African Journal of Environment and Natural Science Research
ISSN: 2689-9434
Volume 9, Issue 2, 2026 (pp. 80-95)
www.abjournals.org

ASSESSMENT OF METALS/METALLOIDS IN STONE QUARRYING RESPIRABLE DUST IN JOS SOUTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

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Cite this article:

G. M., Mafuyai, M. S., Ayuba, A. P., Lungaku (2026), Assessment of Metals/Metalloids in Stone Quarrying Respirable Dust in Jos South Local Government Area, Plateau State, Nigeria. African Journal of Environment and Natural Science Research 9(2), 80-95. DOI: 10.52589/AJENSR-35EOSJGQ

Manuscript History

Received: 2 Mar 2026

Accepted: 1 Apr 2026

Published: 13 May 2026

ABSTRACT: *Environmental pollution is one of the factors responsible for global mortality and morbidity due to human exposure metals/metalloids, Respirable exposure to toxic chemicals through anthropogenic activities. Quarrying is a form of mining activity with associated environmental and health consequences; the extraction processes cause the release of respirable dust containing heavy metals into the air, soil, and groundwater. In this study, we determined the impact of quarry on the concentrations metals/metalloids in respirable dust (Ar, Cd, Pb, Mn, Zn, Co, Cu, Fe, Ni and Cr) in five quarry sites (RQ, GQ, DQ, LQ and ZQ) in Jos South Local Government Area of Plateau State, Nigeria using Atomic Absorption Spectrophotometer (Agilent Technologies 200 series). The concentration of dust in morning and afternoon sessions was in the increasing order of RQ < DQ < LQ < GQ < ZQ and RQ < GQ < DQ < LQ < ZQ, respectively. The enrichment and Igeo values revealed significant metals/metalloids, in the quarry dust.*

KEYWORDS: Dust, Enrichment, Igeo-accumulation, metals/metalloids, Respirable, Quarrying.

Article DOI: 10.52589/AJENSR-35EOSJGQ
DOI URL: https://doi.org/10.52589/AJENSR-35EOSJGQ

INTRODUCTION

Quarries dust pollution has posed various health risks to workers, including respiratory ailments and skin and eye problems. Depending on the dust's chemical composition and concentration, workers are exposed to it through inhalation, putting them at risk of developing a fatal lung disease. Over a quarter of burden diseases are linked to environmental issues, including overexposure to pollutants from both natural and anthropogenic activities (Pruss–Ustun *et al.*, 2016; Prodanova *et al.,* 2023). Health effects associated with quarrying activities are notable; the impact of noise pollution from rock blasting operations includes stress, discomfort, shock, increased pulse rate, sleep loss, fatigue, and hearing damage (Akinluyi *et al.,* 2019).

Stone quarrying is an unorganized sector that and stones (Bama *et al.,* 2023). It can be regarded as an open–pit surface mining method, in which rocks or minerals are extracted using mechanized or artisanal methods, with simple tools (Jimoh, 2023; Nwachukwu *et al.*, 2018; Felix & Mohammed, 2016). Even though artisanal quarrying is a form of small-scale mining that is unauthorized by the Government, it is significant as a means of sustenance for local and poor people.

Quarrying is a multistage process in which rock is extracted from the ground and crushed to produce aggregate, which is then screened into desired sizes for immediate use or further processing into secondary products.

(www.northstonematerials.com/filestore/documents/aggregate).

Aggregate resources are vital to our way of life because they are the primary raw materials used in the construction of roads, rail lines, bridges, hospitals, schools, airports, factories, and homes (Langer *et al.,* 2004).

The quarry industry is important because it positively impacts the country's economic development, serving as a source of construction materials, generating government revenue through taxation and royalties, and providing employment, especially for the rural population (Divya *et al.,* 2012). The industry also provides employment opportunities for both skilled and unskilled workers, thereby supporting many urban and rural families by contributing to their livelihoods and socio-economic well-being (Wells, 2000).

