COMPARATIVE EVALUATION OF HEAVY METALS IN SOIL AND PLANT AROUND CEMENT INDUSTRIES IN OGUN STATE, NIGERIA

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Abstract
Industrial processes have been implicated among many other anthropogenic sources of hazardous metal in the environment. This study deals with the assessment of heavy metals in soil and plant around three cement factories in Ogun state, Nigeria i.e. Dangote cement factory, Ibese; Lafarge cement factory, Ewekoro and Purechem cement factory, Onigbedu. 27 top soil samples of 0-10cm depth and 27 Vernonia amygdalina plants were collected from different locations around the present study areas and analyzed for Cadmium (Cd), Copper (Cu), Nickel (Ni), Lead (Pb) and Zinc (Zn) using Atomic Absorption Spectrophotometer (AAS). Results revealed that the soils and plants were enriched in these heavy metals and are beyond permissible level except Cu and Zn. The metal distribution was in a fluctuating manner considering the distinctive distances and directions of the cement plant. On the other hand, it was observed that the mean metal concentrations of the soils and plants decreased as distance from the cement plant increased for most metals except Ni and Pb in Dangote cement factory. This indicated that the cement plants which are the main industries in these areas are the main cause of heavy metal contamination.

***Keywords**: Heavy metals, environment, cement plant and contamination*

Introduction

Rapid industrialization and addition of the toxic substances to the environment are responsible for altering the ecosystem in which much of the problems of societal concern today are the heavy metals associated with air pollution (Shannigrahi et al, 2004). Environmental contamination due to dust particle coming from Cement Industries, Coal Mining, Quarrying, Stone Crushing, Thermal Power Plant etc., has drawn much attention to the environmental scientists of today as they create serious pollution problems and pose threat to the ecosystem (Raajasubramanian et al, 2011). One industry that causes significant particle pollution is the production of cement and the cement factories constitute one of the worst polluters in Nigeria. The main airborne pollutants of cement production to the environment are the emission of dust and gases. Cement dust can spread over large areas through wind and rain and are accumulated in and on soils, plants and also have the potential to affect animal and human health adversely. Dust from cement factories adversely affects the forest ecosystem, soil enzymes, fungi and bacteria population within the vicinity of cement factory (Addo et al, 2013). Heavy metal mobilization in the biosphere by human activities has become an important process in the geochemical cycling of these metals. This is evident in industrial areas where stationery and mobile sources release large quantities of heavy metals into the atmosphere, soil and plants exceeding the natural emission levels (Dwivedi & Tripathi, 2007). Pollution of the natural environment by heavy metal is a worldwide problem because these metals are indestructible and most of them have toxic effects on living organisms, when they exceed a certain concentration.

Most heavy metals can be found generally at trace levels in soils and vegetation and in living organisms that need some of them as micro-elements. Metal distribution between soil and vegetation, is a key issue in assessing environmental effect of metals in the environment (Tubonimi and Herbert, 2008). Heavy metal toxicity has an inhibitory effect on plants growth, enzymatic activity, stoma functions, photosynthesis activity and accumulation of other nutrient elements, and also damage the root system (Addo et al, 2013). On the other hand, soil is not only a medium for plant growth or pool to dispose of undesirable materials, but also a transmitter of many pollutants to surface water, groundwater, atmosphere and food. Therefore, soil pollution may threaten human health through its effects on the hygiene quality of food and drinking water, and through its effect on air quality especially in enriched trace metal content in airborne particles originating from soil.

