Global Scientific JOURNALS

GSJ: Volume 9, Issue 11, November 2021, Online: ISSN 2320-9186

www.globalscientificjournal.com

AEROSOL PARTICLE POLLUTION FROM CONSTRUCTION ACTIVITIES BY NEUTRON ACTIVATION ANALYSIS (NAA)

Robert, J. J[1]. Chiemeka, I.U [1]. Chineke, T.C [1]

Department of Physics, Ignatius Ajuru University of Education, Rumuolumeni, Port-Harcourt, Nigeria.

Department of Physics, Abia State University, Uturu, Nigeria.

Department of Physics, Imo State University, Owerri, Nigeria.

Corresponding e-mail Address: robert.james@iaue.edu.ng

Abstract

This study considered neutron activation analysis of aerosol particles emanating from construction activities in the metropolitan city of Port-Harcourt from (October, 2017 — September, 2018). Port-Harcourt City is located at $4^{0}\,47^{'}\,21''$ North, $6^{0}\,59^{'}\,55^{''}$ East and elevations of 52ft (16 meters) above sea level. Direct deposition of particles under the influence of gravity was employed for the collection of particulate matter (PM) samples on filter papers from building construction sites and a Residential Area located 150 meters from the construction sites. Neutron Activation Analysis (NAA) was use in the analyses of the PM samples. The results showed the presence of twenty one elements; sodium (Na), aluminium (Al), calcium (Ca), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), rubidium (Rb), zirconium (Zr), caesium (Cs), cerium (Ce), neodymium (Nd), europium (Eu), terbium (Tb), ytterbium (Yb), hafnium (Hf), tantalum (Ta), titanium (Ti) and thorium (Th). Out of these 21elements, calcium (Ca), iron (Fe), aluminium (Al), vanadium (V), and sodium (Na) had relatively higher annual mean concentrations in milligram per meter cube than other elements for both Construction Site and Residential area in the following order for the period under study:267013.49±19mg/m^{3}and117620.63±68mg/m^3; 135042.07±56mg/m^3 and49766.76±59mg/m^3; 5898.41±22mg/m^3 and 47946.67±11mg/m^3; 36624.84±15mg/m^3 and 33.50±50mg/m^3; 18564.38±89mg/m^3 and 10064.42±39mg/m^3 and respectively. Calcium (Ca) had the highest annual mean concentration for both Residential Area and Construction Site. The relatively higher annual mean concentration of calcium (Ca), iron (Fe), aluminium (Al), vanadium (V), and sodium (Na) as revealed in this study could possibly be due to their relative abundance in the earth and partly as components of building materials. Annual mean concentrations of 15 out of the 21 elemental components of the particulate matter for Construction Site and Residential Area exceeded the 8-hour total weighted average (TWA) established permissible limits by OSHA and NIOSH. Long-term exposure to very high concentrations of these elements may lead to serious health challenge and short life's span of human being and other living organisms within the environment. This calls for adequate measures to protect construction workers and people whose residences are located few meters from construction

Keywords: Aerosol Particle, Pollution, Construction, Neutron Activation, Analysis

1.1 INTRODUCTION

Research on aerosol particles involves important concepts such as size distribution, mass concentration, elemental or chemical composition of the particulate matter as well as impacts on human's health and environment, but this study focused on the analysis of the elemental components of particulate matter generated from building construction.

Most studies on anthropogenic sources of particulate matter pollution in Nigeria have largely focussed on vehicular emissions (Okerede et al. 2017). This means not much has been done to account for other man-made particulate matter pollution such as construction activities and their elemental compositions.

Measurement of particulate matter with PM monitor, which the bulk of research on PM is based will not identify what kind of elemental components are present in the air and how toxic they are, but will only indicate the concentration and how many airborne particles of a certain size are present in the environment. Therefore, any research that leans towards identification of constituents of particulate matter sample is important, because it will reveal the source, toxicity and the best way possible to address or curb the menace of particulate matter pollution.

1.1.1AEROSOL DYNAMICS

"Aerosol size distribution is an important determinant of the dynamics of aerosol particles in the atmosphere, which include; their transport, residence time and deposition" (Lizaridis, 2011). According to Fan and Zhu (2005), Gaussian distribution, also called normal distribution, the density function is given by

$$f_N(d) = A_N \exp\left(-\frac{(d-do)^2}{2\sigma d^2}\right) \quad \ldots\ldots (1)$$

Where A_N is the normalizing constant; d_o is arithmetic mean of d; and σ_d is the standard deviation of d.

$2\sqrt{]2\sigma}$ is the width of the distribution curve defined as the cord length of two points shown in figure 1.1.

where

$$\frac{f_N(d)}{f_N(do)} = \frac{1}{e} \quad \ldots\ldots (2)$$

The particle size range of a given sample is bounded by d_1 and d_2 as shown in figure 1.1.

Hence, equation 1 can be written as

$$\int_{d1}^{d2} A_N \exp\left(-\frac{(b-d_o)^2}{2\sigma d^2}\right) db = 1 \quad \ldots\ldots 3)$$

This gives

$$A_N = \frac{1}{\sigma_d}\sqrt{\frac{2}{\pi}} \left[\operatorname{erf}\left(\frac{(d_2-d_o)}{\sqrt{2}\sigma_d}\right) + \operatorname{erf}\left(\frac{d_o-d_1}{\sqrt{2}\sigma_d}\right)\right]^{-1} \quad \ldots\ldots (4)$$