Though dust generated by these aggregates affects the lives around them, the demand for their resources is vital to our way of life because they are the major raw materials used in the construction of roads, rail lines, bridges, hospitals, schools, airports, factories, and homes (Langer et al., 2004). It generates dust particles that have heavy metals, silica, and organic solvents with different aerodynamic diameters ranging between 1 and 100 microns (Sharma *et al.,* 2018; Olusegun *et al.,* 2009)

Quarrying produces significant fugitive dust emissions from drilling and blasting, crushing, transportation, and stockpiling of crushed stone (Langer *et al.,* 2004). These activities generate significant dust particles that have heavy metals/metalloids, silica, and organic solvents with different aerodynamic diameters ranging between 1 and 100 microns

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(Sharma *et al.,* 2018; Olusegun *et al.,* 2009). Dust from stone quarries is a major air pollutant and contains particulate matter with diameters of 1–60 µm (USEPA, 2008; Nobel *et al*., 2016), which can be fugitive, inhalable, thoracic, mineral, or respirable dust.

Respirable dust is the smallest in size ($PM_{2.5}$). It is more problematic because of deep penetration into human alveoli causing adverse health challenges in quarry workers and host communities when the threshold value 5µg/m3, while 24hrs average exposure should not exceed15µg/m3 more than 3-4 days per year (WHO, 2021; Sairanen *et al*., 2018; Katra, 2019; Tripathy and Dash,2018). Air pollution accounted for 8.1 million deaths globally in 2021, becoming the second leading cause of death, including among children under five, due to fine particulate matter ($PM_{2.5}$) pollution (UNICEF, 2024). Nine out of ten people breathe air with high levels of pollutants. Studies have shown a strong association between respirable dust and metals (Pramod *et al*., 2011., Obi, 2002), and also Trace metals/metalloids are associated with chronic diseases such as cardiovascular, diabetes, and cancer (Xun *et al.,* 2010). It is also reported that exposure to quarry dust without proper protection can even cause lung cancer, which could be prevented if proper precautions were provided by employers. Exposure to quarry dust without proper protection was reported to even cause lung cancer, which could be prevented if proper precautions were provided by employers (Bama *et al.,* 2023).

The major health concern is Respirable dust, which lodges various chemical substances in the human lungs, thereby causing respiratory and pulmonary damage such as silicosis and increasing the risk of other lung diseases, including bronchitis, pneumonia, tuberculosis, and lung cancer (Odeyemi *et al.*, 2020; Last, 1998). (Galloway, 2007), while dust deposition causes skin and eye problems (Ugbogu *et al.,* 2009). Over nine million premature deaths are attributed to pollution-related diseases, and nearly four million people in developing countries die each year from environmental pollution emanating from quarrying activities (Odeyemi *et al.*, 2020).

Heavy metals are ubiquitous natural components of the earth's crust with high-density metallic chemical elements that are toxic at low concentrations (Adams et al., 2024; Koller and Saleh, 2018; Lentech, 2020). Examples of these metals include Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Manganese (Mn), and Lead (Pb).

They are toxic, non-biodegradable elements present in the rock and soil, and their concentration increases around quarry sites, potentially contaminating surrounding soil and water systems. (Bama *et al.,* 2023; Dentoni *et al.,* 2023).

The growing apprehension about the potential for exposure to Heavy Metals around the world, due to drastic increase in their output worldwide as a result of their routine quarrying, mineral exploration, mining, infrastructure construction, industries, metal technology (Wells, 2000). Nearly 4 million people in developing countries die each year due to environmental pollution emanating from quarrying, sandblasting, and emission of dangerous chemicals (Oyinloye and Olofinyo, 2017).

One of the major elements of health concern found in quarry dust is silicon, normally inhaled as crystalline silica, which lodges in human lungs, thereby causing respiratory and pulmonary damage such as silicosis, bronchitis, pneumonia, tuberculosis, and lung cancer (Last, 1998). The silica-related diseases are preventable, although once present, they are incurable. The National Institute of Occupational Safety and Health (NIOSH, 2002) recommends an exposure limit of 0.005g/m3for respirable quartz-bearing silica. Long exposure to crystalline silica

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ISSN: 2689-9434

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causes silicosis or other severe respiratory illnesses due to high concentrations of the respirable silica particles in dust (Langer *et al.,* 2004).

