Heavy metal contamination of topsoil around a cement factory – A case study of Obajana Cement Plc

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**ABSTRACT**

The concentration of heavy metals (Cd, Co, Cr, Pb, and Ni) in topsoil samples around Obajana Cement Plc was determined to assess the impact of cement dust emitted from the factory environment. The analysis was carried out using Atomic Absorption Spectrophotometer. Samples of the topsoil were collected from the factory at various distance points. The control was collected from a sparsely populated area which is 15 km away from the factory. The pH of the soils ranges from 6.18 to 8.43 against a controlled pH of 6.11. The EC level decreases with increasing distances from the factory. The soils of all the studied sites have very low silt content and a high sand content. There was significant decrease in Cr, Cu and Cd with an increase in the distance from the cement factory. The concentrations of the metals at each point were below the WHO standard of the individual metal in the soil.

**Introduction**

The desire to explore the earth in order to improve living conditions has resulted in the pollution of the environment. These activities include; urbanization, industrial activities and modernization of agricultural practices, in terms of the application of fertilizers, pesticides and other chemicals whose end products result in a harmful effect on humans [1,2]. The quest for development has been one of the major reasons why humans in one way or the other pollute the environment. Metal pollution of bodies such as rivers, soil, air, and water has been a concern and an issue in many industrialized countries throughout the world due to human activities and natural processes that have resulted in environmental deterioration [3–5].

It has been established that the soil accumulates significant concentrations of hazardous metals resulting from human activities [6,7]. Heavy metals and other chemicals are released into the environment in significant quantities, particularly by industries amongst which the Cement Industry is a major player [8]. Cement factories are known to emit a variety of pollutants, including particulate matter, gases, and various heavy metals, all of which are harmful to the biotic environment, manifesting themselves in soil, plants, and terrestrial and aquatic flora and fauna [9].

Soil has been recognized as the major sink for anthropogenic heavy metal deposition through various pathways [10]. Heavy metal pollution of soil can be problematic on numerous levels because they do not dissolve biologically, resulting in a variety of soil dysfunctions that raise environmental issues [6,7].

The Central Pollution Board lists the cement industry as one of the most polluting industries, with noise and dust as its primary pollutants. Pollutants are released at every stage of the manufacturing process, including raw material extraction, crushing, and manufacture. The elemental content of soil, as well as its physicochemical properties, are affected by cement dust [11]. It is also the major source of such particulate matter as SO\textsubscript{x}, NO\textsubscript{x}, and CO\textsubscript{2} emissions. The dust contains heavy metals like chromium, nickel, cobalt, lead, and mercury, which are hazardous to the environment and affect human and animal health. Carcinogenesis, reduced antioxidant capacity, acute respiratory symptoms, and acute ventilatory effects have all been linked to cement dust in humans and animals [12]. In addition, heavy metal poisoning also causes plant withering, scorched leaf edges, and reduced leaf growth [13].

Soil is the main source of trace elements for plants both as micronutrients (necessary for plant growth) and as pollutants. It occupies a basic role for humans because the survival of man is with the maintenance of its productivity. Soil is a source of these elements to humans due to soil ingestion affected by ‘pica-soil’, geophagia, dust inhalation and absorption through skin. Cement industry is one of the 17 [13], most polluting industries listed by the central pollution control board. It is the major source of particulate matter, SO\textsubscript{x} (Sulphur oxides), NO\textsubscript{x} (Nitrogen oxides), and CO\textsubscript{2} emissions. Cement dust contains heavy metals like chromium,
nickel, cobalt, lead and mercury, which are harmful to the biotic environment like soil with impact on vegetation, human health, animal health and ecosystem [14].

Nature has provided varying degrees of minerals in various parts of the universe, but man’s inquisitive nature, his quest to explore the earth, introduced minerals or materials into the environment in quantities greater than their natural concentration (pollution), which has a net negative effect on the environment, which in turn affects man. Numerous research have been conducted throughout the years to determine the appropriate concentration of heavy metals. The research aims to determine the concentration of heavy metals (Cd, Co, Cr, Ni and Cu) in topsoil samples.

