



Mass Concentration and Elemental Constituent of Particulate Matter in Ambient Air of Two Cement Industries and Its Health Risk Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. Author GOA designed the study. Author CPO performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MO managed the analyses of the study and' managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Particulate matter concentration was measured over two cement production sites in Nigeria using a gravimetric high volume air sampler and Atomic Absorption Spectroscopy (AAS) for elemental analysis. The mass concentration of SPM ranged from 7.50 $\mu\text{g}/\text{m}^3$ to 303.1 $\mu\text{g}/\text{m}^3$ with mean value of 157.9 $\mu\text{g}/\text{m}^3$ /day in Okpella Bua cement production site and 4.4 to 283.3 $\mu\text{g}/\text{m}^3$ with mean value of 103.2 $\mu\text{g}/\text{m}^3$ /day for Unicem cement production site, Calabar. The elemental analysis shows the presence of Zn, Pb, Ni, Mn, Cr and Cd. The heavy metals in the order of decreasing concentration are Zn> Pb> Ni > Mn> Cr> Cd: 7.84> 2.60> 2.00> 0.80> 0.76 > 0.11 ($\mu\text{g}/\text{m}^3$) respectively. All the values were higher than NESREA limit except Mn in Okpella Bua site. In UNICEM Calabar site, heavy metal distribution showed Zn> Pb> Ni> Mn> Cr> Cd: 12.50> 3.00> 1.26> 0.66> 0.41> 0.14 ($\mu\text{g}/\text{m}^3$), respectively. The carcinogenic risks estimated exceeded the acceptable limit for adult, workers and children. The result showed that about 106 adults and 227 children will be affected by cancer related health problem. The mean value of the hazard quotient (HQ) was 1.46 and 2.46 from Unicem and 1.76 and 2.95 from Bua cement area for chromium and lead exposure of adult

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and children respectively, which shows the occurrence of the non-carcinogenic health effect on both adult and children. The result of this work revealed that children have higher risk than adult due to exposure to this inhalable particulate matter.

Keywords: *Dust load; heavy metal; unicom; atomic absorption spectroscopy; suspended particulate matter.*

1. INTRODUCTION

Air pollution is a major environmental problem affecting human race on earth. Anthropogenic activities that range from domestic energy utilization to large scale industrial operations are largely responsible for the undesirable status of the atmospheric constituents due to release of pollutants to the atmosphere [1]. The particulate matter (PM) plays a vital role in the worsening of the local as well as regional air quality, though the emission of particulate matter depends on the sources [2,3]. The origins of the particulate matter in the atmosphere are sea salt, suspended dust, natural gaseous emissions, industrial processes, manufacturing and production, vehicular emission and biomass combustion [4]. Epidemiological evidence such as increasing the incidence of lung cancer, asthma, and cardiovascular diseases indicates that PM is a significant health risk factor [5,6]. The chemical composition of particulate trace elements has been recognized as a factor for the development of the air pollutant-associated diseases. The continuous exposure of toxic or non-toxic chemicals of particulate matter is more responsible for the human health effect rather than their mass concentrations [2,7]. The persistence and potential for long-range atmospheric transport and atmospheric emissions of heavy metals virtually affect even more regions around the world.

The emission of particulates is quite outstanding from quarries, the effect of dust emission from these quarries have both micro and regional dimension. Quarrying operations generally involve removal of over burden, drilling, blasting and crushing of rock minerals. The various impacts produced by these operations are both size and locations dependent and are manifested on air, water, soil, earth surface, flora and fauna, and human beings [8]. Francis [9] stated that particulate matter is one of the problems faced in environmental science. It has health effects on man and animals in both developing and developed countries. Suspended particulate matter is quite outstanding among all pollutants emanating from quarrying operations [10].

Opuntoke, et al. [11] investigated the levels of suspended particulate matter in the ambient air in and around selected quarries and analyzed the prevalent health problems suffered by nearby residents and quarry workers. In their work they found that particulate matter was responsible for both psychological and health problems suffered by nearby residents.

The trace elements like Co, Ni, Mn, Fe, Cu, As, Cd of particulate matter are linked to various acute and chronic health effects such as asthma, dermatitis, memory disturbance, sleep disorder, anger, fatigue, blurred vision, throat or nose irritation and lung cancer of human along with another environmental impact [12-14]. About, 7.6% of deaths and 4.2% of disability-adjusted life are caused by the exposure to ambient particulate matter globally [15].