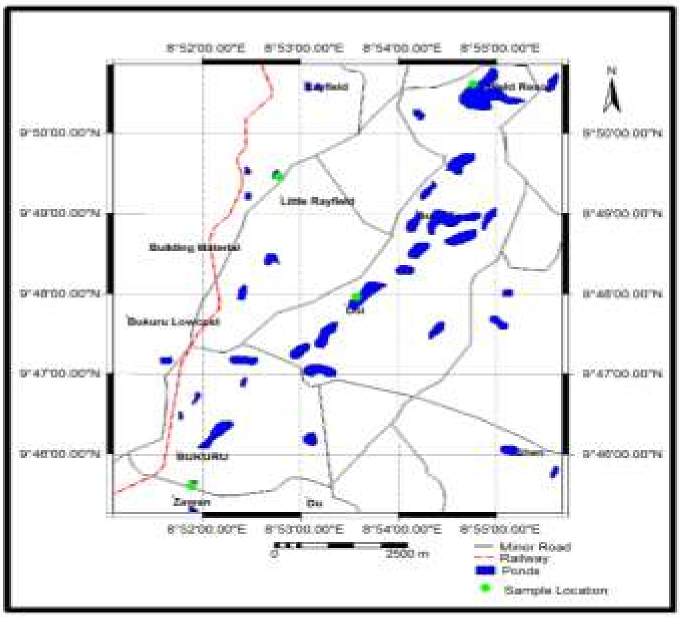
The crushed stone quarries in Jos, South Plateau State, produce high concentrations of dust and therefore, expose the workers to various respiratory and pulmonary diseases due to dust inhalation. The dust also contains trace elements that have devastating effects on human health, since toxicity and the resultant threat to human health are usually a function of the concentration of these metals/metalloids in the environment. When deposited on the skin and in the eyes, the dust may cause skin and eye irritation depending on the chemical composition and the concentration of the dust. Air pollution not only affects the respiratory system but also poses significant risks to cardiovascular health. Studies have shown that long-term exposure to air pollutants increases the incidence of heart attacks, strokes, and other cardiovascular diseases. Therefore, monitoring dust and the level of metals/metalloids is important to ascertain their concentration in quarrying the respirable dust.

METHODOLOGY

Study Area

Jos-South is a local Government Area in Plateau State, Nigeria. It is located in the North Central part of the State. The study areas lie between longitude 9°43’ 21.5’’N to 9°50’ 49.5"N and latitude 8°51’ 0.19’’E to 8°52’ 42.9’’E and this covers an area of about 510 km^2 in terms of land mass. According to the National Population Commission NPC, (2006), the studied area has an estimated population of three hundred and six thousand seven hundred and sixteen (306,716) people who were inhabitants of the area. The study areas played host to a lot of mining and quarrying activities by foreign companies and some indigenous ones.

Figure 1: Map of Jos -South Local Government Area Showing the Quarry Sites.



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Sampling of Dust

A respirable dust sampler was used for monitoring of dust for both morning and afternoon sessions. The respirable dust sampler (Envirotech APM 460BL) was set, marked, and a pre-weighed filter paper was placed between the top cover of the filter adaptor assembly of the machine. The filter cover was closed, and the respirable dust sampler was switched on, taking note of the time. The filter paper was removed after 8 hours and reweighed to obtain the weight after exposure. The volume of sampled air was obtained from the flow–meter reading and sampling time. Samples were taken from five different sites (RQ, DQ, LQ, GQ and ZQ) in triplicate for five days. The concentration of dust was obtained using the mathematical expression

$$RD\ \mu g/m^3 = \left(\frac{M2 - M1}{V}\right) \times 10^6$$

Where RD = Mass concentration of dust in $\mu g/m^3$

M_1 – Initial mass of filter paper in grams

M_2 – Final mass of filter paper in grams

10^6 – Conversion Factor

V – Volume of sampled air in m^3 calculated as V = QT

Q – Average airflow in m^3/min

T – Sampling time

This same procedure was followed for control samples obtained from the same sites where there were no quarrying activities for both morning and afternoon sessions.

Preparation and Determination of Metals/Metalloids

The dust collected was digested with 10mL of digestion mixture in the ratio of 1:2:2 Perchloric acid, Nitric acid, and Sulphuric acid respectively, and heated on the hot plate in a fume cupboard. The cooled samples were diluted with 20mL of de-ionized water and made up to 100mL in a volumetric flask, then transferred into a plastic sample bottle. Blank was also prepared similarly without a sample. The digested filtrates were then analyzed using an Atomic Absorption Spectrophotometer (Agilent Technologies 200 series).