Dangote Plc’s flagship factory and the largest of the company’s three plants in Nigeria is located in Obajana, Kogi State. The factory was launched in 2008, with two 5-million-tonne-per-year production lines. The plant used to be Sub-Saharan Africa’s largest cement plant. With the addition of Line 3, the factory’s capacity was increased to 10.25 Mta in 2012. A 3.0Mta line was built in 2014, and another 3.0Mta line will be added in 2020. Obajana has a 647 million ton limestone reserve that will last for 45 years. A fleet of 2,370 trucks with a total capacity of 10.25 million tonnes per year supports the plant’s three lines. Nigeria is now self-sufficient in cement production and an exporter of the commodity thanks to this company’s efforts. The cement dust has been sprayed and wrapped around the communities surrounding the cement mill. Since the start of cement production in the area, residents have claimed that they both breathe and eat dust.

The investigation was prompted by the harmful effects and human health risks posed by these chemical byproducts of anthropogenic activity. As a result, the research intends to evaluate the level of heavy metal contamination in the surrounding topsoil of the Obajana cement factory in Nigeria at various distances from the factory and to obtain some indices for heavy metal contamination.

Materials and method

Study area

The research was carried out in Obajana Cement Plc which is situated in Obajana, North Central Nigeria (7.9104° N, 6.4399°E) and around. The factory is located in the North Central of Kogi State (see Figs 1 & 2). Obajana district covers about nine (9) villages [15]. Because of the research area’s size, only the Obajana community was chosen from among the district’s communities. This is due to the fact that, among the 13 neighboring communities in the district, Obajana has the highest human population and residential structures. Obajana is also the center of economic activity because it is home to a massive industrial.

Sample collection

A total of 48 composite topsoil samples were collected in the west, south, north and the east parts of the factory and specific distance apart from the factory. Topsoils (0–15 cm) samples were collected randomly in triplicates from four different locations of the factory. The factory was made the central point while profile lines of about 1 km, 3 km and 6 km long will be defined to the east, west, north and south of the factory respectively and topsoil samples are collected along the defined profiles surrounding the cement factory and scrapped into labelled plastic containers. The control sample was collected from a sparsely populated area which is 15 km away from the factory. The samples from each points were bulked together to obtain a composite sample and recorded against the coordinate position. The soil samples collected were placed in polyethylene bags, properly labeled and transported to the laboratory.

Sample preparation

Coarse materials and debris were sorted out of the soil samples and air-dried for 72 hours. After which they were ground with a mortar and pestle, passed through a 2 mm sieve and stored for analysis. Exactly 1 g of each soil sample was weighed in a 100 ml clean Kjeldahl digestion flask, 20 ml of aqua regia (mixture of concentrated nitric acid HNO3 and concentrated hydrochloric acid HCl in a ratio of 1:3) was added, it was then heated in a fume cupboard to near dryness until a slightly clear colour solution was obtained. It was cooled and filtered using Whatman filter paper into a 50 ml standard flask and made up to mark with distilled water. The digests were analyzed using Atomic Absorption Spectrophotometer (AAS). Soil pH was determined with 1:4 soil/water suspension using a pH meter. Soil texture was determined using the hydrometer method. Soil conductivity was determined using a conductivity meter. Cation Exchange Capacity (CEC) was also determined.

Data analysis

All determinations were performed in triplicate. The statistical analyses were conducted using One Way Analysis of Variance (ANOVA) and the mean value separated by Duncan’s multiple-range test (DMRT) using SPSS.
Results and discussion

Physico-chemical analysis results

The Physicochemical Properties of the soil is presented in Table 1. The Table reveals that the soil temperatures were within the temperature range of the control soil. This implies that there was no effect of the cement factory on the temperature of the soil both in the factory and its surrounding.