Studies have shown that exposure of lead (Pb) can be correlated with developmental and neurobehavioral effects in children and adults [16]. Cadmium (Cd) was categorized as a potential human carcinogen. Kidney and bone are also critical target organs concerning environmental exposure [17,18]. Nickel (Ni) is a known human carcinogen and also produces other health effects such as skin allergies, cardiovascular effects, pulmonary fibrosis, and renal damage [19].

Various studies in the past decades have shown the deleterious effects of heavy metals of particulate matter in Italy [20], Malaysia [21], Canada [22], China [23], China [24] and India [25]. Chen, et al. [24] reported the heavy metal concentration of particulate matter such as Cd, Zn, Cu, Ni, Pb and Cr in Asian countries like Japan, China, India, Korea, Indonesia, Vietnam and Taiwan.

The high concentrations of heavy metals (Cd, Pb, Zn, and V) have been found in China and India than in other Asian countries [26]. In India, the primary sources of heavy metals associated with PM_{2.5} and PM₁₀ were found to be vehicular emissions and re-suspended dust [2].

Cement production industry is one of the largest manufacturing industries that generate a lot of dust particles and its workers are exposed to dust at various manufacturing and production processes [27]. Portland cement dust is composed of Calcium Oxide, Silicon Oxide, Aluminum Trioxide, Ferric Oxide, Magnesium Oxide and other impurities. The aerodynamic diameter of cement dust particle is within the inhalable extent consequently, occupational exposure to cement dust can cause numerous health hazards including the onset of acute or chronic respiratory diseases and respiratory function deficits [28]. Anthropogenic and natural activities are responsible for the causes of elevated suspended particulate matter in the atmosphere [9]. Occupational and environmental exposure to cement dust and their effects on man's health is a leading respiratory health problem such as respiratory diseases including respiratory function impairment [29].

Okoro, et al. [30] Investigated heavy metal content in the soil of cement factory in Ewekoro Nigeria and established that heavy metal concentration decreases as the distance of the communities from the factory increases. Various studies show the higher concentrations of Zn, Pb, Cd, Ni, Mn, and Fe at industrial and residential sites of Kolkata, Hyderabad, Delhi, and Pune [31]. Similarly, Mfamosing, Calabar Cross River and Okpella Edo State all in Nigeria are experiencing a high load of ambient particulate matter (PM) due to Cement production activities, biomass burning, industries, automobile emission, agricultural practices, and rapid increase in urbanization [32]. The children, elderly, smokers, people with poor health suffering from cardiovascular diseases, especially allergy and asthma and chronic respiratory difficulties are the more susceptible group in these areas.

The knowledge on the concentration of different types of metals in respirable particulate matter is essential because they influence the toxicity of metal when inhaled. Hence, this study aims to ascertain the mass concentration of these two areas, determine their chemical constituent and analyze for health risks associated with the exposure of individuals in the area of study.

2. MATERIALS AND METHODS

2.1 Location of Study Areas

The two study areas are Mfamosing, Calabar, Cross River state and Okpella, Edo state,

Nigeria. Mfamosing, Calabar plays hosts to UNICEM cement factory. Its geographical coordinates are Latitude 5.310°N and Longitude 8.310°E and its original name is Mfamosing. This area covers Akpabuyo and parts of Odumkpani Local government area. According to Iloje, [33] the elevation of this area is less than 100m above sea level. The climate of this area is that of equivocal belt which is characterized by wet and dry seasons, the wet season starts from April to September with peak in June and July, while dry season starts from October to March with break in August. Geological, the area is composed of tertiary to recent, continental fluvialite sand clay, known as the coastal plan sand. The inhabitants of this area are predominantly famers.

Okpella is a clan situated along Benin-Abuja federal high way located at coordinate of 7.2721°N latitude, 6.3465°E longitude is the host community of BUA cement factory. Going by the last National census figure, it is the third largest autonomous clan in Edo state after. Okpella is known for its natural sedimentary rock based mineral resources, which include limestone, calcium and granite, feldspar, talc, clay, marble etc. the town play host to the Edo cement company. In view of the abundance of other solid minerals, it is home for several granite and marble-making industries, which gives the community a vibrant industrial outlook.

2.2 Sampling and Analysis

The particulate were collected on quartz fibre filter (GFA) using gravimetric high volume sampler. Sampling was done once a week and the glass fibre filter meant for this investigation were taken to the laboratory to determine their initial masses marked F_1 to F_8 , with F_8 as the control in all the locations. These filters were taken one after another in the field and pointed on the gravimetric high volume air sampler which was connected to the generating set at a known location and coordinate. Ambient air was drawn through the filter at a constant flow rate of 1.4 m³/min. suspended particulate matter having diameter (Strike equivalent diameter) between 0.1 and 100 μ m were removed from air stream by filter filtration on the quartz fibre, for each filter used in counting, one hour duration was allowed. After which the filter was removed from the sampler and put in a desiccator for the removal of moisture and weighed before and after the sampling for obtaining the mass of particulate matter (the masses F_2) [1].