Geo-accumulation Index (Igeo)

To quantify the degree of metal contamination in the roadside dust, the geo-accumulation index (Igeo) was calculated based on the formula.

$$Igeo = \log_2 \frac{Cn}{1.5\ Bn}$$

Where Cn = metal concentration in the roadside dust and Bn = concentration in unpolluted soil. Due to the non-availability of the studied heavy metals in background soil dust, Igeo was calculated using the global average shale data (Doung & Lee, 2011). The 1.5 is a factor used because of the possible variations of the background data due to lithological variations. This

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method assessed the metal pollution in terms of seven (0 to 6) enrichment classes ranging from background concentration to very heavily polluted as follows.

Table 1. The Igeo Classes with Respect to Dust Quality

Igeo value	Igeo class	Designation of soil quality
> 5	6	Extremely contaminated
4 – 5	5	Strongly to extremely contaminated
3 – 4	4	Strongly contaminated
2 – 3	3	Moderately to strongly contaminated
1 – 2	2	Moderately contaminated
0 – 1	1	Uncontaminated to moderately contaminated
0	0	Uncontaminated

Enrichment Factor (EF)

This is used to evaluate the anthropogenic impact of heavy metals and is calculated by comparison of each tested metal concentration with that of the reference metals in samples. The regularly used metals are Mn, Al, and Fe. EF has been studied by Hassan *et al.*, 2016).

$$EF = \frac{\frac{M}{Fe}Sample}{\frac{M}{Fe}Background}$$

where EF = Enrichment Factor

M/Fe Sample = The ratio of metal and Fe concentration of the sample

M/Fe Background = The ratio of metal and Fe concentration of the background

Table 2: Classes of Enrichment Values

Value	Soil Dust Quality
EF < 2	Deficiency to minimal enrichment
2 < EF < 5	Moderate enrichment
5 < EF < 20	Significant enrichment
20 < EF < 40	Very high enrichment
EF > 40	Extremely high enrichment

Source: Zazouli *et al.* (2021)

Quality Assurance

Appropriate quality assurance procedures and preparations were carried out to ensure the reliability of the results. Double-distilled deionized water was used throughout the study. Glassware was properly cleaned, and the reagents were of analytical grade. Reagent blank determination was used to correct instrument readings with standard reference materials. The coefficient of variation of replicate analysis was determined for the measurement to calculate the analytical precision.

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Statistical Analysis

The mean and standard deviation of the analysis were calculated using the Statistical Program for Social Sciences Version 26.

RESULTS AND DISCUSSION

Respirable Dust

The mean values of the mass of dust in each sampling site, along with their standard deviations, are presented in Table 3. The concentration of dust in the morning and afternoon, respectively, in the increasing order of RQ < DQ < LQ < GQ < ZQ, while for the afternoon sessions, RQ < GQ < DQ < LQ < ZQ. The total mass of respirable dust (<10μm) collected in ZQ was the highest in both morning and afternoon, 3.6580±0.002 and 1.0940±0.003g, respectively. while RQ has the lowest values of 0.0954±0.001and 0.0588±0.001 g in both morning and afternoon periods respectively. The masses of respirable dust particles were high in most quarrying sites as work intensified during dry seasons. This is in line with literature reports of the high value of total masses of the dust collected from Jos to be 3.3 ± 1.1 g during the harmattan using smeared microscope slide for sample collection (Tsor, 2003). This high value could be due to climatic condition of harmattan, as it is similar to haze, where at times visibility is very poor. In addition to the harmattan situation, the methods of sampling could also contribute to the high masses. This observation was in line with the literature report that naturally derived heavy metals are usually found in respirable dust particles (Stone *et al.,* 2011). This high value of respirable dust may have a negative impact on the quarry workers and the immediate community, thereby causing respiratory diseases (Kim *et al.,* 2002). However, heavy metals of anthropogenic origin are mainly distributed in fine particles, which are able to carry more toxic chemicals to human beings and the ecosystem than the coarse fractions (Zhao *et al.,* 2011).

