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ASSESSING HEAVY METAL CONTAMINATION IN SOILS AROUND ASHAKA CEMENT FACTORY, GOMBE STATE, NORTHEASTERN NIGERIA USING ECOLOGICAL POLLUTION INDICES

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ABSTRACTS

The mining sector is an important segment of Nigerian's socio-economic development especially now that the price of crude oil has fallen drastically at the international market. The impact of limestone mining and processing on soil quality in Ashaka and environs was investigated using ecological pollution indices. Soil samples were collected from Ashaka, Badebdi, Gongila, Juggol, Feshingo and Jajami communities at depths of 0.0 m, 0.5 m and 1.0 m respectively and analyzed for their heavy metal content (Cd, Fe, Cu, As, Ni, Pb, Cr and Zn). The results of the analyses were interpreted using geo-accumulation index (Igeo), contamination factor (CF), degree of contamination (Cd), enrichment factor (EF) and correlation analysis (CA). The result of the computed Igeo indicates that the soil in the area is unpolluted while CF values show low to moderate contamination. The calculated EF values show no enrichment to minimal enrichment while Cd values reveal low degree of contamination for the soils in the area. The correlation coefficient further reveals a very low correlation among the metals which implies a low pollution status. The mean concentrations of the metals were found to be far below their respective average crustal abundance, which is an indication that the soil in the study area has not witnessed any serious contamination. However, the concentration of cadmium in some locations was slightly higher than the average crustal abundance. It may be attributed to the anthropogenic activity domiciled in the area. A periodic monitoring of soil quality level in the area is advocated.

Keywords: Soil assessment, heavy metal contamination, Ecological Pollution Indices Ashaka Cement Factory, Northeastern Nigeria,

INTRODUCTION

Limestone is a sedimentary rock which is chiefly composed of calcium carbonate. It is formed by the compaction of corals, plants or animal remains through the action of rivers, sea, wind, and glaciers (Benkhil, 1989). It can also be formed by direct crystallization of carbonates with some impurities such as clay, sandstone and shale. Limestone is an important non-metallic raw material used in the manufacture of cement for construction purposes. Limestone is also primary raw materials for other manufacturing industries such as sugar, fertilizer, ceramics, fillers and extenders (Okunlola *et al.*, 2016). In Nigeria limestone occurrences are widespread and serve as raw material for Sokoto, Ashaka and Nkalagu cement factories.

Mineral exploitation has supported the social and economic development of both developed and developing countries. The exploitation of these mineral has led to pollution of almost all the environment media: soil, air and water with the host communities being the most affected. Although mining provides a wide variety of socio-economic benefits, its environmental and social effects if not properly handle can be massive in terms of land degradation, habitat alteration, water and air pollution. In Africa, the mining sector is the second largest source of pollution after agriculture. Several authors such as Amadi *et al.* (2015) and Okunlola *et al.* (2016) have commented on potentially-adverse impacts of mining, which include displacement of local people from ancestral lands, marginalization and oppression of people belonging to lower economic class, land degradation, soil pollution, groundwater and surface water contamination, air pollution, and destruction of biological resources. In northern Nigeria, large scale exploitation of industrial minerals such as limestone and quarrying used in construction contributes immensely to soil, air, surface and groundwater polluttion.

According to Adekoya (2003), mining is an integral part of development of civilization, and early mining operations have left a historical legacy of negative environmental impact. Potentially environmental effects are greatly influenced by geological factors: deposit size, host rock lithology and wall rock alteration, nature of ore and trace element geochemistry, ore and gangue mineralogy and zonation, secondary mineralogy, topography, physiography and climate, mining and milling method employed (Amadi *et al.*, 2014). According to Weber-Fahr (2002), surface mining though less dangerous than underground mining, has a greater impact on surface landscape. Vast agricultural lands are destroyed through opencast mining or surface mining affecting food production in the country, and the source of income for the people affected Opencast mining requires the removal of massive amount of top soil in order to gain access to the mineral, which can cause erosion, loss of habitat, and dust pollution. It can also cause heavy metal to dissolve and seep in to both surface and groundwater thereby erupting marine habitats and deteriorate drinking water sources.