Ini and Akuro [33] permitted one (1) hour sampling where there are high levels of particulate emission. The sampling duration for this investigation is one (1) hour, the volume of air sampled was $1.4 \text{ m}^3/\text{min} \times 60 \text{ min} = 84 \text{ m}^3$ of air. This is because the shorter the averaging period, the greater the volume of data collected.

The mass concentrations of the particulate matter were determined by dividing the difference in the mass of filter paper after and before the sampling (μg) by total air volume (m^3). That is:

The mass of SPM (M_{spm}) was calculated using the formula

$$M_{\text{SPM}} = M_F - M_{I(g)} \quad (1)$$

Where

M_{spm} = Mass of suspended particulate matter

M_F = Final mass of filter after sampling

M_I = Initial mass of filter before sampling

Therefore, mass concentration of SPM was calculated according to the World Health Organization [34] using the formula thus,

$$C_{\text{SPM}} = \frac{M_{\text{spm}}}{\text{vol. of air sampled}} \quad (2)$$

The materials used for the digestion of the sample include: Hot plate, 100 ml volumetric flask, 500 ml beaker, sample bottle, filter paper, washing balance, distilled water, funnel, concentrated H_2SO_4 , conc. Per chloric acid and Hydrochloric acid.

Each filter sample was inserted in 500 ml beaker, 100 ml of conc. H_2SO_4 , 20 ml per chloric acid and 20 ml of aqua regia (3 ml of HCL: 1 ml of HNO_3) were added and beaked on hot plate for eight (8) hours. At the end of digestion the solution formed a paste and was brought down to cool. 50 ml of distilled water was added and stirred with stirring rod and filtered into 100 ml volumetric flask. A greater proportion of the solution was transferred into a sampling bottle for heavy metals analysis using atomic absorption spectrophotometer [1].

The exceedance factor is calculated by the ratio of the annual mean concentration of particulate matter (PM) and their respective standards [35] which is given below:

$$\frac{\text{Exceedance factor}}{\frac{\text{observed concentration of pollutant}}{\text{standards for the respective pollutant}}} = \quad (3)$$

The air quality is said to be critical pollution (C) if the exceedance factor is greater than 1.5, high pollution (H) if the exceedance factor lies between 1.0 and 1.5; moderate pollution (M), if the exceedance factor is between 0.5 and 1.0 and low pollution (L) when exceedance factor is below 0.5.

2.3 Health Risk Assessment

The health risks of trace elements (Cr, Ni, Pb, Cd, Mn and Zn) of particulate matter (PM) in terms of carcinogenic and non-carcinogenic was calculated by using the following formula [36]:

$$EC = \frac{CA \times ET \times ED}{AT} \quad (4)$$

where EC ($\mu\text{g m}^{-3}$) = exposure concentration (time-weighted average concentration); CA ($\mu\text{g m}^{-3}$) = contaminant concentration in air; ET = exposure time (period over which a person is likely to be exposed) which in our study was 24 h per day for resident air exposure time while worker air exposure time is 8 hours; EF(days y^{-1}) = exposure frequency (resident exposure frequency (EFr) is 350 days y^{-1} , workers exposure frequency indoor (EFw) is 250 days/year and outdoor is 225 days /year); ED (years) = exposure duration (person exposed during lifetime viz., 20 years and 6 years for adults and children, respectively); ED for workers exposure duration is 25 years for both indoor and outdoor), AT = average time (period over which exposure is averaged) (for non-carcinogenic AT = ED x 365 days y^{-1} x 24 h day^{-1} and for carcinogenic AT = 70 years x 365 days y^{-1} x 24 h day^{-1}) [36,37].

The non-carcinogenic health risk was computed by using the hazard quotient (HQ) and carcinogenic health risk was computed by using excess lifetime cancer risk (ELCR) formulae as follows:

$$HQ = \frac{EC}{\text{RFC} \times \text{CF}} \quad (5)$$

$$\text{ELCR} = \text{IUR} \times \text{EC} \quad (6)$$

Where HQ is the hazard quotient, EC is the exposure concentration (μgm^{-3}), RFC is the inhalation reference concentration (mg m^{-3}) and CF is the conversion factor (taken as 1000 $\mu\text{g mg}^{-1}$). IUR is the inhalation unit risk (μgm^{-3}). The IUR is defined as the excess lifetime cancer risk, which was estimated from the exposure of air in $1 \mu\text{gm}^{-3}$ and RFC is the inhalation exposure to the human population.