Table 3: Mean Respirable Dust Mass, Flow Rate, and Volume of Air Sampled in Jos - South Between October 2024 to June 2025

Sites Codes	Mass of Dust (g) $PM_{2.5}$		Flow Rate (m^3/min)		Average sampling Time (mins)	Volume of Samples (m^3)	
	M	A	M	A		M	A
RQ	0.095±0.001	0.059±0.001	0.90	0.95	480	432	456
LQ	0.138±0.002	0.142±0.001	0.98	0.85	480	470	408
GQ	0.144±0.006	0.066±0.001	0.96	1.00	480	461	480
DQ	0.104±0.001	0.083±0.001	0.85	0.90	480	408	432
ZQ	3.658±0.002	1.094±0.003	1.00	1.00	480	480	480

M = Morning, **A** = Afternoon

The monthly mean concentration obtained for all the sampling stations is presented in Figures 2 and 3, ranging from 220 - 7621 and 129 – 2279 μg/m^3 in both morning and afternoon, respectively. The highest concentration was obtained in ZQ both morning and afternoon, respectively. The mean concentration of the dust in all the sites studied is lower compared to the literature value of 739.69 μg/m3 obtained at Otukpo in Benue State (Sombo, 2006) and that obtained in Cairo, Egypt, 396-652 μg/m^3 (USAID/Egypt, 1994).

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ZQ Site produced the highest amount of dust, 7621 and 2279 µg/m^{3,} both in morning and afternoon, compared with the other sites, this might have been attributed to mechanized quarrying taking place in the site, while the activities in the other sites were artisanal.

Figure 2. Concentration of Respirable Dust (µg/m^3) Sampled in the Morning

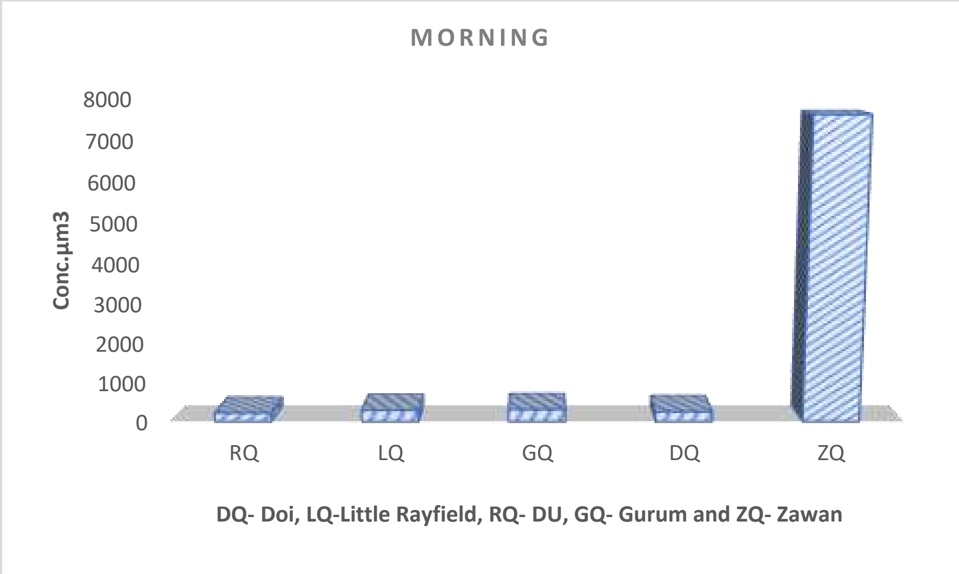
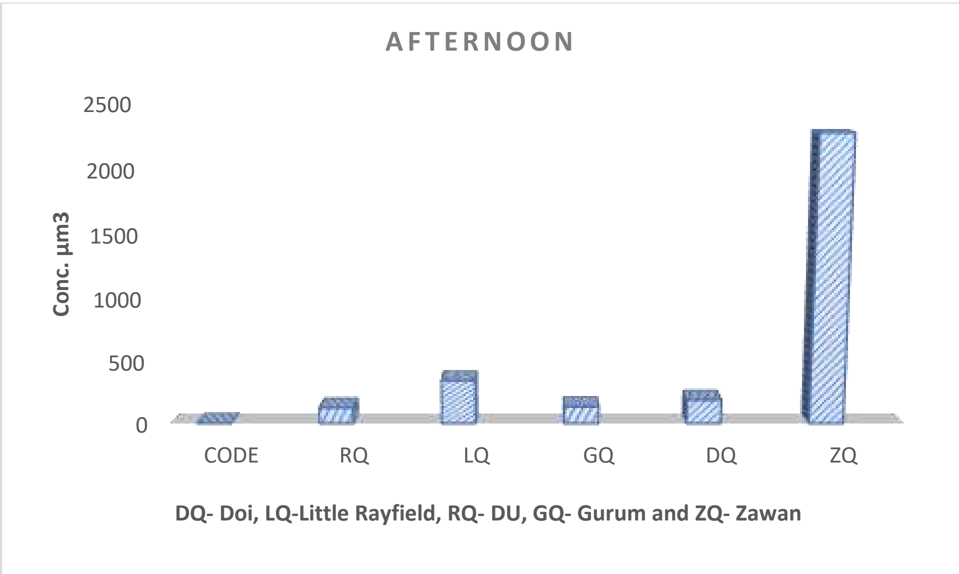