Cement contains 3-8% Aluminum Oxide (Al_2O_3), 0.5-0.6% Iron Oxide (Fe_2O_3), 60-70% Calcium Oxide (CaO), 17-25% Silicon Oxide (Si_2O_3), 0.1-4.0% Magnesium Oxide (MgO) and 1-3% Sulphur Oxide (SO_3) and often include other heavy metals like Arsenic (As), Cadmium (Cd), Lead (Pb), Zinc (Zn), Manganese (Mn), Cobalt (Co), Mercury (Hg), and Chromium (Cr). These elements in cement dust are potentially harmful to the environment (Gbadebe and Bankole, 2007). The direct effects of cement dust pollution are alkalization of the ecosystem and the changing of the chemical composition of the soil (Mandre, 2005). The pollutant particles can enter the soil as dry, humid or occult deposits and can undermine the physico-chemical properties. Hence, contaminated soil can adversely affect plant survival and growth.

The particulates and gaseous pollutants, alone and in combination, can cause serious setbacks to the overall physiology of plants. Of all plant parts, the leaf is the most sensitive part to the air pollutants and several other such external factors. Plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollutant level in the environment (Chauhan and Joshi, 2010). Thus, plants can be effectively used as bio indicators of air pollutants, although their sensitivities could vary across the plant community with tolerant species showing no or minimal symptoms while sensitive ones showing symptoms even if the air pollutants increase in small amounts (Singh, 2003). The resulting impact can be used for monitoring of suspended particulate matter in cement industry in terms of SPM concentrations to observe the air quality in the locality. Limestone and cement dusts, with pH values of 9 or higher, may cause direct injury to leaf tissues or indirect injury through alteration of soil pH. Damages caused by air pollutants to plants include chlorosis, necrosis, and epinasty (Katiyar and Dubey., 2000). Suspended Particulate Matter (SPM) affects the overall growth and development of plants according to their physical and chemical nature. Specifically morphology and anatomy of leaves are altered (Shrivastava and Joshi, 2002). Surface dust deposits may alter the optical properties of leaves, particularly the surface reflectance in the visible and short wave infrared radiation range (Prajapati and Tripathi, 2008). Pollutants enter into the plants and react in a variety of ways before being removed or absorbed that may include accumulation, chemical transformation and incorporation into the metabolic system. In the process some plants are injured, while others show minimal effects (Priyanka and Dibyendu, 2009).

This study was therefore aimed at assessing the heavy metal concentrations in soils and plant around Dangote cement factory, Ibese, Lafarge cement factory, Ewekoro and Purechem cement factory, Onigbedu, all in Ogun State in order to assess the level of pollution that may be done to each of the communities where these factories are located.

Materials and Methods

The Study Areas

The study areas are Dangote Cement Factory, Ibese, Lafarge Cement Factory, Ewekoro and PureChem Cement Factory, Onigbedu all in Ogun State, Southwest Nigeria. Dangote cement factory is located in Ibese in Egbado (Yewa) North which lies on latitude 6^o 58’ 0” N and longitude 3^o 2’ 0” E. It commenced production in 2011.

Ewekoro is one of the sites of West African Portland Cement Company (WAPCO) now Lafarge cement factory. It is on a latitude 5^o 50’ 0”N and longitude 3^o17’ 0”E, approximately 64 kilometers north of Lagos and 42 kilometers south of Abeokuta.

Purechem cement factory is the first private company to invest into a mini-cement plant in 2001. The factory is situated along Onigbedu-Ibese via Itori-Ewekoro road with a geographical coordinates are latitude 6^o 58’0” North and longitude 3^o 8’0”. Purechem cement commenced production in 2005.

The areas lie within the dry equatorial climate of the region. It has two rainy seasons with the major rains in April to June, and the minor rains between September and November. The factories surrounding areas are essentially rural with minor agricultural activities. Settlements are scattered houses at varying distances with the nearest settlement of about 300m. The surrounding vegetations are covered with several shrubs and grasses.

There are no other industrial developments within these areas so the cement factories are the major employer in the areas. Majority of the inhabitants in these areas are farmers because these areas are largely rural, the farmers engage in the planting of sugar cane, cassava, maize, vegetables and rearing of livestock like small ruminants, poultry and pigs. The cement factories play a significant role in the local building industry in the economy of Nigeria.