3. RESULTS

The results of suspended particulate matter investigated from sixteen (16) different locations of studied areas, showing mass concentration of suspended particulate matter within the environment are presented in Table 1 and Fig. 1. The results of analysis of heavy metals distribution in suspended particulate matter (SPM) at Okpella and Calabar location sites and their environment are presented as in Table 2 and Fig. 2.

4. DISCUSSION

The results of the investigated concentration of suspended particulate matter at Okpella BUA is shown in Table 1 and illustrated in Fig. 1. This result showed locations 0 m, 50 m, and 100 m with higher SPM values above the NESREA standard limit of $200 \mu\text{g}/\text{m}^3$,

whereas other locations fall below the NESREA standard limit. Six (6) locations in Okpella BUA were higher than WHO standard limit of $50 \mu\text{g}/\text{m}^3$ and all locations were higher than the control limit of $7.5 \mu\text{g}/\text{m}^3$. Generally, the mean value of SPM was $157.9 \mu\text{g}/\text{m}^3/\text{day}$, which was lower than NESREA [38]. This result was lower to what was obtain in part of Koper Slovenia which was $> 350 \text{ mg}/\text{m}^3/\text{day}$ [39], but in agreement to that done in Calabar, Nigeria that ranged $108.98 - 269.93 \mu\text{g}/\text{m}^3$ [40].

Table 2 Showed mean concentration of selected metals in Okpella Bua cement and its environment in order of decreasing concentration are $\text{Zn} > \text{Pb} > \text{Ni} > \text{Mn} > \text{Cr} > \text{Cd}$ for $7.84 > 2.56 > 1.999 > 0.799 > 0.76 > 0.108 \mu\text{g}/\text{m}^3$ respectively. Comparing the results with their controls and NESREA [38] standard, all heavy metals were higher than their control values and the standard