The mining in Ashaka involved the extraction of limestone using open cast system of mining and the impact of such large scale mining as currently practiced in Ashaka quarry is worrisome. The need to undertake an assessment of such mining activities on the surrounding soils cannot be overemphasized, hence the need for the present study. Soil quality determines the sustainability and productivity of agro-ecosystems. The excessive use of mineral fertilizers in intensive agriculture has reduced the soil organic matter in most soils leading to increase in erosion and fertility loses (Nachtergaele *et al,* 2002; Amadi *et al*., 2014). Exploration and exploitation of limestone in the area has led to the enrichment of soil in the area with varying degree of heavy metal and this study was undertaken to know the extent the soils in Ashaka area have been contaminated with heavy metals due to mining and farming activities in the area. Their enrichment is a function of soil pH, grain size, organic matter, cation exchange capacity (CEC) and hydraulic conductivity (Amadi and Nwankwoala, 2013; Aigbbedion and Iyayi, 2007). A total of eight of metals (Pb, Fe, Zn, Cu, Cr, Cd, Ni and As) were investigated for this study.

Description of the study area

The study area is located at about 140 km, north of Gombe town, Funakaye Local Government area of Gombe State. The surrounding settlements include Ashaka, Gari, Feshingo, Badebdi, Juggol, Borkono, Jalingo, Jajami, and Gongila Villages. The study area lies within latitudes 10°50' N and 11°00' N and longitudes 11°25' E and 11°32' E (Fig. 1). The area is accessible through Gombe-Bajoga-Ashaka Cement Factory road as well as several untarred roads and Gombe-Maiduguri rail line.

Geology and Stratigraphy of Ashaka Area

The Ashaka area is part of the Gongola Basin of the Upper Benue Trough of Nigeria underlain by two formations: Bima Sandstone and Gongila Formation both deposited in contrasting geologic environments and the Recent Alluvium of the Gongola River (Fig. 1; Table 1). The Yolde Formation separates the two formations, though not distinguishable and presumed to lie between Bima Sandstones and Gongila Formation (Zaborski *et al*., 1997; Adegoke *et al*., 1978). According to Carter *et al*. (1963) the Bima sandstone is the oldest known cretaceous rock in the area. The Bima Formation varies in age from upper Aptian to Middle Albian and rests unconformably on the uneven surface of the basement complex (Fig. 1, Table 1).