Sample Collection

This study was carried out between July and September 2016 to ensure that metals from the cement factories would have been absorbed into the soil and its impact laid out in the plants. The plant Vernonia amygdalina commonly called bitter leaf, Ewuro in the west and Onugbu in the eastern part of the country was used for this analysis because it can be found in the three cement plants. The sampling points were selected in such a manner to cover the entire vicinity of the cement factories. Three (3) sampling points around the cement plant up to a distance of 10km were identified for collection of soil and plant samples. 27 top soil samples of 0-10cm depth and 27 Vernonia amygdalina plants were collected (each at the distances of 3, 7 and 10km in triplicates from the factories) simultaneously with the soil at the same point where the plants occur. Soil specimens were taken with a small plastic shovel from the upper 10 cm of the soil and scrapped into labeled plastic containers. Large stones or foreign objects were removed. In the laboratory, the soil samples were sun-dried in plastic bowls for five continuous days and were screened through a 2mm mesh sieve to obtain a more homogeneous distribution.

The screening process further enabled the removal of small stones, roots and large organic residues. The plant specimens were obtained by cutting at a height of 5 cm from the surface of the soil. The samples were immediately packed in aluminum foil and labeled accordingly as the soil samples. Subsequently, they were dried in an oven at a temperature of 60°C for two days after which they were pulverized in a blender and kept in similar plastic containers as the soil samples until analysis.

Sample Preparation

Before being analyzed for heavy metals, the samples were digested using aqua regia (hydrochloric acid: nitric acid, in a 1:3 volume ratio). One gram of the sample was weighed into a beaker. 10 ml hydrochloric acid and 30 ml nitric acid were added and covered so as to allow for any reaction to subside. The mixture was then placed on a hot plate and heated at 100ºC for about 20 minutes. After digestion, the solution was allowed to cool and then filtered. The filtrate was then made up to the 50 ml volume and transferred to plastic bottles.

Sample Analysis

The digested samples were analyzed for Lead, Nickel, Copper, Cadmium and Zinc using Buck Scientific 210/211VGPAtomic Absorption Spectrophotometer. The statistical analysis of the heavy metals was carried out using SPSS.

Results and Discussion

Three (3) study sites, denoted D1, D2 and D3 (for Dangote Cement Factory), L1, L2 and L3 (for Lafarge cement factory) and P1, P2 and P3 (for Purechem cement factory) located at distances of 3, 7 and 10km respectively were used for the study. The sites were located at the north-eastern direction of the cement factory where the dust is thought to be concentrated. The results of the concentrations of heavy metals present in the soil of the three locations studied are appended in Tables 1.1 and 1.2 in terms of simple statistical parameters which are the mean and standard error. The mean values of the metal concentrations in the soil and plant samples (i.e. from the three communities) are found to be higher than the average permissible concentration given by United States Environmental Protection Agency (USEPA) and Federal Environmental Protection Agency (FEPA except for copper and zinc which is in line with previous studied by Okoro et al, 2016. All the five metals display their presence in all the soil and vegetable samples used for the study.

Lead is a non-essential heavy metal that enters into the body system through air, water and food and cannot be removed by washing fruits and vegetables. It is a serious cumulative body poison, which can affect every organ and system in the body (Khan et al, 2008). It contributes to the pathogenesis of lead poisoning by distrupting the delicate antioxidant balance of the mammalian cells. Exposure to its high levels can severely damage the brain, kidneys and ultimately cause death and long-term exposure result in decreased performance nervous system; weakness in fingers, wrists, or ankles; small increases in blood pressure; and anaemia. Others are abdominal pain, anaemia, arthritis, attention deficit, back problems, blindness, cancer, constipation, convulsions, depression, diabetes, migraine headaches, thyroid imbalances and tooth decay (Rehman et al, 2013). The lead concentration in the soil samples for this study is in the range of 0.02 – 0.19 mg/kg with the soil of Lafarge factory at 3km exhibiting the highest concentration and the soil of Dangote factory at 3km exhibiting the lowest. The concentration range for the plant samples are 0.46 – 0.72 mg/kg as shown in Table 1.2. The concentrations of the soil and plant samples are all beyond the permissible limit of USEPA but below the limit of FEPA as shown in Table 3.