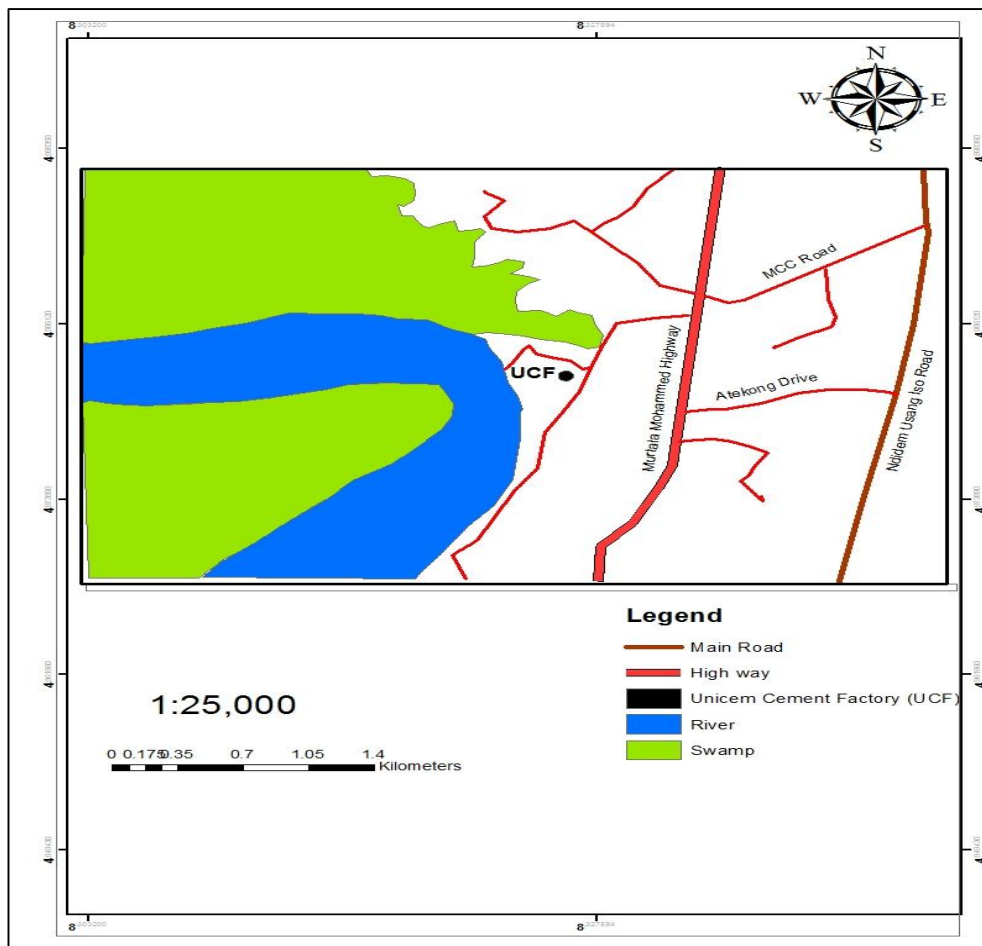


Fig. 1. Map showing the location of UNICEM production site

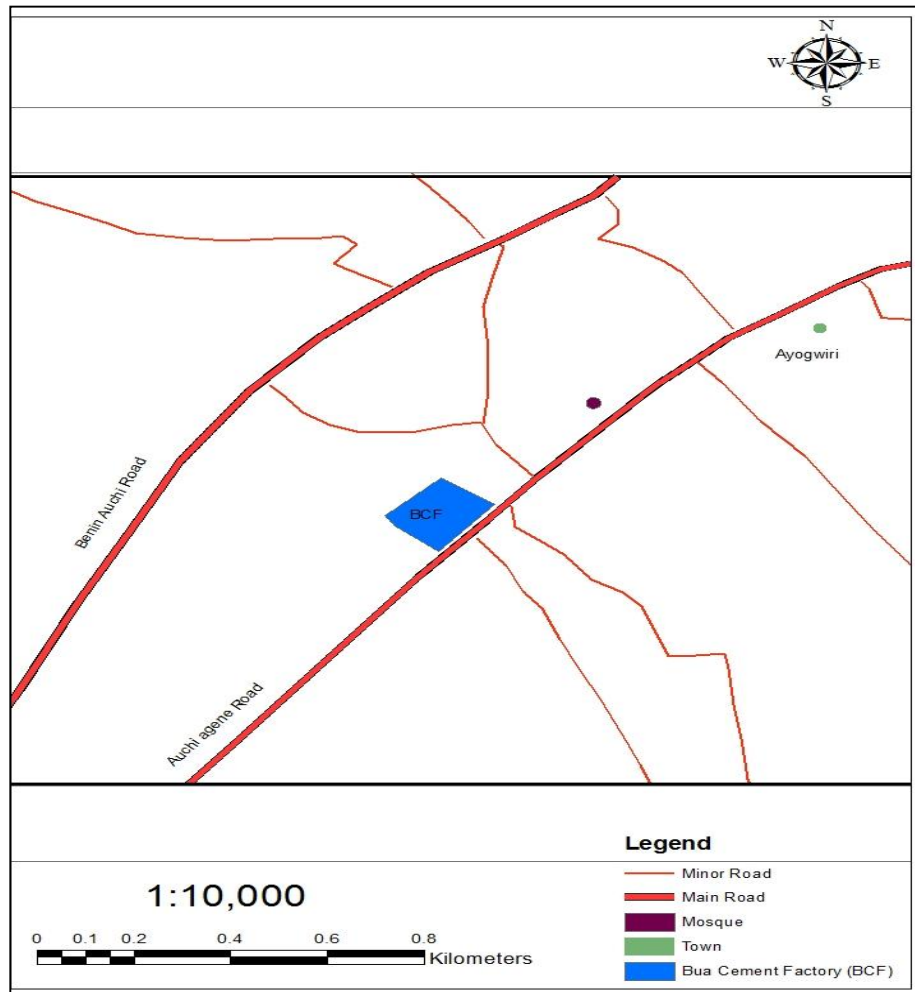


Fig. 2. Map showing the location of Okpella BUA cement production site

except for Manganese (Mn) which was lower than the standard. This indicates higher level of Heavy metal pollution and this could be attributed to the mining and processing activities going on in this area. Apart from cement quarry in Okpella (BUA cement) there are other mining processes like granite quarrying which might have triggered or elevated the concentration of Heavy metals in the Area.

The results of the investigated mass concentration of suspended particulate matter in Unicem Calabar is presented in Table 4 and illustrated in Fig. 2. The result showed that location OM is the only one higher than NESREA [38] limit. The SPM concentration ranged from $4.4 \mu\text{g}/\text{m}^3$ to $283.3 \mu\text{g}/\text{m}^3/\text{day}$ with mean value of $103.2 \mu\text{g}/\text{m}^3$ which is lower than NESREA limit of $200 \mu\text{g}/\text{m}^3$. This result obtain was lower than the value recorded in Benin City $173.6 - 520 \mu\text{g}/\text{m}^3$

[41]. The elevation in Dust load against the control is an indication of the anthropogenic activities in the study area.

