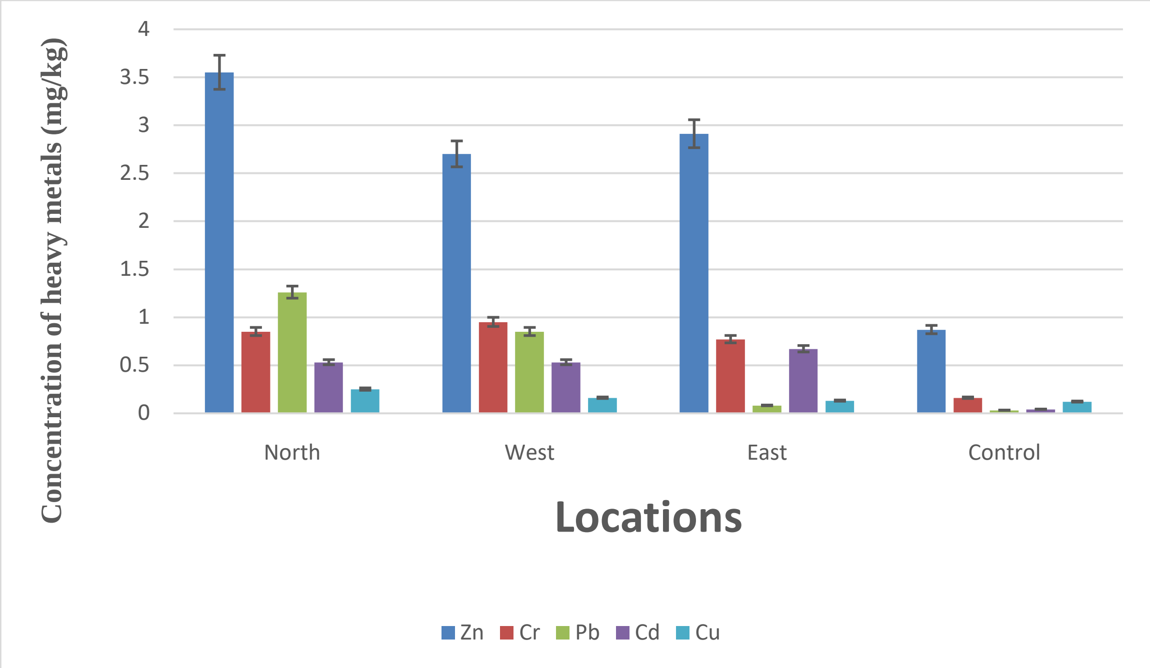

Figure 2: Hazard Quotient for sampled plant
HQ>1- Potential health risk   HQ<1- No potential health risk

The average concentrations of the other quantified heavy metals (Zn, Cd and Cu) were below the CCME limits. Although, their concentration were slightly higher than those recorded for the control sites. Howbeit, there is no fear of acute toxicity of Zn, Cd and Cu since the concentration is below the permissible limits. The concentration of Cd in soil is significantly lower than what was reported by Gabdebo and Bankole (2007); Mandal and Voutchkov (2011) around some cement factories.

Conclusion

The soil pH of the study area before the commencement of cement production was generally acidic. However, due to the continuous deposition of cement dust soil pH is currently, slightly alkaline. Based on this findings, it can be concluded that if such trend of dust deposition continues, soil properties of a vast area around the cement plants are likely to change in terms of its physico-chemical properties. These changes will in turn have multiple deleterious effects particularly on agriculture, flora and fauna of the area in the near future.

The heavy metal pollution of soil around Obajana cement factory was found to be slightly higher in the dry seasons than in the rainy season. Metal concentration of the soil was generally within the permissible limits except for Chromium and lead in some hot spots. Crops grown around the factory all bioaccumulated heavy metals from the soil at varying degrees. There is health concern arising from the consumption of vegetables owing to slightly high Cr content mainly in crops grown on the northern axis of this mega factory. This portends hazard not only to Obajana community but also to commuters who buys and consume some of these fruits sold along the ever busy Lokoja/ Kabba road that transverses right in front of this mega cement factory.

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