Nickel is an essential element for plants and animals though in small quantity, it is necessary for the regulation of lipid contents in tissues and for the formation of red blood cells. It becomes toxic at high level and can lead to cancer (oral and intestinal), depression, heart attacks, hemorrhages, kidney dysfunction, low blood pressure, muscle tremors and paralysis, nausea, skin problems and vomiting (Shah et al, 2013). The experimental data revealed the concentration of nickel that occurred in a range of 2.35 – 2.93 mg/kg for the soil samples and 2.60 – 3.17 mg/kg for the vegetable sample which are way beyond the limit specified by USEPA and FEPA as illustrated in Tables 1.1, 1.2 and 1.3. The high concentrations of nickel in the samples could indicate that the plant absorb the metal from the respective soils.

Copper is an essential substance to human life that is needed for normal growth and development. Its critical doses can cause anaemia, acne, adrenal hyperactivity and insufficiency, allergies, hair loss, arthritis, autism, cancer, depression, elevated cholesterol, depression, diabetes, dyslexia, failure to thrive, fatigue, fears, fractures of the bones, headaches, heart attacks, hyperactivity, hypertension, infections, inflammation, kidney and liver dysfunction, panic attacks, strokes, tooth decay and vitamin C and other vitamin deficiencies (Khan et al, 2008). The metal was found in all the samples and very minimal compared to the standards shown in Table 3.

Cadmium is a non-essential metal which is very toxic even at low concentration. Its long-term exposure to lower levels leads to a buildup in the kidneys and possible kidney disease, lung damage, and fragile bones. Hypertension, arthritis, diabetes, anaemia, cancer, cardiovascular disease, cirrhosis, reduced fertility; hypoglycaemia, headaches, osteoporosis, kidney disease, and strokes are its some odd long term results (Liu et al, 1997). Among the soil samples, the cadmium concentration ranges from 0.01 – 0.23 mg/kg and 0.01 – 0.13 mg/kg in the plant samples. The Purechem second location (7km) has the highest concentrations for cadmium in both soil and plant sample, this could be characterized to any other source. Though this concentration is below the permissible limit for FEPA, it is above that of USEPA.

Zinc is the basic component of a large number of different enzymes and plays structural, regulatory and catalytic functions. It also plays a very important role in DNA synthesis, normal growth, brain development, bone formation and wound healing. It is an airborne pollutant, so in general it majorly accumulate to open and above-earth crops; however root crop plants also assimilate great proportion from Zn contaminated soils. At high level, zinc is neurotoxin (Ghrefat and Yusuf, 2006). The soil concentrations range from 0.57 – 1.97 mg/kg and 0.11 – 0.54 mg/kg for the plant samples. The least soil concentration is found in Purechem third location (10km) while the highest concentration was found in the soil of Lafarge first location (3km). The determined concentrations are all below permissible limit of USEPA and FEPA.

The distributions of the heavy metals across the three communities are in such a way that the metals are concentrated more at the first location (3km) than at the two other locations (7km and 10km) except for Lead and Nickel in Dangote factory where the third location (10km) is more concentrated than others, this could be attributed to other factors such as processing of copper-containing materials or combustion.

The analyses showed that soil samples collected from Lafarge and Purechem factories are mostly polluted with these metals though Dangote factory recorded the highest in Cadmium as shown in Figure 1.1. The Nickel concentration was recorded highest for all the factories and Cadmium was the least. For the three factories, the metal concentrations can be seen in the increasing order of Cd<Pb<Cu<Zn<Ni.