The elemental analysis of the PM from Unicem cement producing industry and its environment revealed the presence of chromium, manganese, cadmium, lead, zinc and nickel as presented in Table 4. The result in order of decreasing concentration showed that $\text{Zn} > \text{Pb} > \text{Ni} > \text{Mn} > \text{Cr} > \text{Cd}$ which is $12.50 > 2.92 > 1.26 > 0.66 > 0.41 > 0.14 \mu\text{g}/\text{m}^3$ respectively. All the heavy metals are higher than their control limit except for manganese Mn. Similarly, all heavy metals were higher than NESREA limit except Mn, the heavy metals can pose threat to life of residents and such need to be monitored regularly. The exceedance factors have been calculated and are presented in Tables 2 and 4. From Table 2, the annual exceedance factor was

15.28, 0.1598, 51.28, 5.375, 1.567 and 1.999 for Cr, Mn, Pb, Cd, Zn and Ni respectively. From Table 4, the annual exceedance factor are 8.25, 0.131, 58.48, 7.13, 2.49 and 1.26 for Cr, Mn, Pb, Cd, Zn and Ni respectively. The exceedance factor in both Okpella Bua cement and Unicem cement and its environment maintains the high to critical level of pollution. The pollutant level is rising alarmingly as the concentration of the pollutants is almost double their standards. The slight variation in concentration of the particulate may be due to variation in sources and the sources strength during the study period and variation in meteorological conditions (Temperature, wind speed and relative humidity).

The exposure concentration of trace metals of PM has been calculated by carcinogenic and non-carcinogenic risk for resident adult, children and workers and presented in Tables 5 and 6 for Bua cement environment and Unicem environment respectively. Zinc (Zn) showed the highest EC among the other non-carcinogenic elements, followed by lead (Pb). The result highlights the fact that metals pose higher non-carcinogenic risk than the carcinogenic. Various studies have also shown similar results [42,43]. The high EC values of carcinogenic risk in adults was recorded for Zn, Ni and Pb in both children and adult.

Table 1. Result of suspended particulate matter concentration measurement at Okpella BUA site

S/N	Coordinate	Location (m)	Filter Identity	Mass of final (µg)	Filter initial (µg)	SPM (µg)	Mass conc. (µg/m ³)	Mass conc. per day (µg/m ³)
1	N07° 21' 06.4" E006° 23' 38.5"	0	1	3.4121	2.8011	0.6110	7273.8	303.1
2	N07° 21' 14.4" E006° 23' 19.3"	50	2	3.3938	2.8217	0.5721	6810.7	283.8
3	N07° 21' 24.7" E006° 23' 24.6"	100	3	3.2376	2.8070	0.4306	5126.2	213.6
4	N07° 21' 42.8" E006° 23' 7.2"	200	4	3.1505	2.7500	0.4005	4767.9	198.7
5	N07° 21' 47.2" E006° 23' 6.14"	250	5	3.0737	2.7720	0.3012	3587.1	149.5
6	N07° 21' 01.0" E006° 23' 5.32"	500	6	2.9625	2.8002	0.1525	1815.5	75.7
7	N07° 21' 6.42" E006° 23' 6.04"	1000	7	2.8640	2.8100	0.0638	759.5	31.7
8	N07° 21' 57.4" E006° 23' 39.5"	Control Point	8	2.8305	2.8155	0.0150	178.6	7.5
Mean \bar{X}							3789.9	157.9 / day
NESREA							200	
WHO							50	

Table 2. The result of mean concentration of selected heavy metal in suspended particulate matter at BUA cement (µg/m³) and their standards

Heavy metal	Mean concentration (µg/m ³)	Control F ₈ (µg/m ³)	NESREA 2009 (µg/m ³)	Exceedance
Chromium	0.7638	0.20	0.05	15.276 (C)
Manganese	0.7990	0.41	5.0	0.1598 (L)
Lead	2.5638	1.20	0.05	51.276 (C)
Cadmium	0.1075	0.02	0.02	5.375 (C)
Zinc	7.835	2.60	5.0	1.567 (H)
Nickel	1.9990	1.70	1.0	1.999 (H)

C = Critical, L = low level, H = high level

Table 3. Results of suspended particulate matter concentration measurement at UNICEM cement production site