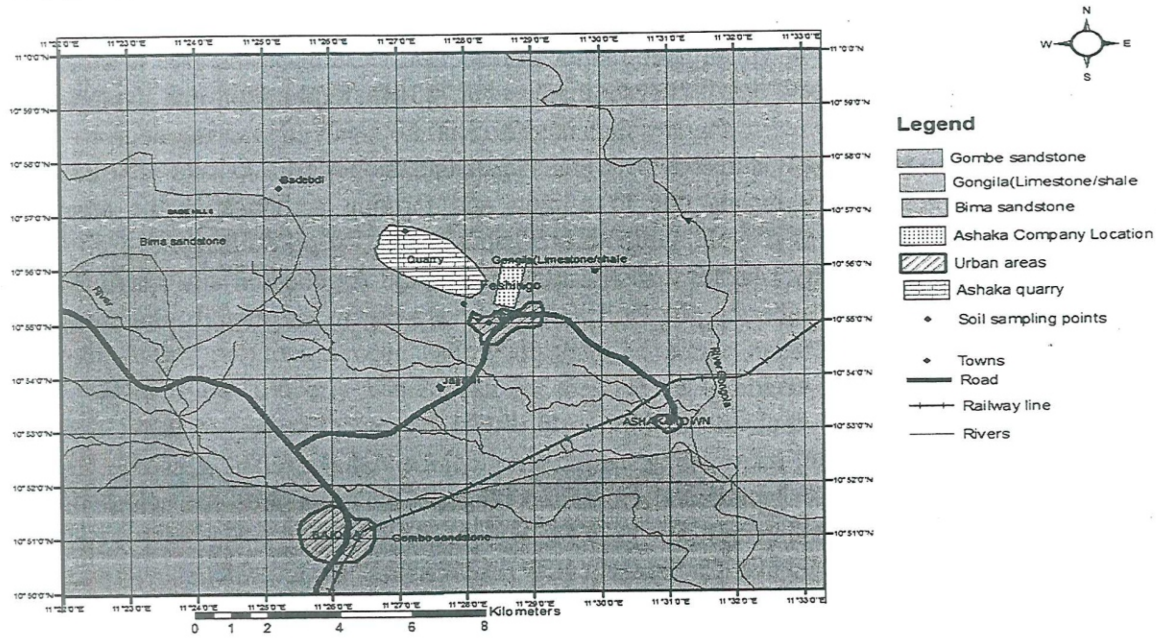


Fig. 1: Geology and Sample Location Map of Ashaka and Environs

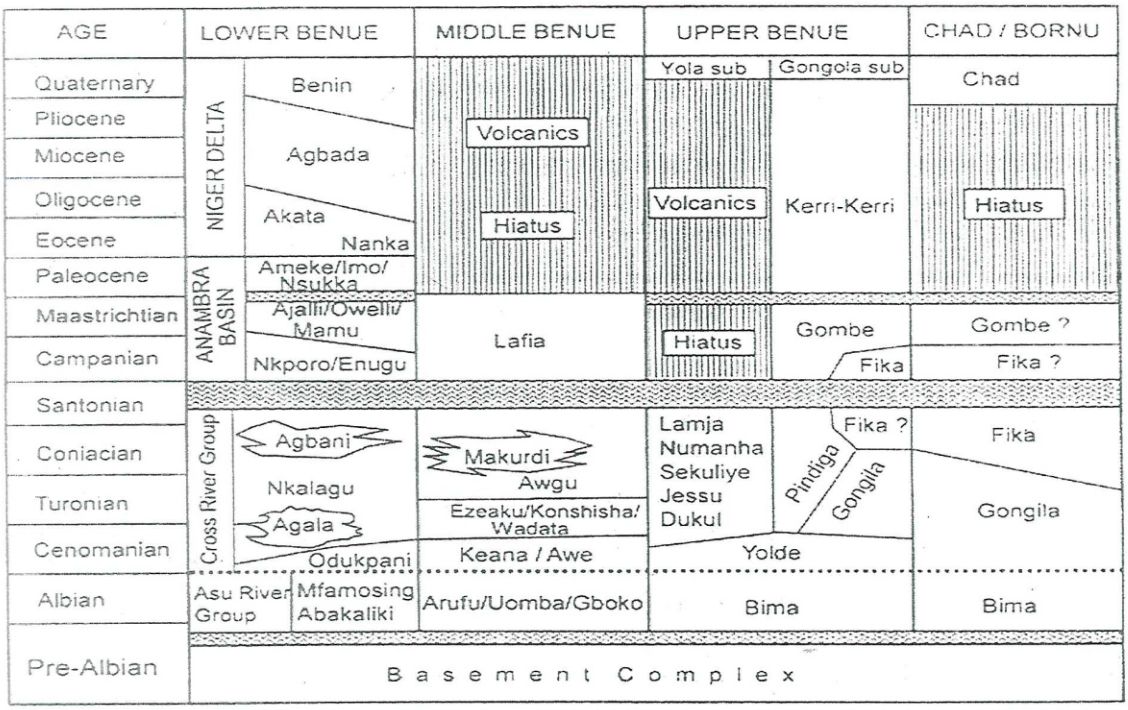
The sandstones are medium to coarse grained, feldspatic and commonly coarsely cross-bedded. Top sections of the sandstones are highly ferruginized, sandstone beds are massive and in some places the thickness of about 250m has been exposed. The Bima Sandstone has total thickness of about 2,961m (Carter *et al.,* 1963). The Yolde Formation is a variable sequence of sandstone and shale which mark the transition from the continental Bima Sandstone to the marine Gongila Formation (Table 1). The Yolde Formation is not clearly exposed in the study area. The formation is defined by the first disappearance of sandstone and commencement of the limestone-shale deposition. Yolde Formation is characterized by rapid alternation of sandy siltstones with siltyshales and fine sandstones (Bassey *et al*., 2006). The Gongila Formation outcrops in the Ashaka cement factory quarry (Fig. 1). The outcrop displays 12 m of limestone and overlain by 25 m of clay Carter *et al.* (1963). The age of Gongila formation is from lower Turonian to Upper Santonian. Barber *et al.* (1957) described the sequence as calcareous beds and clayey shales with a number of thin inter-bedded limestone (Table 1). Fossils found in this formation are Ammonites, Gastropods, Branchiopods and other micro-fossils.