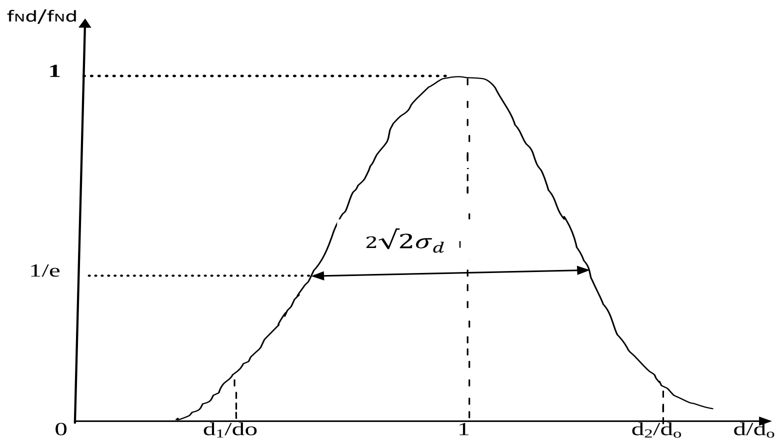

Fig 1.1 Gaussian distribution function

Equation 1 is the number density function. Then, the corresponding mass density function can be written as

$$fM\,(d) = AM\frac{\pi}{6}\ \rho p d^3 \exp\left(-\frac{(d-do)^2}{2\sigma d^2}\right) \text{..(5)}$$

The normalizing constant A_M can be calculated from equation (7), That is,

$$\int_{d1}^{d2} A_M\ \rho p d^3 \exp\left(-\frac{(b-d_o)^2}{2\sigma d^2}\right)db = 1 \text{..(6)}$$

The t expression for A_M but in terms of narrow size distribution where $\sigma d/do \ll 1$, A_N and A_M are given by

$$A_N = \frac{1}{\sqrt{\pi}\sigma_d} \text{..……(7)}$$

and

$$\frac{1}{A_M} \approx \frac{(2\pi)^{3/2}}{6}\rho p\frac{d}{\sigma_d}\left(\frac{3}{2} + \frac{d_o^2}{2\sigma_d^2}\right)\sigma_d^4 \text{.. .... (8)}$$

For particles obeying the Gaussian distribution given by equations 1 and 8. It has been shown that 95percent of the sizes of these particles are between $(-2\sigma_{d} + d_o)$ and ($2\sigma_{d} + d_o$) (Fan and Zhu, 2005).

Particle size: According to Ruzer and Harley (2005), the most important attribute characterizing the properties and behaviour of aerosols is particle size. Studies have shown that certain size ranges of particles is an important factor in determining the adverse health effects associated with them. This was also posited by McDonagh and Byrne (2014) that impacts of aerosol particles on human’s health is primarily governed by the size of particulate pollution.

Particle shape characterisation: One major importance of knowing particle shape is to help in the determination of its flow rate. According to Bumiller (2013), spheres flow more easily than needles. Particle shape and size determines aging, transport, and deposition of particles (Morawska, 1999).

Form factor is a measure of irregularly shaped particles and is defined as:

$$\chi = \frac{4\pi A}{P^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

where A= surface area in meter square, P = perimeter in meter. For spherical particles, $\chi = 1$.

Shape factor is the reciprocal of the form factor and is defined as the aspect ratio:

$\beta = \frac{L}{W}$, where L and w, are length and width, both measured in meters (m);

Settling Velocity: According to Rees (200) "a particle of radius of 1µm will fall at the rate of about 10^{-4} ms^{-1} and a situation in which the particle falls in a completely still air; it will take the particle to fall through a distance of 1 km in 100days".From Stokes' law, the settling velocity is given by;

$$Vs = \frac{2r^2 \rho g}{9\eta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10),$$

where η = viscosity of air; r = radius of particle, v_s = velocity of particle, ρ = density of the particle, and g = acceleration due to gravity respectively.

1.1.2 EFFECTS OF AEROSOL PARTICLE POLLUTION

Aerosol optical properties affect radiation, temperature, atmospheric stability, clouds and precipitation due to their radiative effect (Rocio et al. 2015). Atmospheric particles play some major roles in atmospheric chemistry, especially provision of reaction sites for heterogeneous reactions which ordinarily would not have taken place (Bloss, 2014). Poor visibility affects tourism, air travel, quality of life, property values, and our general wellbeing (BCAQ, 2018). The very fine particulate matter of $PM_{2.5}$ are said to be mostly responsible for the scattering of visible light and a cause of reduced visibility (Sloane et al. 1991). In urban areas, precipitation is believed to increase by the amount of air pollution in the clouds of which some particles (fine ice, pollen or dust) form condensation nuclei or hygroscopic nuclei for water vapour to settle in the atmosphere (British Geographer, 208). From microphysical consideration, some research studies have shown that an increase in aerosol suppresses rainfall (Boucher et al, 2013). "The initial view that an increase in aerosol concentration will also increase the amount of low clouds has been challenged because a number of counteracting processes come into play". More so, 'quantifying the overall impact of aerosols on cloud amounts and properties is understandably difficult' (Boucher et al, 2013).

Another effect of particulate matter pollution is the loss of aesthetic beauty. "When acid rain and dry acidic particles fall to earth, the nitric and sulphuric acid that make the particles acidic can settle on statues, buildings, and damage their surfaces or cause paint and other materials to deteriorate more quickly" (USEPA, 2017). "Exposure to a given mass concentration of airborne PM may lead to widely differing phytotoxic responses, depending on the particular mixture of deposited particles" (Mohapatra and Biswal, 2014).The process of photosynthesis also, is greatly hampered by deposition and accumulation of dust particles on plant leaves. Dusts with pH values of greater than or equal to nine (pH ≥ 9), may cause direct injury to leaf tissues on which they are deposited (Vardak et al, 1995).

1.2 MATERIALS AND METHOD

Study Area: Port-Harcourt is the capital of Rivers state, the garden city of Nigeria and chief oil-refining city in Nigeria due its large oil and gas reserves and contiguous to other oil and gas producing states, namely Bayelsa, Delta, Akwa-Ibom, Abia and Imo. Port-Harcourt is located at the coastal region of Nigeria popularly called 'the Niger Delta' The topography of Port /Harcourt is generally flat and covers an area of 369 kilometres square (km^2) . The geographical coordinates of Port-Harcourt are $4^o 47^{'} 21''$ North and $6^o 59^{'} 55^{''}$ East, and elevation of

52ft (16 meters) above sea level. The Population of Port-Harcourt in urban area based on 2018 population estimate was 2,731,000 *(populationstat.com/nigeria).*

Meteorology of Port Harcourt: Port-Harcourt has a tropical climate since it is located in the tropics. The annual mean temperature of Port- Harcourt is 26.4^{o}C with significant rainfall most of the months. Annual mean Precipitation is put at 2708 mm. The month of January is the driest month, with 36mm of rainfall while February has an average temperature of 27.6 ^{o}C and is said to be warmest month of the year, while August is the coldest month, with mean temperature of 25.2^{o}C *(Climate–Data.org).*

Sampling Point: This sampling point was purposefully chosen because it has a huge building construction activity closed to the residential area.