Figure 3. Concentration of Respirable Dust (µg/m^3) Sampled in the Afternoon



These values are far above the 10mg/kg permissive limit set by OSHA (2023); this could have adverse health effects on quarry workers and host communities. It has been reported by WHO (2021) that about nine out of ten people breathe air with high levels of pollutants, and about seven million die every year from pollution due to fine particles.

There have been reports on the adverse health effects even when respirable dust concentrations are below Ambient Standards of EPA or WHO (WHO, 1997). It is logical too that these standards ignore the synergistic effects of the concentration of toxic air pollution (Curtis *et al.,*

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2006). Respirable dust in three suburban and rural sites has also been reported to vary from 37 - 959 µg/m^3 and 151 - 422 µg/m^3 at the suburban site Ronke, India (Vandana *et al.,* 2011). The highest concentration reported in this work is above the range of literature values reported by various workers.

Metals/Metalloids in Respirable Dust

The mean concentrations of arsenic in the respirable dust studied both in the morning and afternoon Table 4) were 5.46±4.73 and 5.79±4.00, respectively, with the highest concentration being in the afternoon. Arsenic is one of the most toxic metals extensively dispersed naturally in the biosphere; it is present in the air, water, and soil (Curkovic *et al.,* 2016). This high concentration of As can be attributed to the usage of pesticides in these areas, since inorganic arsenic can occur in soils, rocks, and mineral ores that contain copper or lead in inorganic and organic forms and in different oxidation states (Hughes *et al.,* 2011). Exposure to Arsenic occurs through the oral route, inhalation, and dermal contact (Matschullat, 2000). Ingestion of excessive quantities of inorganic Arsenic can cause vomiting, circulatory system disorder, nervous system disruption, blood cell production reduction, liver enlargement, and skin discoloration (Machado *et al.,* 2020).

Table 4: Concentration of Metals/Metalloids (mg/kg) from Respirable Dust

Metals	Control		Dust Samples	
	Morning	Afternoon	Morning	Afternoon
As	0.002±0.001	0.002±0.004	5.460±4.730	5.790±4.000
Cd	0.001±0.001	0.001±0.001	0.249±0.300	0.231±0.280
Co	0.001±0.000	0.001±0.000	0.065±0.143	0.080±0.178
Cu	0.003±0.003	0.003±0.002	0.192±0.111	0.240±0.120
Cr	0.001±0.000	0.001±0.000	0.092±0.034	0.076±0.036
Fe	0.084±0.029	0.116±0.047	1.021±0.463	0.953±0.437
Ni	0.021±0.008	0.017±0.004	0.384±0.177	0.410±0.119
Pb	0.015±0.007	0.014±0.006	0.117±0.012	0.111±0.010
Zn	0.381±0.169	0.411±0.089	1.271±0.815	1.660±0.979
Mn	0.065±0.072	0.143±0.032	0.321±0.120	0.432±0.091
SIO_2	0.010±0.020	0.080±0.110	0.540±0.120	0.516±0.120

The mean concentration of Cd was 0.249±0.229 mg/kg in the morning, higher than 0.231±0.248 mg/kg of the sample obtained in the afternoon; however, these values were all higher than the control and the threshold value of 0.005. Cadmium is found as a mineral combined with elements such as oxygen (CdO), chlorine ($CdCl_2$), or sulphur ($CdSO_4$ or CdS). It enters air from mining, industry, burning coal, and household wastes. Particles of Cd in air can travel long distances before falling to the ground or water. The high Cd in the sampling area may be associated with the stone quarrying processes that release dust particles in the atmosphere; other sources could be vehicular emissions, including tyre abrasions (Awan & Ahmed, 2011). Cd stays in the body for a very long time, and hence, exposure to lower levels of Cd leads to a buildup of Cd in the kidneys and may lead to kidney disease. Other potential long-term effects are lung damage, fragile bones, and abdominal pain (Mafuyai *et al.,* 2014).