MATERIALS AND METHODS

Soil Sampling

Soil samples were collected from the following communities: Ashaka Gari, Badebdi, Juggol, Feshingo, Jalingo, Gongila and Jajami and their coordinates taken with the aid of GPS. The samples were conditioned and prepared in laboratory for the determination of the following heavy metals: Pb, Cd, Zn, Cu, Cr, Ni, Fe and As using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) Model-Optima 200. Soil samples were collected using hand auger at 0.0 m, 0.5 m and 1.0 m respectively. The sampled soil were labeled and put in black polythene bag and taken to the laboratory for analysis.

Table 1: Stratigraphic Succession of the Benue Trough (After Obaje, 2013)



Sample preparation

The soil samples were air-dried, mechanically ground using a stainless steel roller and sieved to obtain < 2 mm fraction. About 40-50 g of sub-sample was taken from the bulk soil and re-ground to obtain < 200 µm fraction using a mortar and pestle. The soil samples were digested in a mixture HNO_3 and HCl acids according to USEPA method 3050 for the analysis of heavy metals (USEPA, 1996). The extracts were analyzed using Inductively Coupled Plasma-Optical Emission spectrometer (ICP-OES) Model-Optima 200.

RESULTS AND DISCUSSION

The results of the laboratory analysis of the soil samples from different communities and at various depths are shown in Table 2. Limestone (calcium carbonate) is the major rock type in the area and it was the major factor that influenced the sitting of the factory in the area. The concentration of arsenic ranged from 0.003-0.1.165 mg/kg with an average value of 0.328 mg/kg (Table 2). Arsenic has a crustal abundance of 5.00 mg/kg (Prasad and Kumari, 2008). Studies have shown that soils overlying sulphide deposits and those in which pesticides have been applied can have arsenic concentration as high as 10,000 mg/kg and 500 mg/kg respectively.

Table 2: Results of Heavy Metal Analysis on Soils from Ashaka and Environs

Location/Depth	Pb	Cd	Zn	Cu	Cr	Ni	Fe	As
Badebdi/Depth								
0.00 m	0.106	0.063	2.46	3.642	1.631	0.005	1.542	ND
0.50 m	0.082	0.055	2.45	3.500	0.833	0.005	1.550	ND
1.00 m	0.077	0.059	2.46	3.500	0.800	0.005	1.344	ND
Gongila/Depth								
0.00 m	0.160	0.116	2.47	2.590	0.900	ND	2.631	0.003
0.50 m	0.200	0.182	2.83	2.500	0.653	ND	1.017	0.003
1.00 m	0.290	0.205	3.11	2.411	0.526	ND	1.005	0.003
Juggol/Depth								
0.00 m	0.261	0.061	3.45	1.591	0.084	0.062	3.518	0.517
0.50 m	0.220	0.064	5.66	2.334	0.173	0.060	3.502	0.652
1.00 m	0.265	0.052	5.87	2.832	0.325	0.065	3.511	0.722
Ashaka/Depth								
0.00 m	0.072	0.161	2.60	0.50	0.526	0.080	2.557	0.051
0.50 m	0.193	0.188	2.00	0.58	0.677	0.009	4.215	0.084
1.00 m	0.252	0.216	1.30	0.60	0.900	0.004	4.616	0.165
Feshingo/Depth								
0.00 m	0.360	0.222	0.844	0.84	0.075	ND	1.437	ND
0.50 m	0.307	0.315	1.320	1.05	0.208	ND	1.548	ND
1.00 m	0.215	0.327	1.477	1.63	0.571	ND	1.660	ND
Jajami/Depth								
0.00 m	0.115	0.115	0.611	0.09	1.532	ND	4.188	1.045
0.50 m	0.132	0.132	0.900	0.65	1.000	ND	4.921	1.165
1.00 m	0.153	0.153	1.055	1.20	0.942	ND	5.550	1.502
Mean Value	0.192	0.150	2.380	1.781	0.686	0.016	2.795	0.328

ND - Not Detected

Anthropogenic source of arsenic in the environment include fertilizers, limestone mining, sewage sludge from metal processing industries and to a lesser extent at present, herbicides. Cadmium concentration ranged between 0.052-0.327 mg/kg with a mean value of 0.150 mg/kg (Table 2). The result of the analyses revealed that the soil in the area is slightly contaminated with cadmium. The widely used phosphatic fertilizers are regarded as the most ubiquitous source of cadmium contamination of agricultural soils (Lambarkis *et al*., 2004; Amadi *et al.,* 2012). It is also used with inorganic fertilizers produced from phosphate ores and is found in agro-chemicals such as pesticides and herbicides. Cadmium is extremely toxic and the primary use of soil high in Cd in form of manure for the cultivation of vegetables and other food crops could cause adverse health effect to consumers such as renal disease and cancer (Gorenc *et al.,* 2004).