Table 1.1: Heavy metal concentrations in the soil around the three (3) cement factories

Location	Heavy Metals				
	Lead (Pb) (mg/kg)	Nickel (Ni) (mg/kg)	Copper (Cu) (mg/kg)	Cadmiu(Cd) (mg/kg)	Zinc (Zn) (mg/kg)
	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE
D1	0.02167±0.007638	2.35000±0.010000	0.63000±0.010000	0.23333±0.005774	0.97333±0.011547
D2	0.03167±0.002887	2.57333±0.020817	0.60667±0.005774	0.13333±0.005774	0.90333±0.015275
D3	0.05667±0.015275	2.72667±0.028868	0.58133±0.002309	0.10667±0.005774	0.84533±0.005033
L1	0.19333±0.005774	2.93167±0.007638	0.74167±0.002887	0.13167±0.002887	1.97333±0.030551
L2	0.14000±0.000000	2.84333±0.045092	0.74000±0.000000	0.10667±0.005774	1.67000±0.017321
L3	0.33167±0.012583	2.72000±0.000000	0.67667±0.015275	0.06000±0.000000	1.04000±0.036056
P1	0.32333±0.005774	2.84333±0.015275	0.81667±0.020817	0.02833±0.002887	0.82333±0.025166
P2	0.56667±0.005774	2.76667±0.011547	0.76333±0.015275	0.01067±0.001155	0.66333±0.020817
P3	0.37333±0.005774	2.54333±0.015275	0.64000±0.100000	0.01367±0.003215	0.57333±0.005774

Table 1.2: Heavy metal concentrations in the plant around the three (3) cement factories

Location	Heavy Metals				
	Lead (Pb) (mg/kg)	Nickel (Ni) (mg/kg)	Copper (Cu) (mg/kg)	Cadmiu(Cd) (mg/kg)	Zinc (Zn) (mg/kg)
	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE
D1	0.56333±0.005774	2.91333±0.011547	0.48333±0.011547	0.10833±0.007638	0.15000±0.000000
D2	0.54333±0.015275	2.77667±0.015275	0.47667±0.005774	0.06333±0.075056	0.24167±0.002887
D3	0.47667±0.005774	2.77667±0.005774	0.40833±0.007638	0.05833±0.007638	0.11000±0.010000
L1	0.71667±0.005774	2.65000±0.010000	0.60000±0.020000	0.13000±0.010000	0.54333±0.015275
L2	0.71000±0.010000	2.65000±0.000000	0.47667±0.015275	0.13000±0.010000	0.35000±0.010000
L3	0.59333±0.005774	2.60667±0.005774	0.25667±0.005774	0.11000±0.000000	0.24000±0.010000
P1	0.54667±0.005774	3.17000±0.010000	0.61167±0.002887	0.02667±0.005774	0.36000±0.010000
P2	0.53500±0.005000	3.06000±0.010000	0.58000±0.000000	0.01033±0.000577	0.24667±0.005774
P3	0.45667±0.020817	2.92000±0.000000	0.46333±0.005774	0.01733±0.008737	0.17833±0.007638

Table 1.3: Standard Concentrations for metals

Metals	**USEPA (mg/kg)**	**FEPA (mg/kg)**
Lead	0.015	1.0
Nickel	0.05	0.02 – 0.10
Copper	1.00	2.0 – 4.0
Cadmium	0.005	0.2 – 1.80
Zinc	2.0	50

Source: Aremu et al (2010)