S/N	Coordinate	Location (m)	Filter identity	Mass of final (µg)	Filter initial (µg)	SPM (µg)	Mass Conc (µg/ m ³)	Mass Conc per day (µg/ m ³)
1	N05° 04' 05.3" E008° 30' 45.0"	0	1	1.9481	2.5192	0.5711	6798.8	283.3
2	N05° 04' 29.7" E008° 30' 32.2"	50	2	1.8221	2.1785	0.3564	4242.9	176.8
3	N05° 04' 42.8" E008° 30' 09.6"	100	3	2.0124	2.1950	0.1826	2173.8	90.6
4	N05° 04' 480" E008° 30' 025"	200	4	1.9220	2.1373	0.2153	2563.1	106.8
5	N05° 04' 121" E008° 30' 305"	250	5	2.0215	2.0433	0.0218	258.5	10.8
6	N05° 04' 11 E008° 30' 446"	500	6	1.9220	2.1373	0.2153	2563.1	106.8
7	N05° 04' 58.6" E008° 30' 301"	1000	7	2.8057	2.8950	0.0925	1101.2	45.9
8	N05° 04' 140" E008° 30' 129"	Control Point	8	2.8011	2.8094	0.00883	105.1	4.4
Mean \bar{x}							2475.81	103.2
NESREA (WHO)							200 (50)	

Table 4. The mean concentration of selected heavy metal in suspended particulate matter at UNICEM in (µg/m³) and their standards

Heavy metal	Mean concentration (µg/m ³)	Control F ₈ (µg/m ³)	NESREA, 2009 (µg/m ³)	Exceedance
Chromium	0.4125	0.17	0.05	8.25 (C)
Manganese	0.657	1.15	5.0	0.1314 (L)
Lead	2.924	2.40	0.05	58.48 (C)
Cadmium	0.1425	0.12	0.02	7.125 (C)
Zinc	12.450	3.24	5.0	2.49 (C)
Nickel	1.258	0.80	1.0	1.258 (H)

C= critical level, L = low level, H = high level

The health risks from heavy metals were correlated with exposure of various substances which shows the effect on adults and children's lifetime and referred to as excess lifetime cancer risk (ELCR) [11]. The higher carcinogenic risk has been found in children and adult for lead (Pb) and Nickel (Ni). Various studies have also reported that the carcinogenic risks by lead exposure exceeded the acceptable level for both children and adult [44-47]. Summing of the ELCR of all the toxic metals gives the integrated carcinogenic risks. The integrated carcinogenic risks were 106.13×10^{-3} , 31.76×10^{-3} and 127.35×10^{-3} for resident adult, worker and resident children respectively in Unicem cement production area and 189.46×10^{-3}

, 56.38×10^{-3} and 227.34×10^{-3} for resident adult, worker and resident children in Okpella Bua cement production area. These results reveals that out of 1000 persons exposed, about 106 of adults, 31 of workers and 127 of children may probably develop cancer in their lifetime as a result of their exposure to these toxic metals.

The non-carcinogenic effect of heavy metals has been determined using the hazard quotient (HQ) values. If the HQ value is below unity, it shows no risk of non-carcinogenic effect and if the HQ value is above unity, it indicates the occurrence of non-carcinogenic effect [37]. The mean value of the hazard quotient (HQ) for chromium (Cr)

and lead (Pb) was 1.46 and 2.46 respectively for adult resident while for resident children, HQ was 1.76 and 2.95 respectively. HQ for Nickel is approximately unity, which is 0.75 and 0.90 for adult and children respectively. HQ for workers were lower than unity and so there will be no non-carcinogenic effect on workers. Exposure to Ni and Pb has been associated with respiratory

Table 5. Carcinogenic and non-carcinogenic risk from Unicem cement environment

Element	Exposure Concentration (EC) ($\mu\text{g m}^{-3}$)			Hazard Quotient (HQ) (mg/l)			Excess lifetime cancer risk		
	Resident (Adult)	Worker	Resident children	Resident (adult)	Worker	Resident children	Resident (adult) x 10^{-3}	Worker x 10^{-3}	Resident children x 10^{-3}
Cr	7.91	2.35	9.49	0.7910	0.2354	0.9493	6.32	1.98	7.57
Mn	12.6	3.75	15.12	0.0252	0.0075	0.0302			
Pb	56.08	16.69	67.29	2.804	0.8345	3.3646			
Cd	2.73	0.813	3.28	0.0273	0.0081	0.0328	94.94	28.34	11.39
Zn	238.76	71.06	286.52						
Ni	24.13	7.18	28.95	1.194	0.3553	1.4326	4.97	1.53	5.94
Total							106.13	31.76	127.35