Collection of Samples: The method of particulate matter (PM) sample collection was by direct deposition under gravity using Whatman filter paper placed inside a plastic funnel at a height of 2 meters above the ground. This PM sample was collected on a monthly basis for a period of 12 months (October, 2017 to September, 2018).

Sample Analyses: Neutron Activation Analysis (NAA) being one of the most sensitive methods used to measure the concentration of trace amounts of many elements in a variety of sample types was employed. The energy associated with the radiation is characteristic of the radioactive isotope, and hence it is used for element identification i.e., qualitative analysis, while the correlation of the number of gamma rays emitted to the number of atoms present in the sample gives quantitative analysis (Landsberger, 2017).

Irradiation: Irradiations were performed at University of Texas, Austin's 1.1 MW TRIGA MARK II Reactor. The block diagram of neutron activation analysis set-up is shown in figure 1.2.

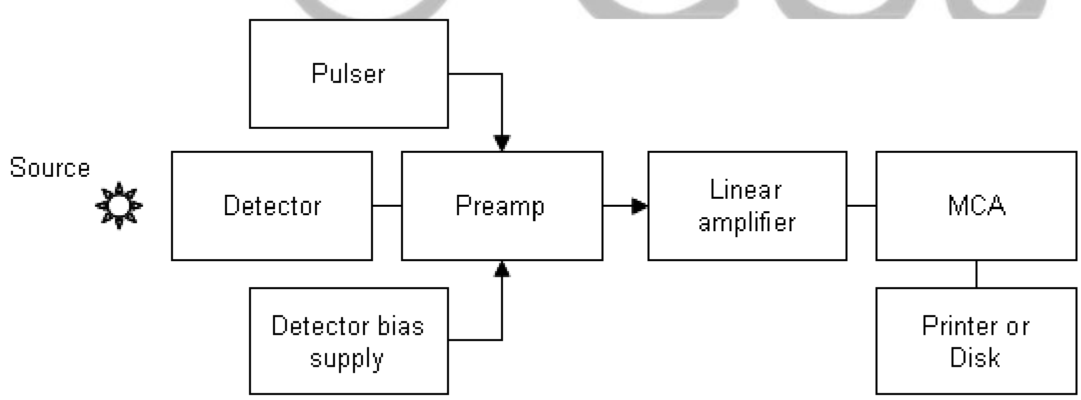

Figure 1.2: Block diagram of neutron activation analysis set-up

Source: University of Texas, Austin's 1.1 MW TRIGA MARK II Reactor

1.3 RESULTS AND DISCUSSION

The Neutron Activation Analyses of the PM samples revealed the presence of twenty one elements which include sodium (Na), aluminium (Al), calcium (Ca), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), rubidium (Rb), zirconium (Zr), caesium (Cs), cerium (Ce), neodymium (Nd), europium (Eu), terbium (Tb), ytterbium (Yb), hafnium (Hf), tantalum (Ta), titanium (Ti) and thorium (Th).

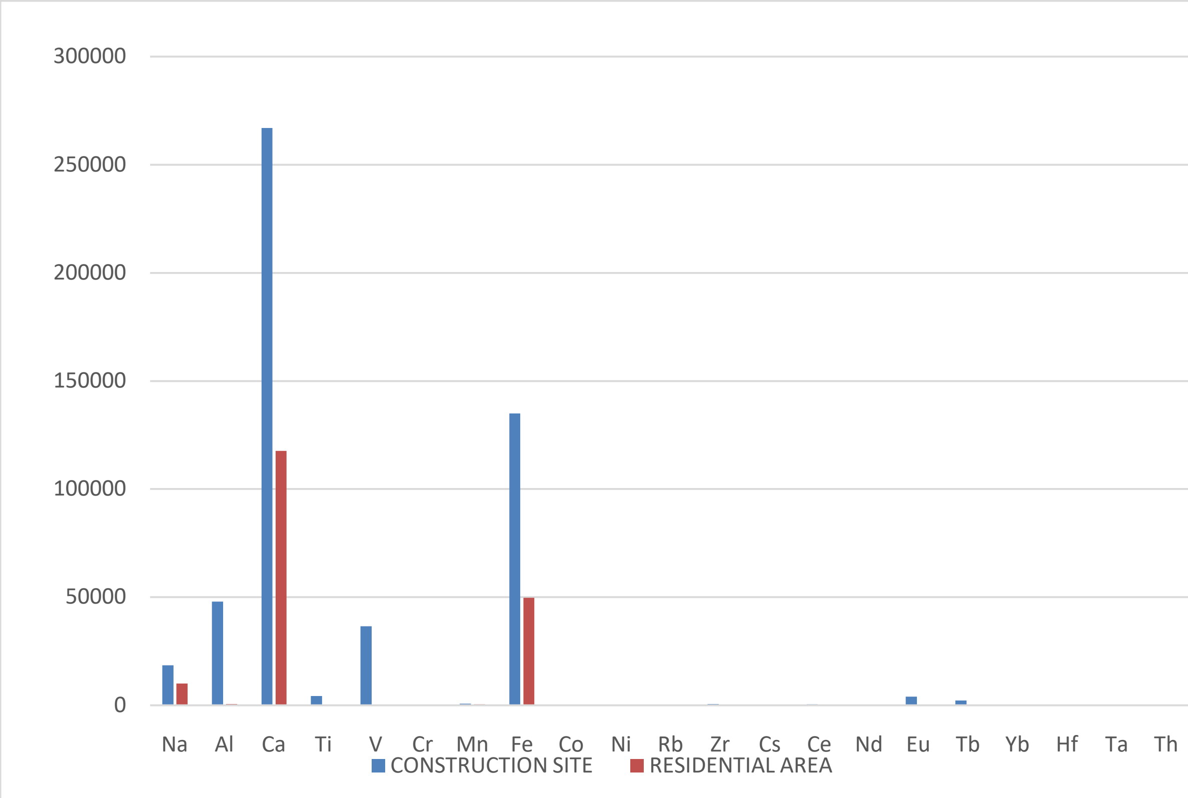

Figure 1.3: Elemental Annual Mean Concentrations for the Construction Site and Residential Area

1.3.1 DISCUSSION

Figure 1.3 represents elemental annual concentrations of the analysed PM for Construction Site and Residential Area of Port-Harcourt city.