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Co has the lowest mean concentration of (0.0650±0.143 mg/kg) in the morning respirable dust and 0.080±0.178 higher in afternoon in both sites. This work corroborated with the cobalt concentration from dust in Kaduna state that 0.090-2.690 mg/kg reported by Henry *et al.,*2023.

In nature, Cr is part of ores mainly as chromite ($FeCr_2O_4$) and cryolite ($PbCrO_4$), and heavy metal pollution of the air can arise from quarrying sources. The mean chromium concentration ranged from 0.076 - 0.092 mg/kg, with the highest concentration obtained in the morning dust. Cr being chief constituent in dust can be from the rocks, soils, fossil burning, etc. It settles in air in less than 10 days and builds up on soil particles, and when in water, it sticks to dirt particles, settling at the bottom, and only a small fraction is dissolved. Inhalation of high concentrations of Cr can irritate the lining of the nose and cause nose ulcers, running nose, wheezing, cough, and shortness of breath (GSA, 2022). Exposure to Cr^{6+} in air can damage and irritate your nose, lungs, stomach, and intestines. Skin contact with solids containing Cr^{6+} may lead to ulcers.

When Pb is released to the air from industry or burning of fossil fuels, or waste, it stays in air about 10 days and falls as particles into the soil out of the air. Pb dust, fumes, or vapours are more easily absorbed from the respiratory tract. The concentration of Pb determined in all the sampling sites was 0.117±0.0120 mg/kg and 0.110±0.010mg/kg in the dust sampled, as depicted in Table 5. The values obtained both in the morning and afternoon are higher than the permissible 0.05mg/kg set by OSHA (2023).

Ni is found primarily combined with oxygen or sulphur, and small particles in the air settle to the ground or are taken out of the air in rain. The concentration of Ni determined in all the respirable samples, both morning and afternoon, was 0.384±0.177 and 0.410±0.119 mg/kg, with the highest value observed in the afternoon dust. The concentration of Ni at the control site was significant; perhaps this might be so due to the action of wind current or as a result of anthropogenic sources of nickel emissions to the atmosphere through combustion of fuel. Other sources of exposure are tobacco smoke, auto exhaust, and fertilizers applied in farms. Cancers of the lung and nasal sinus have resulted when workers breathed dust containing high levels of nickel compounds while working in nickel processing plants (Lazor *et al.,* 2012). The concentrations of Ni in this research were lower than those reported from Ebonyi quarry dust, 0.769-1.92mg/kg by Obi *et al.* (2012).

The concentration of Cu determined in all the sampled respirable in both morning and afternoon was 0.240±0.120 and 0.192±0.111 mg/kg, respectively, as shown in Table 5. The concentrations of Cu were high in the morning compared to those measured in the afternoon dust. This occurrence of Cu in the dust implies that the particulates originate from the crushing of a unique form of a local geological rock.

Zinc is one of the commonest elements in the earth's crust and is found in air, soil, water, and food. Zn is normally attached to particles in the air and removed by rain into soil and water. The highest mean concentration was in the afternoon, 1.66±0.979 mg/kg, while low 1.271±0.815mg/kg obtained in the morning, Table 5. Zn pollution has increased among other trace metals because of quarrying activities (Masindi and Muedi, 2018). Inhalation of excess Zn compounds causes metal fume fever, characterized by chest pain, cough, dyspnea, nausea, malaise, and leukocytosis (Plum *et al.,* 2010).

Iron is an essential element needed for growth and development, but large amounts of intake might cause inflammation of the stomach lining and ulcers, decrease in zinc absorption, etc.

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The range of Fe in respirable dust was within 0.953-1.024 mg/kg, with the highest concentration from the morning samplings.

The mean concentration of Mn in both morning and after in dust was found to be 0.321±0.120 and 0.432±0.091mg/kg, respectively. The value was higher in the afternoon compared to the morning period; this might have been due to the fact that Mn is a naturally occurring element, comprising approximately 0.1% of the earth's crust, being the twelfth most abundant element (Röllin and Nogueira, 2019). It occurs naturally in soil, rock, water, and it is released into waterways mainly through the erosion of rocks and soil. Mn exposures occur through oral and inhalation in a number of environmental media and nutritional sources like water, soil, and air (O'Neal and Zheng, 2015).