Chromium concentration ranged from 0.075-1.631 mg/kg and an average value of 0.686 mg/kg while the concentration in copper varied from 0.090-3.642 mg/kg with a mean value of 1.781 mg/kg (Table 2). Gabbro and basalt have the highest concentration of copper while granodiorite and granite have the lowest copper contents. This therefore means that soils derived from mafic rocks would have higher natural copper contents than those from felsic varieties (Pascual *et al.,* 2004; Amadi *et al*., 2015). Copper and chromium pollution in soils could result from weathering insitu rocks containing copper and chromium bearing minerals as well as application of agro-chemicals such as fungicides and pesticides. Exposure to high concentration of these metals can result in serious health consequences such as lung carcinoma and transitory fever (Pascual *et al.,* 2004; Aboud and Nandini, 2009).

The main ore of lead geogenically is from galena (PbS). The Pb ion replaces potassium and calcium in carbonates and apatities (Amadi *et al*., 2016). Limestone mining and application of lead bearing pesticides increases the averages crustal concentration of lead in soils. The lead concentration in the soil ranged between 0.072-0.360 mg/kg with an average value of 0.192 mg/kg (Table 2) and these concentrations are below its crustal abundance. Lead is non-essential for plants and animals and is toxic by ingestion-being a cumulative poison (MacFarlane and Burchett, 2002). Lead toxicity leads to anaemia both by impairment of haemo-biosynthesis and acceleration of red blood cell destruction. In addition, Pb reduces sperm count, damages kidney, liver, blood vessels, nervous system and other tissues in human (Anglin-Brown *et al.,* 1995).

The main anthropogenic route of entry of nickel into the environmental is through the disposal of metal rich solid wastes from metallurgical industries. Sewages sludge from factory disposed on land is another major source of nickel contamination of soils. Other sources include fertilizer and cement production. Nickel concentration ranged between 0.004-0.080 mg/kg with a mean value of 0.016 mg/kg (Table 2) and these values are below the average crustal abundance of 80.00 mg/kg in an uncontaminated soil (Dineley *et al*., 1976). Nickel is used mainly as alloys, which are characterized by their hardness, strength, and resistance to corrosion and heat. It is a major component in the production of cement, stainless steels, non-ferrous alloys and super alloys.

Zinc concentration in soil is a function of the composition of parent rock, as well as anthropogenic activities domiciled in the area. Zinc in the study ranged between 0.611-5.870 mg/kg with an average value of 2.380 mg/kg (Table 2). With this values, the concentration of Zn in soils from the area are within the stipulated guideline limits for an uncontaminated soil (Preda and Cox, 2002). It is an essential growth element for plants and animals but can be toxic at elevated concentration. The iron content of soils ranged between 1.017-5.550 mg/kg and a mean concentration of 2.795 mg/kg (Table 2). The concentration of iron in soils is dependent upon the source rocks from which the soil was derived, transport mechanisms, and overall geochemical history. It has been observed that the high iron value in the groundwater system from the area is due to the infiltration of iron contained in the thick lateritic soil into the shallow water table.

Ecological Pollution Indices

In order to quantitatively analyze and ascertain the level and extent of heavy metal in the soil, ecological pollution indices was applied which include: geo-accumulation index, contamination factor, degree of contamination and enrichment factor. The relationship among the metals was confirmed using Pearson's correlation analysis.

Geo-accumulation index (Igeo)

Geo-accumulation index was determined by the following equation according to Müller (1969):

$$Igeo = Ln\,(Cn / 1.5\,Bn) = 2.303\,Log\,(Cn / 1.5\,Bn)$$

Where: Cn = Measured concentration of heavy metal in the soil.

Bn= Geochemical background value / Average crustal Abundance of element

The factor 1.5 is used for the possible variations of the background value due to lithological variations. According to Müller (1969), Igeo are classified into seven grades with respect to pollution intensity (Table 3) while the computed Igeo values are shown in Table 4. The values of Igeo fall under the unpolluted class (Table 4), which implies that as at the time of this investigation, the soil in the area are not polluted with respect to the Igeo guideline.