The concentration and health implication of each of the elemental components of the particulate matter are discussed below:

Sodium (Na): The annual mean concentrations of sodium for Port-Harcourt Construction Sites and Residential Areas are 18564.38 ± 86mg/m^3 and 10064.42±39mg/m^3 and respectively. The Occupational Safety and Health Administration and American Conference of Governmental Industrial and Hygienist (ACGIH) have not established any occupational permissible limit for sodium metal, but their protective criteria values are PAC-1 = 0.5 mg/m^3, PAC-2 = 5 mg/m^3, and PAC-3 = 50 mg/m^3 (New Jersey Department of Health, 2016). Here, the annual mean concentration of sodium is higher than the PAC value. Sodium is an important element that plays a major role in electrical signal process of the central nervous system, but Centres for Disease Control (CDC) says excess sodium intake can lead to an increased blood pressure and cardiac (heart) problems CDC, 2016). According to Agency for Toxic Substances and Disease Registry (ATSDR), dust, mist, or aerosols containing sodium hydroxide if inhaled can cause irritation of the respiratory tract and throat (ATSDR, 2014). Higher exposure to sodium could possibly lead to pulmonary oedema (build-up of fluid in the lungs), with serious breathing difficulty (NJDH, 2010).

Aluminium (Al): The annual mean concentrations of aluminium for Construction Site and Residential Area are; 47946.67±11mg/m^3 and 5898.41±22mg/m^3 respectively. These concentration values are above NIOSH and OSHA set limits of 5mg/m^3 total weight average (TWA) (CDC, 2018). Aluminium has been identified as the most abundant metal in the earth's crust. Inhaling dust particles containing aluminium can result in irritation and metal fume fever (Bull, 2010). Inhalation of large amounts of aluminium dusts by workers can lead to coughing (ATSDR, 2008).

Aluminium has also been identified as posing a potential risk factor in elderly cognitive impairment (Janssen, 2018).

Calcium (Ca): Calcium concentration annual mean for Construction Site and Residential Area are 267013.49±19mg/m^3 and 117620.63±68mg/m^3 respectively. These concentration values are greater than fNIOSH and OSHA set limits of 5mg/m^3 TWA (CDC, 2018). Excess inhalation of dust particles containing calcium carbonate causes coughing, sneezing and irritation of the nasal mucosal membranes (Edouard, 2015). Breathing in calcium hydroxide through the nose or mouth can cause pain and swelling of the throat and nasal passages which may obstruct respiratory tracts and renders breathing difficult or impossible (Baum, 2019). Inhaling excessive concentrations of calcium oxide particulate matter can cause individuals with respiratory problems such as emphysema (alveolar breakdown) or chronic bronchitis to further degenerate the condition (Chem Watch, 2009).

Vanadium (V): The annual mean concentrations of vanadium for Construction Site and Residential Area are 36624.84±15mg/m^3 and 33.53±5mg/m^3 respectively. These concentration values are higher than NIOSH and OSHA set exposure limits of 50 µg/m^3 TWA for vanadium (CDC, 2018). Commonly reported health cases by workers who are exposed to vanadium due to their occupation are "irritation of the respiratory linings conjunctivitis, dermatitis, cough, bronchospasm, pulmonary congestion, and bronchitis" (Opresko, 1991).

Titanium (Ti): The annual mean concentrations of titanium for Construction Site and Residential Area are 4326.90±38mg/m^3 and 7.30±13mg/m^3 respectively. There is no established exposure limits by OSHA and ACGIH for titanium metal, but these two bodies established 15mg/m^3 averaged over an 8-hour work shift and 10mg/m^3 exposure limit for titanium oxide respectively (NJDH, 2016).

A **r**esearch work in West Virginia University School of Medicine shows epigenetic changes in the heart tissue of rat offering which can culminate into kidney and liver diseases when a pregnant rat is subjected to aerosols containing tiny particles of titanium dioxide(Stapleton et al. 2018)

Chromium (Cr): The annual mean concentrations of chromium for Construction Site and Residential Area are 149.58±2mg/m^3 and 72.30±1mg/m^3 respectively. These concentration values exceed California Division of Occupational and Safety Administration (CalOSHA) set exposure limits of 0.5 mg/m^3 TWA for chromium (CalOSHA, 2018). Large amount of chromium inhalation leads to the obstruction of the airways, irritation, asthma, chronic bronchitis, pharyngitis and ulceration of the mucous nasal membrane (Achmad et al. 2017). Inhalations of chromium compounds by workers who are exposed to them have been reported to suffer from Chromosomal aberrations (Wilbur et al, 2012).

Manganese (Mn): The annual mean concentrations of manganese for Construction Site and Residential Area are 690.29±37mg/m^3 and 489.18±21mg/m^3 respectively. These concentration values are far above California Division of Occupational and Safety Administration (CalOSHA) set exposure limit of 0.2 168mg/m^3 TWA for manganese (CalOSHA, 2018). Studies have shown that exposure to high of manganese results in an increased incidence of pneumonia in rats, pulmonary congestion in monkeys, bronchiolar lesions in rats and neurotoxic effects such as psychiatric and movement disorders in workers (WHO, 2001).