South; E: East; W: West; N: North; F: Factory;
1 km: 1 kilometer from cement Factory
3 Km: 3 kilometers from the cement factory
6 km: 6 kilometers from the cement factory

The comparison of electrical conductivity (EC) levels at the factory with that of soils collected from varying distances from the factory showed that the level of EC decreases with increasing distances from the factory. W6Km, which is the furthest away from the cement mill, had the lowest EC. However, the soil closest to the plant site had the highest level of EC. In comparison to the control location, the concentration of EC in soils surrounding cement factories was greater. The degree of soil conductivity was shown to increase significantly under the influence of cement dust, based on the findings. The influence of cement dust on soil EC was validated by [16].

The soil texture class was evaluated for all the study sites and control sites (see Table 1). The soils of all the studied sites have very low silt content and a high percentage of sand content. All of the analyzed sites’ soils had a high percentage of sand and a low amount of silt. The mean value ranges were K⁺ (2.32 to 6.85 mgkg⁻¹), Na⁺ (3.12 to 12.63 mgkg⁻¹), Ca²⁺ (8.07 to 25.31 mgkg⁻¹) and Mg²⁺ (2.01 to 6.33 mgkg⁻¹).

Metal analysis results

Table 2 shows the analytical result of the metals (Cu, Co, Cr, Cd and Ni) analyzed. The result is the mean of triplicate measurement and its standard deviation.

Metal distribution across the distance separation

The analytical data shown in Figure 3 show that the concentration of examined metals decreases as the distance from the production increases. Higher
Figure 2. Map showing the sampling location.

Table 1. Physico-chemical properties of the sampling location.