Table 3: Geo-Accumulation Index Classification after Muller (1969)

S/No	Igeo	Igeo Class	Pollution Intensity
1	≤ 0	0	Unpolluted
2	$0 < Igeo \leq 1$	1	Slightly Polluted
3	$1 < Igeo \leq 2$	2	Moderately Polluted
4	$2 < Igeo \leq 3$	3	Moderately Severely Polluted
5	$3 < Igeo \leq 4$	4	Severely Polluted
6	$4 < Igeo \leq 5$	5	Severely Extremely Polluted
7	> 5	6	Extremely Polluted

Table 4: Computed Geo-accumulation Index values

S/No	Parameters	Igeo	Pollution Intensity
1	Pb	-4.760	Unpolluted
2	Cd	-0.095	Unpolluted
3	Zn	-2.940	Unpolluted
4	Cu	-2.540	Unpolluted
5	Cr	-2.180	Unpolluted
6	Ni	-6.840	Unpolluted
7	Fe	-8.990	Unpolluted
8	As	-3.300	Unpolluted

Contamination Factor (CF)

The contamination factor (CF) is used to determine the contamination status of the soil in the present study. The CF values was postulated by Hakanson (1980) and used to describe the intensity of contamination in soils (Table 5).

The Contamination Factor was calculated using the equation:

CF = C metal / C background value (Hakanson, 1980)

CF = contamination factor.

C metal = Metal concentration in polluted soil

C Background value = Background value of that metal.

The result of the computed contamination factor revealed that the soil in the Ashaka area is moderately contaminated with cadmium while remaining heavy metals fall within the low contamination region (Table 6). This is because the concentrations of heavy metals analyzed with the exception of cadmium were found to be far below their respective average crustal abundance (background value). Cadmium concentration was slightly above the crustal abundance which implies that the soil in the area is moderately contaminated by cadmium. The fact that the computed values of cadmium alone is greater than the summation of other metals is a confirmation to the fact that soil in the area is slightly contaminated with cadmium. The concentration of cadmium ranges from 0.052-0.327 mg/kg with a mean concentration of 0.150 mg/kg. The values of cadmium in Ashaka, Feshingo and Gongila were found to be slightly higher than the average crustal abundance of 0.15 mg/kg in an uncontaminated soil (Dineley *et al.*, 1976) while cadmium concentration in remaining communities (Badebdi, Juggol and Jajami) far below the average crustal abundance. Cadmium is one of the components of inorganic fertilizers produced from phosphate ores and since majority of the villagers are farmers, cumulative effect of continuous fertilizer application leaves the soil enriched with cadmium.

Table 5: Classification based on Contamination Factor by Hakanson (1980)

S/No	CF	Contamination Factor
1	$CF < 1$	Low Contamination Factor
2	$1 \leq CF < 3$	Moderate Contamination Factor
3	$3 \leq CF < 6$	Considerable Contamination Factor
4	$CF \geq 6$	Very High Contamination Factor

Table 6: Calculated Contamination Factor values

S/N	Parameters	CF	Contamination Factor
1	Pb	0.0128	Low Contamination Factor
2	Cd	1.364	Moderate Contamination Factor
3	Zn	0.079	Low Contamination Factor
4	Cu	0.119	Low Contamination Factor
5	Cr	0.023	Low Contamination Factor
6	Ni	0.0016	Low Contamination Factor
7	Fe	0.00019	Low Contamination Factor
8	As	0.056	Low Contamination Factor

Degree of Contamination

The degree of contamination (Cd) was defined as the summation of all contamination factors.
Mathematically, $Cd = \Sigma\,(CF)$
Where: Cd = Degree of contamination
CF = Contamination factor

According to Amadi and Nwankwoala (2013), four classes were used to describe the degree of contamination (Table 7). The summation (addition) of the contamination factors from Table 6 gave a value of 1.656. This value falls in the region of low degree of contamination (Table 7). The computed degree of contamination for the selected metals confirms that soils around Ashaka Cement Factory are within the low contamination degree which implies the soil in the area is currently not polluted. This finding also agrees with the geo-accumulation index as well as the degree of contamination which suggests that soils in Ashaka area range from uncontaminated to moderately contaminated and this is with respect to cadmium.