Iron (Fe): The annual mean concentrations of iron for Construction Site and Residential Area 135042.07±56 mg/m^3 and 49766.76 ±59mg/m^3 respectively. These concentration values exceed American Conference of Governmental Industrial and Hygienists (ACGIH) established limit of 5.0 mg/m^3 for iron. According to New Jersey Department of Health and Senior Services exposure to iron oxide during breathing process could lead to flu-like illness and certain symptoms such as metallic taste, fiver, aches, 176]cough and tightness of chest (NJDHS, 2007).

Cobalt (Co): The annual mean concentrations of cobalt for Construction Site and Residential Area are 23.04±0.4mg/m^3 and 13.67±0.3mg/m^{3}respectively. These concentration values are higher than California Division of Occupational and Safety Administration (CalOSHA) of 0.020 mg/m^3 total weight average (TWA) permissible exposure for cobalt (CalOSHA, 2018). Cobalt has been described as the most common cause of occupational asthma (Swarz and King, 2001). Cement has been noted to contain traces of cobalt. Inhaling cobalt containing dust causes skin and the respiratory tract infections, and allergic dermatitis (Lauwerys and Lison, 1994).

Nickel (Ni): The annual mean concentrations of nickel for Construction Site and Residential Area are 153.70±17mg/m^3 and 57.69±10mg/m^3 respectively. These concentration values exceed California Division of Occupational and Safety Administration (CalOSHA) of 0.5 mg/m^3 total weight average (TWA) permissible limit for nickel (CalOSHA, 2018). ATSDR reports on harmful effect of nickel stated that long exposure to nickel, especially those working in nickel processing plants suffer chronic bronchitis, reduced lung function, cancer of the lung and nasal sinus (ATSDR, 2005).

Rubidium (Rb): Inhalation of dust containing rubidium can severely irritate he nasal cavity and respiratory duct (EPSI Metals, 2015). The annual mean concentrations of rubidium for Construction Site and Residential Area are 273.44±84mg/m^3 and 165.93±10 mg/m^3 respectively. These concentration values are 193]above permissible exposure limits of 5mg/m^3 and 10mg/m^3 established by US- Wyoming Toxic and 194]Hazardous Substances and Canada- Prince Edward Island respectively (Chem Watch, 2009).

Zirconium (Zr): The annual mean concentrations of zirconium for Construction Site and Residential Area are 575.69±88mg/m^3 and 19.59±19mg/m^3 respectively. These concentration values exceed 5mg/m^3 average over an 8-hour permissible exposure limit for zirconium (NJDH, 2008). Zirconium is an example of long-lived radionuclide normally released into the atmosphere during nuclear weapon testing and has been noted for causing cancer. When zirconium is inhaled, it is capable of causing irritation of the lungs, coughing and shortness of breath (NJDH, 2018).

Caesium (Cs): The annual mean concentrations of caesium for Construction Site and Residential Area are 30.08±1mg/m^3 and 10.92±0.6mg/m^3 respectively. Annual mean concentration of caesium for construction site is less than 15mg/m^3 total dust permissible exposure limit (PEL), but the Residential Area annual mean concentration value of 30.08±1mg/m^3 exceeds 5mg/m^3 respirable fraction of nuisance dust (Stuarnt Hunt and Associate ltd, 2001). Caesium isotopes are radioactive in nature. Caesium is known to be the most alkaline and most electropositive element (Lentech B.V, 2019). Caesium is liquid at room temperature, including gallium, and mercury (Inhaling Caesium can induce irritation of the lungs, cough and shortness of breath (NJDHS, 2004).

Cerium (Ce): The annual mean concentrations of cerium for Construction Site and Residential Area are 412.50±8mg/m^3 and 137.87±5mg/m^3 respectively. These values of concentration exceed TWA of 15mg/m^3 total dust and 5 mg/m^3 respirable fraction set limits for cerium (Angstron Science, n.d). Breathing in nanoparticles of cerium oxide (CeO_2) into the lungs can cause pulmonary and extra pulmonary toxicity (Srinivas et al, 2014).

Neodymium (Nd): The annual mean concentrations of neodymium for Construction Site and Residential Area are 90.96±24mg/m^3 and 43.32±13mg/m^3 respectively. Neodymium is a rare element and known as the second most abundant of the rare-earth elements (REE). Dust or salts containing neodymium are known to be very irritating to the eyes (Lentech B.V, 2019). Inhaling neodymium dust can lead to lung embolisms, and accumulation due long term exposure damages the liver National Centre for Biotechnology Information (NCBI, 2019). Neodymium has no permissible exposure limit (PEL) but has similar properties like yttrium (Hale and Bun, 1989).

Europium (Eu): The annual mean concentrations of europium Construction Site and Residential Area are 3945.40±26mg/m^3 and 3.61±1mg/m^3 respectively. There is no established set limit by OSHA, NIOSH or ACGIH for europium (Barbalace, 2019). There is permissible limit of 2.6 mg/m^3 on its nitric compound (Roth, 2016). Europium causes irritation of the respiratory tract if inhaled (EPSI Metals, 2016). Inhaling europium or its nitrate may cause itching, sensitivity to heat, and an increased awareness of odour and taste (NCBI, 2019).

Terbium (Tb): The annual mean concentrations of terbium for Construction Site and Residential Area are 1.25±0.4mg/m^3 and 2228.95±0.7mg/m^3 respectively. There is no set limit by NIOSH for terbium (Barbalace, 2019). Terbium is a stable element but its dust can cause fire and explosion (Rim et al, 2013). Terbium is said to have no serious environmental threat to plants or animals (Lentech B.V, 2019).

Ytterbium (Yb): The annual mean concentrations of Ytterbium for Construction Site and Residential Area are 3.45±0.9mg/m^3 and 6.52±1.4mg/m^3 respectively. According to EPSI Metals exposure or permissible limit for ytterbium has not been established by OSHA or ACGIH (EPSI Metals, 2015). Ytterbium, a rare cause irritation to respiratory linings and mucous membrane. Other health challenges associated with inhalation of ytterbium include lung granulomas, asthma, writhing, and loss of muscle coordination, difficult respiration, sedation, hypotension and cardiovascular degeneration (EPSI Metals, 2010).