Table 6. Carcinogenic and non-carcinogenic risk from Bua cement environment

Element	Exposure Concentration (EC) ($\mu\text{g m}^{-3}$)			Hazard Quotient (HQ) (mg/l)			Excess lifetime cancer risk		
	Resident (Adult)	Worker	Resident children	Resident (Adult)	Worker	Resident children	Resident (Adult) x 10^{-3}	Worker x 10^{-3}	Resident children x 10^{-3}
Cr	14.65	4.36	17.58	1.46	0.435	1.758	9.968	2.967	11.96
Mn	15.32	4.56	18.39	0.031	0.009	0.037			
Pb	49.17	14.63	59.00	2.46	0.731	2.950	-		
Cd	2.06	0.61	2.47	0.021	0.006	0.025	175.78	52.315	210.93
Zn	150.26	44.72	180.31	-	-	-	-		
Ni	38.34	11.41	46.00	0.75	0.224	0.901	3.71	1.10	4.45
Total							189.458	56.382	227.34

effects apart from gastro-intestinal distress and pulmonary fibrosis, neurotoxicity, immune toxicity and cardiotoxicity leading to increased morbidity or mortality rate.

5. CONCLUSION

Particulate matter (PM) concentration was measured over two cement production industries within Niger Delta region of Nigeria. The result showed that SPM concentration in Six (6) locations of Okpella BUA cement were higher than WHO standard limit of $50 \mu\text{g}/\text{m}^3$ and all locations were higher than the control limit of $7.5 \mu\text{g}/\text{m}^3$. Generally, the mean value of SPM was $157.9 \mu\text{g}/\text{m}^3/\text{day}$, which was lower than $200 \mu\text{g}/\text{m}^3/\text{d}$ stipulated by NESREA [38]. The SPM concentration in all the locations of Unicem cement were higher than WHO standard and only one location was higher than the NESREA standard. The SPM concentration in Unicem ranged from $4.4 \mu\text{g}/\text{m}^3$ to $283.3 \mu\text{g}/\text{m}^3/\text{day}$ with mean value of $103.2 \mu\text{g}/\text{m}^3$ which is lower than NESREA limit of $200 \mu\text{g}/\text{m}^3$. The slightly high concentration observed in the two areas could be due to cement dust generated during bagging and production.

The particulate matter collected was also analyzed for heavy metals. The elemental analysis of the PM from Unicem cement producing industry and its environment revealed the presence of chromium, manganese, cadmium, lead, zinc and nickel. The result in order of decreasing concentration showed that $\text{Zn} > \text{Pb} > \text{Ni} > \text{Mn} > \text{Cr} > \text{Cd}$ which is $12.50 > 2.92 > 1.26 > 0.66 > 0.41 > 0.14 \mu\text{g}/\text{m}^3$ respectively. The elemental analysis of the PM from Unicem cement producing industry and its environment revealed the presence of chromium, manganese, cadmium, lead, zinc and nickel. The result in order of decreasing concentration showed that $\text{Zn} > \text{Pb} > \text{Ni} > \text{Mn} > \text{Cr} > \text{Cd}$ which is $12.50 > 2.92 > 1.26 > 0.66 > 0.41 > 0.14 \mu\text{g}/\text{m}^3$ respectively. Comparing the results with their controls and NESREA [38] standard, all heavy metals were higher than their control values and the NESREA standard except for Manganese (Mn) which was lower. This indicates higher level of Heavy metal pollution and this could be attributed to the mining and processing activities going on in this area. The exceedance factor in both Okpella Bua cement and Unicem cement and its environment maintains the high to critical level of pollution.

Health risk analysis was done for carcinogenic and non-carcinogenic risk in adult, children and

workers during the study period. The carcinogenic risks exceeded the acceptable limit for adult, workers and children. The result showed that about 106 adults and 227 children will be affected by cancer related health problem. The mean value of the hazard quotient (HQ) (non-carcinogenic risk) was 1.46 and 2.46 from Unicem and 1.76 and 2.95 from Bua cement area for chromium and lead exposure of adult and children respectively which shows the occurrence of the non-carcinogenic health effect on both adult and children. The result of this work revealed that children have higher risk than adult due to exposure to this inhalable particulate matter. Based on these findings, cement producing companies should incorporate a technology that will collect the dust from the point of production to reduce the dust load. Also people should live at least 200 m away from the production site which will reduce exposure of residents (both adult and children) to nearest minimum.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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