| LC  | pH  | Temp. | EC ds/m | Na⁺ | K⁺ | Mg²⁺ | Ca²⁺ | %Sand | %Silt | %clay |
|-----|-----|-------|---------|-----|----|------|------|-------|-------|-------|
| EF  | 8.43±0.14 | 30.60±0.10 | 6.67±0.01 | 11.89±0.11 | 5.60±0.11 | 2.01±0.11 | 25.31±2.21 | 89.28±7.85 | 9.00±0.23 | 1.72±0.00 |
| SF  | 8.12±0.11 | 30.50±0.10 | 6.27±0.07 | 10.02±0.11 | 4.02±0.12 | 5.70±0.23 | 23.95±2.08 | 75.28±4.00 | 18.00±1.01 | 6.72±0.21 |
| NF  | 8.19±0.02 | 30.50±0.10 | 6.68±0.03 | 12.63±0.20 | 6.17±0.20 | 3.12±0.12 | 22.04±2.12 | 84.28±5.96 | 13.00±0.89 | 2.72±0.04 |
| WF  | 8.37±0.02 | 30.57±0.15 | 6.22±0.00 | 10.01±0.18 | 7.02±0.23 | 6.17±0.28 | 16.23±1.54 | 67.28±6.05 | 10.00±0.11 | 2.72±0.02 |
| E1km| 7.45±0.15 | 30.30±0.60 | 5.67±0.02 | 9.89±0.12 | 4.00±0.11 | 3.02±0.18 | 23.01±2.02 | 89.28±4.89 | 4.00±0.12 | 6.72±0.54 |
| S1km| 7.52±0.04 | 30.33±0.20 | 5.67±0.08 | 8.21±0.16 | 3.12±0.02 | 5.00±0.20 | 22.99±1.89 | 85.28±8.57 | 6.00±0.21 | 8.72±0.17 |
| N1km| 7.78±0.12 | 30.03±0.40 | 5.33±0.07 | 11.75±0.21 | 5.22±0.17 | 4.57±0.16 | 21.75±0.98 | 87.28±7.22 | 8.00±0.38 | 4.72±0.08 |
| W1km| 7.65±0.16 | 30.40±0.17 | 5.67±0.01 | 7.23±0.45 | 6.85±0.32 | 5.55±0.28 | 14.43±0.32 | 77.28±5.60 | 6.00±0.01 | 16.72±1.00 |
| E3km| 7.10±0.13 | 30.43±0.11 | 3.07±0.00 | 7.86±0.11 | 3.23±0.01 | 4.01±0.17 | 20.22±1.22 | 95.28±3.24 | 2.00±0.00 | 2.72±0.01 |
| S3km| 7.01±0.18 | 30.40±0.17 | 3.33±0.00 | 8.00±0.11 | 2.99±0.21 | 4.49±0.12 | 19.11±0.78 | 93.28±6.06 | 0.00±0.00 | 6.72±0.45 |
| N3km| 7.09±0.08 | 30.30±0.17 | 3.00±0.00 | 9.89±0.35 | 4.32±0.24 | 3.29±0.01 | 18.56±0.12 | 97.28±1.23 | 0.00±0.00 | 2.72±0.01 |
| W3km| 7.02±0.07 | 30.30±0.60 | 3.67±0.00 | 6.32±0.14 | 5.00±0.34 | 6.00±0.08 | 12.07±0.12 | 79.28±3.14 | 11.00±1.08 | 9.72±0.89 |
| E6km| 6.49±0.11 | 30.13±0.55 | 1.00±0.00 | 4.11±0.12 | 2.00±0.01 | 5.09±0.25 | 14.44±0.58 | 89.28±4.85 | 4.00±0.00 | 6.72±0.04 |
| S6km| 6.99±0.05 | 30.17±0.40 | 1.33±0.00 | 7.28±0.47 | 2.01±0.01 | 5.23±0.32 | 12.21±1.11 | 94.28±2.36 | 1.00±0.00 | 4.72±0.05 |
| N6km| 6.74±0.32 | 29.83±0.37 | 1.67±0.00 | 7.32±0.09 | 2.01±0.01 | 4.00±0.11 | 11.85±0.96 | 89.28±3.00 | 5.00±0.05 | 5.72±0.12 |
| W6km| 6.18±0.01 | 30.30±0.34 | 1.33±0.00 | 6.01±0.21 | 2.00±0.02 | 6.33±0.32 | 11.01±0.63 | 93.28±2.63 | 3.00±0.07 | 3.72±0.04 |
| Control| 6.11±0.01 | 29.00±0.60 | 1.00±0.00 | 3.12±0.01 | 2.32±0.02 | 4.57±0.20 | 8.07±1.78 | 94.28±1.75 | 1.00±0.00 | 4.72±0.01 |
elements concentrations were found at the four coordinates (East, West, North, and South) in areas closest to the cement factory’s premises, most likely due to their proximity to the cement plant [17]. A similar finding to high metal content around cement plant was also reported by [18]. The lowest amounts were detected at the farthest sites, 6 kilometers from the factory; at this distance, the influence of cement fumes and dust is insignificant in comparison to the factory. This indicates that the further distant you are from a cement plant, the less likely you are to come into contact with a heavy metal related with the factory, which directly translates to living far away from a cement factory being safer and healthier. Cobalt and nickel-metal were not found in any of the locations, nor were they found in the control sites. None of the metals investigated were discovered in the control sites, implying that the metal concentrations found in the study sites were due to anthropogenic contributions to the soil.

Table 2. Metal analysis and distribution result.

| LOCATION | Cu  | Co  | Cr    | Cd      | Ni  |
|----------|-----|-----|-------|---------|-----|
| EF       | 15.87 ± 0.504 | ND  | 7.23 ± 0.720 | 1.12 ± 0.050 | ND  |
| SF       | 13.65 ± 0.212 | ND  | 6.56 ± 0.502 | 1.11 ± 0.054 | ND  |
| NF       | 13.95 ± 0.284 | ND  | 6.40 ± 0.641 | 1.11 ± 0.052 | ND  |
| WF       | 10.25 ± 0.200 | ND  | 5.52 ± 0.451 | 0.50 ± 0.014 | ND  |

1 Km away from the cement factory

| LOCATION | Cu  | Co  | Cr    | Cd      | Ni  |
|----------|-----|-----|-------|---------|-----|
| E1km     | 5.25 ± 0.123 | ND  | 3.23 ± 0.124 | 0.19 ± 0.012 | ND  |
| S1km     | 4.15 ± 0.107 | ND  | 2.64 ± 0.052 | 0.18 ± 0.011 | ND  |
| N1km     | 4.85 ± 0.111 | ND  | 2.76 ± 0.054 | 0.17 ± 0.009 | ND  |
| W1km     | 3.98 ± 0.092 | ND  | 2.10 ± 0.061 | 0.10 ± 0.001 | ND  |