Hafnium (Hf): The annual mean concentrations of hafnium for Construction Sites and Residential Area are 34.31±0.9mg/m^3 and 25.73±0.6mg/m^3 respectively. According to CDC, OSHA established exposure limit for hafnium is 0.5mg/m^3 TWA, but the annual mean concentrations of both cities under study exceeded this value (CDC, 2018). Breathing in hafnium may result in the irritation of the mucous membranes, nose, and throat and could cause irritation when it is in contact with the eye (Dierks, 2003). Hafnium has been described as posing no serious environmental risk in its provided form but if its tiny particles are dispersed in the air may lead to explosion hazard (Kurt J. Lesker Company, 2017).

Tantalum (Ta): The annual mean concentrations of tantalum for Construction Sites and Residential Areas are 10.16±0.8mg/m^3 and 4.34±0.4mg/m^3 respectively. The permissible limit established by CalOSHA for \tantalum is 5mg/m3. Tantalum is a transition element. Tantalum, under normal condition does not pose serious environmental or health problems but its fine particles contribute to air pollution (Element Database, 2015). Tantalum may cause respiratory irritation if inhaled (Bolton, 2012).

Thorium (Th): The annual mean concentrations of thorium for Construction Sites and Residential Areas are 79.20±0.8mg/m^3 and 35.37±0.4mg/m^3 respectively. The annual mean concentrations of thorium for both construction site and residential area exceed the OSHA, ACGIH and NIOSH permissible limits. The OSHA, ACGIH and NIOSH set the exposure limits of thorium at 0.2mg/m^3 TWA and 0.6mg/m^3 for short term exposure limit (STEL) (International Bio-Analytical Industries, Labs, 2014). Thorium is an example of actinide in the periodic table. Those elements classified as actinides are said to be radioactive (Helmenstein, 2018). Thorium is a naturally occurring radioactive element of the family line of uranium decay process. “Inhaling thorium dust increases the risk of lung and pancreatic cancer” (NIH , n.d) . Thorium is said to be highly toxic both by inhalation and ingestion (IBAl IL. 2014).

Comparing the elemental annual mean concentrations between the Construction Site and Residential Area as indicated by the blue and dark red bars in figure 2, only four elements namely; aluminium (Al), titanium (Ti), europium (Eu) and zirconium (Zr) from particulate matter samples collected at Construction Site have higher annual mean concentrations than that of Residential Area, while seventeen elements namely; sodium (Na), calcium (Ca), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), rubidium (Rb), caesium (Caesium (Cs), Cerium (Ce), neodymium (Nd), terbium (b), ytterbium (Yb), hafnium (Hf), tantalum (Ta), and thorium (Th) from particulate matter samples collected at Residential Area have higher annual mean concentrations than that of Construction Site. This large difference in elemental annual mean of these two sampling sites could be attributed to some certain atmospheric conditions such as wind direction and seasonal variation, and other human activities such as the use of fossil fuel within the residential area.

1.4 CONCLUSION

A review of particulate matter studies in Nigeria, from 1985 – 2015 by Offor et al revealed that the “order of the average highest concentrations of metallic elements for $PM_{2.5}$ were magnesium (Mg) > strontium >(Sr) potassium (K) > zinc (Zn) > iron (Fe) > sodium (Na) > aluminium (Al) > chlorine (Cl) > lead (Pb) >silicon (Si), while those of PM_{10} were Sr > Zn > Fe > Mg > calcium (Ca) >Na > Pb > manganese (Mn) >K > Al”(Offor et al. 2016). Comparing the order of concentrations of these elements with the ones obtained in this study, particularly aluminium and calcium, one could observe that the concentrations of aluminium (Al) and calcium (Ca) from particulate matter collected at construction site were higher than those from the review of particulate matter studies in Nigeria, from 1985 – 2015 by Offor et al. Based on Okerede et al submission, it means that the bulk of these elemental constituents could possibly emanate from studies of vehicular emissions (Okerede et al. 2017).

In this study, out of the 21 elemental components of the particulate matter from the NAA, calcium (Ca), iron(Fe), aluminium (Al), vanadium (V), and sodium (Na) had relatively higher annual mean concentrations in milligram per meter cube than other elements for both construction site and residential area in the following order for the period under study; 267013.49±19mg/m^3 and 17620.63±68mg/m^3; 135042.07±56mg/$m^{3/}$ and 49766.76±59mg/m^3; 47946.67±11mg/m^3 and 5898.41±23mg/m^3;36624.84±15mg/$m^3$and 33.53±5.5mg/m^3; and 18564.38±86 mg/m^3 and 10064.42±39 mg/m^3.

The relatively high concentrations of calcium (Ca), iron (Fe), aluminium (Al), vanadium (V), and sodium (Na) as revealed in this study could possibly be due to their relative abundance in the earth and partly as components of building materials. For instance, calcium is a component of raw material for cement production and vanadium serves as a pigment in the manufacturing of glass and ceramics.

More so, the annual mean concentrations of 15 out of the 21 elemental components of the particulate matter for Construction Sites and Residential Area exceeded their established permissible or exposure limits.

Finally, long-term exposure to very high concentrations of these elements may lead to serious health challenge and short life's span of human being and other living organisms within the environment. Hence, the need for adequate measures to protect construction workers and people living near construction sites.

ACKNOWLEDGEMENTS

We sincerely thank Tertiary Education Trust Fund (TETFund) for sponsoring a 3-month bench work of this research at The Nuclear Engineering Teaching Lab., J.J Pickle Research Campus, University of Texas at Austin, USA. Thanks to Dr. Sheldon Landsberger (Texas Atomic Energy Research Foundation Professorship, Area Coordinator, Nuclear and Radiation Engineering Program) for directing the whole process for a successful bench work. Thanks also go to Colin R. Brennan, Dana Judson, Miana N. Tran, and all staff of the Nuclear Engineering Teaching Lab (NETL) for their immense assistance. Thanks to the Management of Ignatius Ajuru University of Education, Port- Harcourt for making the sponsorship possible.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). (2014).Medical Management Guidelines for Sodium Hydroxide (NaOH). *https://www.atsdr.cdc.gov/MMG/MMG.asp?id=246&tid=45* (Accessed 25 February, 2019)**.**

Agency for Toxic Substances and Disease Registry (ATSDR, (2008). Aluminium-ToxFAQsTM. https://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=190&tid=34(Accessed 25 February, 2019).