The mean concentration of Silica in respirable dust $PM_{2.5}$ in the study are in both morning and afternoon was 0.540±0.120 and 0.516±0.120mg/kg in both morning and afternoon, while the control area had 0.010±0.020 and 0.080±0.110g/m^3, respectively. The values obtained in this work are higher compared to the National Institute of Occupational Safety and Health (NIOSH, 2002), which recommends an exposure limit of 0.02g/m^3 for respirable silica. Long exposure to crystalline silica causes silicosis or other severe respiratory illness (Langer *et al,* 2004).

Enrichment Factor and Igeo Values

The enrichment factor and Igeo values of respirable dust are in Tables 5 and 6, respectively. The enrichment factor of Cadmium for both morning and afternoon periods was 7.30 and 5.64, respectively, indicating a significant enrichment of Cadmium in the respirable dust, considering the enrichment factor class (5 < EF < 20). The high Cd in the sampling site may be associated with the stone quarrying processes that release dust particles in the atmosphere; other sources could be vehicular emissions, including tyre abrasions (Awan and Ahmed, 2011).

Table 5: Enrichment Factor of Metals/Metalloids in Respirable Dust

Elements	Morning	Afternoon
As	1.050	1.110
Cd	7.300	5.640
Co	0.007	0.009
Cu	0.021	0.026
Cr	0.003	0.003
Fe	0.410	0.381
Ni	0.030	0.032
Zn	0.014	0.013
Pb	0.048	0.062
Mn	0.024	0.031

The Igeo values of Cadmium for both periods were 1.54 and 1.53, respectively, indicating that there is a moderately contaminated environmental respirable dust (1 < Igeo < 2).

Cobalt enrichment factor and Igeo values were < 1. Therefore, contamination of the respirable dust from the quarry by Co was insignificant in the dust. The enrichment factor and Igeo value for Fe in respirable dust were 0.410 and 0.381 in both morning and afternoon, deficient to minimal enrichment, and 0.254 and 0.273 respectively, uncontaminated to moderately contaminated with the dust.

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The enrichment factor and Igeo values of As for both morning and afternoon were 1.05, 1.11, and 0.287, 0.34, respectively, as shown in Tables 5 and 6. These enrichment values of EF< 2 signify a deficiency to minimal enrichment of As in the dust, while Igeo values of 0 Igeo < 1 indicated an uncontaminated to moderately contaminated environment.

The enrichment factor and Igeo accumulation were 0.024, 0.031 and 0.042, 0.642 in morning and afternoon respectively showing Mn Uncontaminated to moderately contaminated.

Other metals, Cr, Cu, Ni, Pb and Zn show no contamination as all the values obtained were less than 0.1 for both enrichment and Igeo.

Table 6: Igeo Accumulation Values of Metals/Metalloids in Respirable Dust

Elements	Morning	Afternoon
As	0.287	0.304
Cd	1.540	1.530
Co	0.002	0.002
Cu	0.007	0.000
Cr	0.001	0.001
Fe	0.254	0.273
Ni	0.009	0.008
Zn	0.017	0.013
Pb	0.005	0.006
Mn	0.042	0.642

CONCLUSIONS

This study highlights the significant environmental and public health risks associated with increased quarrying activities. The results reveals that there is a considerable increase in harmful levels of particulate matter (PM_{10} and $PM_{2.5}$) frequently exceeded both OSHA and WHO safety thresholds, particularly during peak quarrying hours, which exacerbated the decline in air quality while, that of metal/metalloids shows significant concentration of Cd, As, Cr, Co and Ni in the respirable dust $PM_{2.5}$ with significant enrichment of Cd and Igeo accumulation. Higher concentrations, which exceed the threshold value, were observed in As, Cd and Si. This could have adverse health effects on quarry workers and host communities. Exposure to quarry dust may cause deterioration of lung function and respiratory ailments in quarry workers.

The worker should be provided with proper medical guidance and regular health checkups to protect them from the hazards of quarry dust exposure.

Declaration

It is my honor, on behalf of the co-authors of the work, hereby declare that this manuscript has not been published in any scientific journal or submitted for review and publication.

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Acknowledgement

We would like to express our immense gratitude to the quarry staff for their cooperation and support. The author is grateful to the Department of Chemistry for providing the infrastructure to conduct the research**.**

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