3 Km away from the cement factory

| LOCATION | Cu  | Co  | Cr    | Cd      | Ni  |
|----------|-----|-----|-------|---------|-----|
| E3km     | 1.42 ± 0.054 | ND  | 0.48 ± 0.002 | 0.05 ± 0.001 | ND  |
| S3km     | 1.12 ± 0.041 | ND  | 0.41 ± 0.005 | 0.05 ± 0.000 | ND  |
| N3km     | 1.21 ± 0.048 | ND  | 0.47 ± 0.005 | 0.05 ± 0.000 | ND  |
| W3km     | 1.01 ± 0.021 | ND  | 0.31 ± 0.005 | ND  | ND  |

6 Km away from the cement factory

| LOCATION | Cu  | Co  | Cr    | Cd      | Ni  |
|----------|-----|-----|-------|---------|-----|
| E6km     | 0.14 ± 0.005 | ND  | 0.10 ± 0.005 | ND  | ND  |
| S6km     | 0.13 ± 0.005 | ND  | 0.10 ± 0.005 | ND  | ND  |
| N6km     | 0.11 ± 0.005 | ND  | 0.10 ± 0.005 | ND  | ND  |
| W6km     | 0.09 ± 0.002 | ND  | 0.10 ± 0.005 | ND  | ND  |
| Control  | ND  | ND  | ND    | ND      | ND  |

**Metal distribution within the Factory**

Metal distribution within the factory is shown in Figure 4. The Cu concentration range from 10.25 mg/Kg (WF) to 15.87 mg/Kg (EF). It was observed that all the concentrations of Cu in all the four geographical cardinal points were below the standard recommended by the WHO (36 mg/Kg) in soil [19]. The analytical result shows that the east point (EF) had the highest

![Figure 3. Metal distribution based on location.](image.png)
concentration and the lowest was found in the west point (WF) which is much expected because the direction of the wind in the location moves from the west to the east. This observation was noted in the concentration of all the metal that was studied. The east point had the lowest concentration at each point.

**EF: East Factory**
**SF: South Factory**
**NF: North factory**
**WF: West Factory**

The Chromium concentration in the factory range from 5.52 mg/Kg to 7.23 mg/Kg. The concentrations were below both the DPR intervention level (100 mg/Kg) and WHO (100 mg/Kg) level [20] which implies that the soil is still safe but there is a need to watch against metal build-up. A similar trend was also observed which ascertains that the direction of the wind causes the cement dust to concentrate more in the west direction than the east. The cadmium concentrations in the factory range from 0.50 mg/Kg to 1.12 mg/Kg. The concentration of cadmium in EF, SF, and NF are 1.11, 1.11 and 1.12 mg/Kg respectively which are higher than the target value of the DPR standard of cadmium in soil (0.8 mg/Kg) although lower than the intervention level and WHO standard [21].

**Metals distribution at 3 km from the cement factory**

The metals distribution at 3 km from the factory is shown in Figure 6. The concentrations of the studied metals are very low because of the distance from the source (Cement factory). The abundance of copper and chromium metal in this site is in the order of E3km > N3Km > S3Km > W3km while the Cd have the same concentrations at the four cardinal points at this distance. The overall concentration of the study has been low which shows that the distance of the site to the cement factory (3 Km) has a great influence on the contribution of the cement dust on the topsoil. Although even at this site, there was a similar trend of highest concentration at the east point shown in the Cu and Cr metal distribution but not in cadmium. E3km: 3 kilometers east from factory
S3km: 3 kilometers south from factory
N3km: 3 kilometers North from factory
W3km: 3 kilometers west from factory

**Metal distribution at 1 km from the factory**

Figure 5 shows the metal distribution of the studied metals at 1 km away from the factory at the four cardinal points. The result shows that all the metals concentrations were lower than the concentration of the metal in the factory.