Achmad, R., Budiawan, B & Auerkari, E. (2017). Effects of cchromium on hhuman body. *Annual Research & Review in Biology. 13(2), pp.1-8. 10.9734/ARRB/2017/33462.*

Angstron Sciences (n.d). Material Safety Data Sheet. Retrieved from Angstromsciences.com.

ATSDR. (2005). Public health statement for nickel. Toxic Substances Portal-Nickel. https://www.atsdr.cdc.gov/phs/phs.asp?id=243&tid=44 (Accessed 4 March, 2019).

British Colombia Air Quality. (2018).Visibility.http://www.env.gov.bc. ca/epd/bcairquality/topics/visibility .html (Accessed 17 June, 2018).

Bloss, W. (2014). Atmospheric particulate matter. ECG Environmental Briefs, ECGEB No. 4. School of Geography, Earth and Environmental Sciences, University of Birmingham.

British Geographer. (2018). Urban climate. http://thebritishgeographer.weebly.com/urban-climates.html (Accessed 18 June, 2018).

Boucher, O., Randall, D., Artaxo, P., Bretherton, C., Feingold, G., Forster, P., Kerminen, V.M., Kondo, Y., & Zhang, X.Y.(2013).Clouds and aaerosols in climate change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, and G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Bull, S. (2010). Aluminium-General information. *https://assets. publishing.service.gov.uk/government/uploads /system/uploads/attac*(Accessed 25 February, 2019)

Baum, J. (2019).What are the dangers of calcium hydroxide? *https:// www.livestrong.com/article/182626-what-are-the-dangers-of-calcium-hydroxide/* (Accessed 16 June, 2019).

Barbalace, L. K. (2019). Element-Eu. *environmentalchemistry.com* (Accessed 11 May, 2019).

Bolton, E. (2012).Tantalum metal pieces. *Safety Data Sheet. https://louisville.edu/micronano/files/documents/ safety-data-sheets-sds/Tapieces.pdf*(Accessed 10 March, 2019).;

Bumiller, M. (2013). The Importance of article Shape. Horiba Scientific. Retrieved May 11th, 2019 from https://www.slideshare.net/HORIBA/importance-of-particle-shape.

Centres for Disease Control and Prevention (CDC). (2016). New research: Excess sodium intake remains common in the Un*ited* States. *https://www.cdc.gov/ media/releases/2016/p0106-sodium-intake.htm* (Accessed 25 February, 2019)..

Center for Disease Control and Prevention, (2018). Calcium carbonate.*https;//www.cdc.gov*(Accessed 12 May, 2019).

ChemWatch. (2009). Calcium oxide. *Material Safety Data Sheet.*

California Division of Occupational and Safety Administration (CalOSHA). (2018). Table AC-1. *https://www.dir.ca.gov* (Accessed 11 May, 2019).

Dierks,S.(200*3).*Material safety data Sheet. *https://research.utdallas.edu/cleanroom/app/uploads/2014/12/ hafnium.pdf* (Accessed 17 March, 2019).

Edouard, B. M. D. (2015). Calcium carbonate toxicology. *Occupational & Environmental Medicine. https://digitalfire.comsight/hazardsceramic_hazar_calcium_toxicology_343.html*(Accessed 26 February, 2019).

EPSI Metals. (2015). Rubidium. *Safety Data Sheet*. http://www.espimetal.com/index.php/msds/236-rubidium. (Accessed 4 March, 2019).

EPSI Metals. (2016). Europium. Safety Data Sheet. *http://www.espimetals.comindex.phpmsds/130-europium* (Accessed15March, 2019).

Elements Database. (2015).Tantalum. http://www.elementsdatabase.-element/Ta-73 (Accessed 17 March, 2019).

EPSI metals. (2010).Ytterbium Oxide. Material Safety Data Sheet http://www.espimetals.com/index.php/755-msds/ytterbium-oxide/770-ytterbium (Accessed 15 March, 2019);

Fan, L. & Zhu, C. (2005).Principle of Gas –Solid Flows. Cambridge University Press, New York.

Hales, R & Bun, A. G. (1989).Health Hazard Evaluation. NOISH. https://www.cdc.gov/niosh (Accessed 11 May, 2019).

Helmenstine, M. A. (2018). Actinides (actinide series) properties and reaction of the actinide series elements. *https://www.thoughtco.com/Actinides-606643* (Accessed 10 March, 2019).

International Bio-Analytical Industries, Labs.(2014).Thorium metal. *Safety Data Sheet. ibilabs.com/msds/thorium-compounds-msds/thorium metal-msds/* (Accessed 21 May, 2019

Janssen, N. (2018).Rueful rainfall linked to aerosols. *https://researchmatters.innewsrueful-rainfall-linked-aerosols*(Accessed 17 December, 2018).

Kurt J. Lesker Company. (2017). Hafnium pieces. *Safety Data Sheet*. *http://www.nano.pitt.edusites/defaultfiles MSDS/MetalsHf-Hafnium.pdf*(Accessed 17 March, 2019).

Landsberger, S. (2017). Nuclear and radiation academic program. University of Texas, Austin, Texas.

Lenntech, B.V. (2019). Chemical properties of caesium-health effects of caesium environmental effects of caesium. https://www.lenntech.com periodic/elements*cs.htm* (Accessed 17 March, 2019).

Lauwerys, R., Lison, D. (1994). Health risks associated with cobalt exposure--an overview. *Sci Total Environ*. 150 (1-3), 1-6.;

Lizaridis, M. (2011). First Principle of Meteorology and Air Pollution, Springer, Spain.

McDonagh, A & Byrne, M. A. (2014).A study of the size distribution of aerosol particles resuspended from Clothing Surfaces. *Journal of Aerosol Science.* 75(10), 94 – 103.