Table 7: Degree of Contamination

S/N	Cd	Degree of Contamination
1	$Cd < 6$	Low degree of contamination
2	$6 = Cd < 12$	Moderate degree of contamination
3	$12 = Cd < 24$	Considerable degree of contamination
4	$Cd \geq 24$	Very high degree of contamination

Enrichment Factor (EF)

The Enrichment Factors (EF) was calculated to evaluate the abundance of metals in soil. It is calculated by the comparison of each tested metal concentration with that of a reference metals. Enrichment factors (EF) for the soil at all the stations was calculated using the equation postulated by Acevedo-Figueroa *et al.* (2006). The equation states that:

$$EF = Cn\ (sample) / Cref\ (sample) \div Bn\ (background) / Bref\ (background)$$

Where:

Cn (sample) = the metals concentration (mg/kg) in a sample.

Cref (sample) = the reference metals concentration (mg/kg).

Bn (Background) = the metals concentration (mg/kg) in reference (background) environment.

Bref (background) = the reference metals concentration (mg/kg) in reference background environment.

According to Acevedo-Figueroa *et al.* (2006), six contamination categories are recognized on the basis of the enrichment factor (Table 8). As the enrichment factor increase, the contributions of the anthropogenic origins also increase (Sutherland, 2000; Amadi *et al.*, 2015). The commonly used reference metals are Cu, Al and Fe (Liu *et al.,* 2005). In this study, Cu was used as the reference metal because it was found in abundant amount in the soil and natural environment within the study area. The result of the enrichment factor calculated shows a range of no enrichment to minimal enrichment, which also confirmed the findings of geo-accumulation index, contamination factor and degree of contamination. To further strengthen the relationships among the various metals within the soil, correlation analysis was conducted (Table 9). The correlation coefficient for the metals was low except the correlation between copper and zinc. The low correlation can be indicative of distinctive sources for the metals in the area.

Table 8: Enrichment Factor categorization by Acevedo-Figueroa *et al.* (2006)

S/N	EF	Enrichment Factor Category
1	EF < 1	No enrichment
2	1 = EF < 2	Minimal enrichment
3	2 = EF < 5	Moderate enrichment
4	5 = EF < 20	Significant Enrichment
5	20 = EF < 40	very high enrichment
6	EF ≥ 40	extremely high enrichment

Table 9: Pearson correlation coefficient matrix for heavy metals in Ashaka and Environs

	Pb	Cd	Zn	Cu	Cr	Ni	Fe	As
Pb	1.000							
Cd	0.321	1.000						
Zn	0.070	0.080	1.000					
Cu	-0.167	0.127	0.506*	1.000				
Cr	0.124	0.264	-0.201	0.123	1.000			
Ni	0.109	0.210	0.152	0.528*	-0.198	1.000		
Fe	0.280	-0.058	0.272	0.361	0.246	0.174	1.000	
As	0.311	0.163	-0.084	0.203	0.095	0.263	0.119	1.000

*: Correlation is significant at the 0.05 level (2-tailed)

CONCLUSION

Limestone mining and processing, which is one of the world's most valuable economic activity in recent times has the capacity to contaminate the soil and water when standard procedures are not followed. The soil quality in Ashaka Cement Factory, was evaluated in the present study using geo-accumulation index (Igeo), contamination factor (CF), degree of accumulation (Cd), enrichment factor (EF) and correlation analysis (CA). The result of Igeo shows that the soil is unpolluted while CF shows a range of low to moderate contamination. The EF varied from non enrichment to minimal enrichment while Cd value indicates a low degree of contamination for soils in the area. The result of correlation coefficient further revealed a very low correlation among the metals and by implication low contamination. The consistency in the results of the ecological pollution indexes (Igeo, CF, Cd and EF) obtained is a confirmation that the soil in the study area is currently not polluted with heavy metals except cadmium. The fact that the mean concentration of the heavy metals (Fe, Cu, As, Ni, Pb, Cr and Zn) are by far lower than their respective average crustal abundance is an indication of no contamination by these metals except cadmium. The slight contamination of the soil by cadmium in the area may be attributed to prolonged use of agro-chemicals as well as discharge of untreated industrials effluent in the surrounding. A periodic monitoring of soil pollution level in area is advocated. The management of Ashaka Cement Factory should ensure that global industrial best practices are employed in their daily operation.

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