E1km: 1 kilometer east from factory
S1km: 1 kilometer south from factory
N1km: 1 kilometer North from factory
W1km: 1 kilometer west from factory

**Metals distribution at 6 km from the cement factory**

Interestingly, only Cu and Cr metal among the metal studied were detected at low concentrations as shown in Figure 7. The order of distribution was found to be
E6Km > S6Km > N6Km > W6Km for copper metal but equal concentration was detected at the four cardinals points for Cr metals. The result shows that the cement factory fumes do not influence this distance of 6 km. The Cu and Cr concentration must have been from anthropogenic

E6km: 6 kilometers east from factory
S6km: 6 kilometers south from factory
N6km: 6 kilometers North from factory
W6km: 6 kilometers west from factory

Contamination factor of heavy metals

The contamination factor of heavy metals is presented in Table 3. The result reveals that all areas assessed in this study were very high in contamination except for cadmium in 3 km. Cadmium at 6 km away from the factory shows no contamination at all. The concentration level in all the locations reveals that the cement factory is a major contribution of the heavy metals to the soil.
Figure 7. Metals distribution at 6 km from the cement factory.

CF < 1 – Low contamination factor 1 < CF < 3 – Moderate contamination factor 3 < CF < 6 – Considerable contamination factor CF>6 – Very high contamination factor

**Geoaccumulation factor of heavy metals**

The Geoaccumulation factor of heavy metals in the study area is presented in Table 4. The result shows a range from moderately polluted to extremely polluted. The eastern parts were found to be extremely polluted with Cu and Cr for factory, 1 KM and 3 KM distance. All location for the factory were found to have extreme metal pollution. For 1 KM distance, only Cu and Cr had an extreme pollution while Cd range strongly polluted. 3 KM away from the factory, Cu meat was still at extreme pollution at the 4 axis location while the soil was moderately polluted with Cd.

| Location | Cu  | Cr  | Cd  |
|----------|-----|-----|-----|
| EF       | 1587| 723 | 112 |
| ES       | 1365| 658 | 111 |
| EN       | 1395| 640 | 111 |
| EW       | 1025| 552 | 50  |
| E1km     | 525 | 323 | 19  |
| S1km     | 415 | 264 | 18  |
| N1km     | 485 | 274 | 17  |
| W1km     | 398 | 210 | 10  |
| E3km     | 142 | 48  | 5   |
| S3km     | 112 | 41  | 5   |
| N3km     | 121 | 47  | 5   |
| W3km     | 101 | 31  | 0   |
| E5km     | 14  | 10  | 0   |
| S5km     | 13  | 10  | 0   |
| N6km     | 11  | 10  | 0   |
| W6km     | 9   | 10  | 0   |

Table 4. Geoaccumulation Factor of Heavy Metals.

The farthest distance which was 6 KM away from the factory only had moderate to strong metal pollution. From the result above, the extreme polluted areas are major source of concern that needs urgent attention as this is an indicator that the health of the people that stays around is under threat of metal intake. Reduction in pollution rate was discovered as the distance from factory increased which may be a signal that the factory could have been the major source of the heavy metal contamination.

**Conclusion**

The soil physicochemical properties revealed that, while no effect on soil temperature was recorded, cement dust made the soil alkaline in nature, with pH and EC decreasing as distance from the factory increased. The results of the investigation revealed that cement mill is a big contributor to certain of the metals analyzed. The study found that as the distance from the cement mill increased,
the concentration of metals decreased significantly. It was determined that at 6 km distant from the cement factory, the cement plant dust has no effect on the soil again, implying that houses and occupations at 6 km and above are unlikely to be affected by the factory’s cement dust. Copper was the most abundant metal among the metals studied at all distance sites. The east cardinal point has a higher concentration of metals, which could be due to the direction of the wind, which blows from west to east in the area. The concentration is heavily influenced by the distance from the production.

The metal concentrations at each location were below the WHO standard for each metal in the soil. The metal build-up, on the other hand, is a cause for concern, because inhaling cement dust on a regular basis can lead to health problems and even death. This also implies that nearby edible plants could become contaminated over time, particularly for Cd, which has no known biological function.

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