Mohapatra, K & Biswal, K. S (2014). Effect of particulate matter (PM) on plants, climate, ecosystem and human health. *International Journal of Advanced Technology in Engineering and Science*. 2(4), 118 – 129. ;

Morawska, L. (1999). Environmental Aerosol Physics. Queensland University of Technology Bribane, Australia.

New Jersey Department of Health.(2016).Titanium. Hazardous Substance Fact Sheet. Retrieved May 21st, 2019 from *nj.gov>eoh>rtkweb>documents*.

New Jersey Department of Health. (2010). Sodium. *Hazardous Substance Fact Sheet*. *nj.gov>eoh>rtkweb>documents*(Accessed 21 May, 201).

New Jersey Department of Health and Senior Services. (2007). Iron Oxide. *Hazardous Iron Fact Sheet.* https://nj.gov/health/eoh/rtkweb/*documents/fs/1036.pdf*(Accessed 4 March, 2019).

New Jersey Department of Health.(2008). Zirconium. *Hazardous Substance Fact Sheet nj.gov>eoh>rtkweb>documents.*(Accessed 11 May, 2019).

New Jersey Department of Health.(2018). Zirconium. Zirconium Fact Sheet.*https://nj.gov/health/eoh/rtkweb /documents/fs/2047.pdf* (Accessed 4 March, 2019).

National Centre for Biotechnology Information. (2019). PubChem compound data base; 2019 CID=23934. *https://pubchem.ncbi.nlm.nih.gov/compound/23934* (Accessed 15 March, 2019).

New Jersey Department of Health and Senior Services. (2004).Caesium. *Hazardous Substance Fact Sheet*. *https://nj.gov/health/eoh/rtkweb/documents/ fs/0353.pdf* (Accessed 19 March, 2019).

National Institute of Standards and Technology.(2006). Material and Safety Data Sheet.*https://ehslegacy.unr.ed u/msdsfiles/25013.pdf* (Accessed 15 March, 2019).

National Institutes of Health. (n.d). Respiratory tract. *https:// toxtutor.nlm.nih.gov/10-003.html*(Accessed 29 March, 2019).

Okerede, B.O., Fakinle, S. B., Sonibare, A.J. Elehinafe, B. F & Adesina, A.O. (2017). Particulate matter pollution from open burning of sawdust in South Western Nigeria. *Cogent Environmental Science*. 3(1).

Opresko, M. D.(1991).Chemical hazard evaluation and communication group, Biomedical and environmental information analysis section. *Health and Safety Research Division*, Oak Ridge, Tennessee

Offor, F. I., Adie, U. G & Ana, R. G. (2016). Review of particulate matter and elemental composition of aerosols at selected locations in Nigeria from 1985–2015. *Journal of Health and Pollution*.6 (10), 1–18.

Pierce, S. (2019).What is ytterbium? - uses, compounds & facts. *https://study.com/academy/lesson/what-is-ytterbium-uses-compounds-facts.html*(Accessed 16 March, 2019).

Rees, W. G. (2001). Physical Principles of Remote Sensing. Cambridge University Press.

Rocio, B., Raquel, L., Sonia, J., Pedro, J.M., Pedro, J. (2015). Are atmospheric aerosols able to modify the surface winds? A sensitivity study of the biomass burning aerosols impact on the spatially-distributed wind over Europe. *EGU General Assembly 2015. 17, EGU2015-8963, 2015.*

Rim, T.K., Koo, H.K., Park, S.J. (2013). Toxicological evaluations of rare earths and their health Impacts to workers: A literature review. *Safety Health Work.* 4(1), 12–26.

Roth, C. (2016). *Safety Data Sheet-Fisher Scientific*. https://www.carlrothcom>sdb>SDB_2.. (Accessed 21 May, 2019).

Ruzer, S. V., and Harley, H. N. (2005). Aerosol Handbook: Measurement Dosimetry and Health Effects. CRS Press, USA.

Sloane, S.C., Watson, J., Chow, J., Pritchett, L & Richards, W.(1991). Size-segregated fine particle measurements by chemical species and their impact on visibility impairment in Denver. *Elsevier B.V*. 25 (5–6), 1013-1024.

Stapleton, A. P., Hathaway, A. Q., Nichols, E. C., Abukabda, B.A., Pinti, V. M., Shephered, L. D., McBride, R.C., ...& Nurwicz, T.R. (2018).Maternal engineered nanomaterial inhalation during gestation alters the fetal transcriptome.. *Part Fibre Toxicol. 2018; 15:3.Doi: 10.11861s12989-017-0239-8.*

Stuart Hunt and Associates ltd. (2001). *Radioactive Data Safety Sheets*. www.stuarthunt.com(Accessed 11 May, 2019).

Swarz, I. M & King. E.T, (2001). Interstitial lung disease. *People's Medical Publishing House-USA Shelton*, Connecticut.

Srinivas, A., Selvam, G., Saikumar, M., Goparaju, A & Balakrishna, M. P. (2014).Toxicity and bio-accumulation of inhaled cerium oxide nanoparticles in CD1 mice, *Nanotoxicology*, 8(7), 786 798.

USEPA. (2017). Effects of Acid Rain. *https://www.epa.gov/acidrain/ effects-acid-rain#materials*(Accessed 21 June, 2018).

Vardaka, E., Cook, C.M., Lanaras, T., Lanaras, T., Sgardelis, S.P & Pantis, J.D. (1995). Effect of dust from a llimestone Quarry on the photosynthesis of *Quercus coccifera*, and evergreen *Sclerophyllous* Shrub. *Bulletin of Environmental Contamination and Toxicology,* 54: 414-419.

Wilbur, S., Abadin, H., Fay, M. (2012). Toxicological profile for chromium. *Atlanta (GA): Agency for Toxic Substances and Disease Registry (US)*; 2012 Sep. 3, Health Effects.*https://wwwncbi.nlmnih.gov/ books/NBK158851/*(Accessed 3 February, 2019).

WHO. (2001).Manganese. Air quality guidelines, Copenhagen, Denmark, 2001. *http://www.euro.who.int/_data /assets/pdf_file/0003/123078/ AQG2ndEd_6_8Manganese.pdf*(Accessed 4 March, 2019).