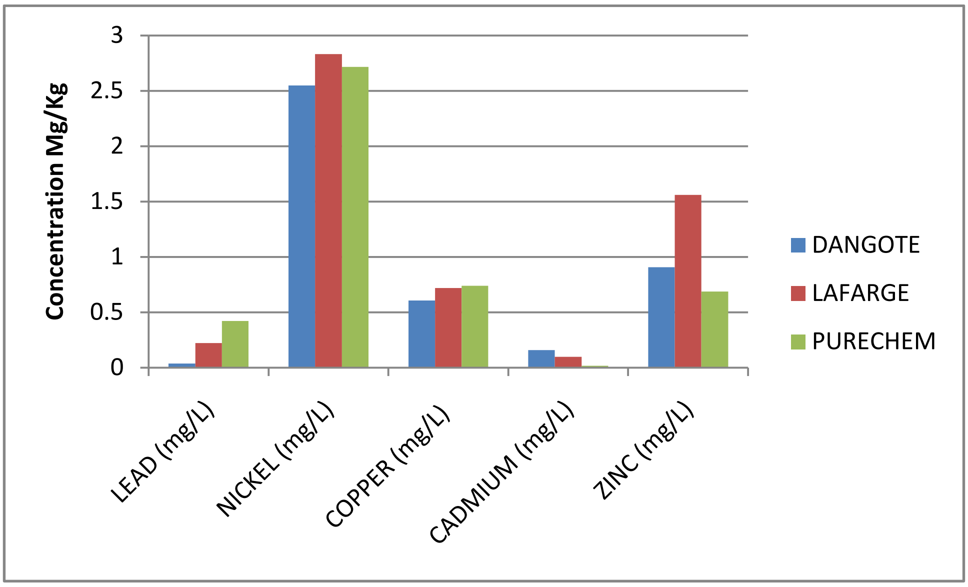

Figure 1.1: Mean concentrations of the metals in the soil

For the plant samples, Lafarge and Purechem factories was found to be more polluted with these metals although Purechem factory recorded the lowest in Cadmium as illustrated in Figure 1.2. The metal concentrations for the plants can be in the increasing order of Cd<Zn<Cu<Pb<Ni.

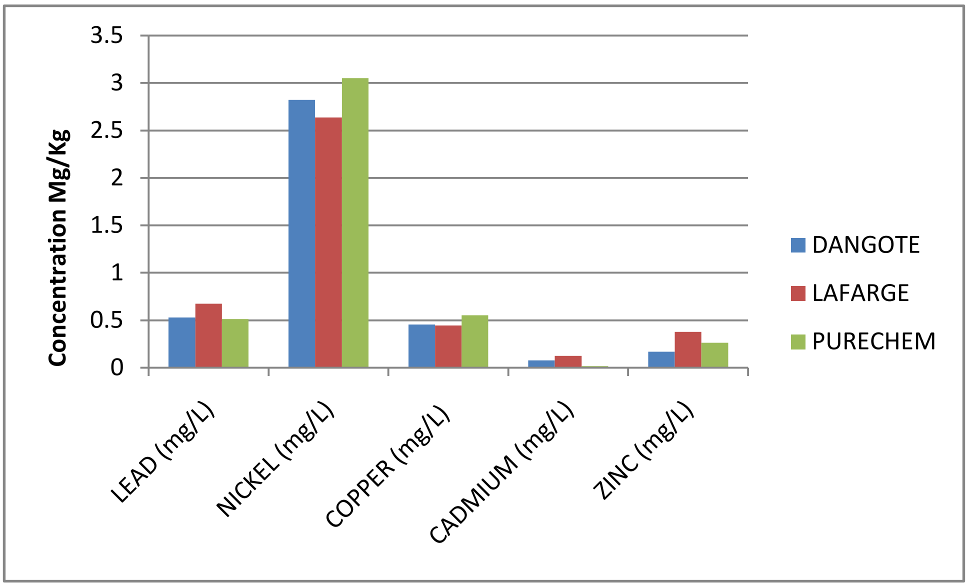

Figure 1.2: Mean concentrations of the metals in the plant.

Conclusion and Recommendations

It has been established from the results obtained that soils and plants in Lafarge and Purechem factories are more contaminated to a large extent by the heavy metals and the mean values of the metal concentration in the soil and plant samples around the cement factories were found to be higher than those farther from the factories. Thus, it could be concluded that the soils and plants of the study areas were affected by dust emissions from the cement factories though there have been substantial efforts on the part of the management of these factories to reduce their noxious impact. More work still needs to be done especially in the area of environmental monitoring so as to reduce the heavy metal contamination to the barest minimum.

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