Asian Journal of Geological Research

4(1): 40-47, 2021; Article no.AJOGER.65397

Assessment of Dust Concentration and Compounds at Quarry Sites in Akamkpa Cross River State, Nigeria

Godwin Igie Inyaka[1], M. Alkali[2], Emeodilichi H. Mba[2*] and Udofia Udeme Alfred[2]

[1]National Oil Spill Detection and Response Agency (NOSDRA), Nigeria.
[2]Department of Geography, Nasarawa State University Keffi, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author GII conducted the study and collected the data. Author EHM analyzed the data. Author UUA interpreted the data and author MA supervised the research. All the authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Ahmed Abdelraheem Frghaly, Sohag University, Egypt.
Reviewers:
(1) Mounia Tahri, National Centre of Energy, Sciences and Nuclear Techniques (CNESTEN), Morocco.
(2) Wan Nazwanie Wan Abdullah, Universiti Sains Malaysia, Malaysia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/65397

Original Research Article

Received 15 December 2020
Accepted 18 February 2021
Published 19 March 2021

ABSTRACT

This study assessed dust concentration, elements and compounds at limestone quarry site and the aim was to determine the level of air pollution due to dust generated from quarrying activities, the elements and risks it poses to health and the environment. Dust samples were collected using a 224-PCXR4 sample pump and analyzed for concentrations and harmful elements/compounds constituents. The results shows that dust concentration at the quarry site was quite high on the average 51.56 mg/m^3, when compared with the limit 10 mg/m^3 and the study revealed that the crushing plant had more dust concentration of 92.5 mg/m^3 than all the other working areas. Quarry pit had the second highest concentration, followed by garage and the office areas in descending order. three main harmful elements/compound detected in the sampled dust are; silicon dioxide with a mean concentration of 0.62 mg/m3, chromium 5.92 mg/m^3 and lead 9.24 mg/m^3 respectively.

The study recommends that environmental management systems, which include a dust management plan, should be employed at the quarries in order to mitigate dust generation. Particularly during drilling/blasting of rocks and at the crushing plant.

**Corresponding author: Email: emodimba@gmail.com;*

Keywords: Silicon dioxide; chromium; lead; limestone.

1. INTRODUCTION

Quarrying is the process of obtaining quarry resources, usually rocks, found on or below the land surface [1]. This process of quarrying involves drilling, blasting, crushing and screening. The overburden is removed to expose the rock surface, the rock is drilled in preparation for blasting and during blasting, explosives are used to break the rock into fragments which are then hauled and fed into a crushing plant for crushing, screening, washing and stockpiling [2]. The difference between mining and quarrying is that quarrying extracts non-metallic rocks and aggregates while mining excavates the site for mineral deposits. Some of the stones extracted are sandstone, limestone, perlite, marble, ironstone, slate, granite, rock salt and phosphate rock. The suitability of the stone for quarrying depends on its quality, the possibility of cheap and ready conveyance to a large market and its inclination and depth below the surface. The two principal branches of the industry are the dimension stone and crushed-stone quarrying. In the former, blocks or sheets of stone, such as marble, are extracted in different shapes and sizes for different purposes. In the crushed stone industry, granite, limestone, sandstone, or basaltic rocks are crushed for use principally as concrete aggregate or roadstone. Quarry industry is important because of its positive impact on economic development of the country being a source of construction materials, revenue for the government through taxation and royalties and employment especially of the rural population [3]. The industry also provides employment opportunities for both skilled and unskilled workers thereby supporting many urban and rural families as it contributes to their livelihood and socioeconomic wellbeing.

Quarrying raises various environmental concerns including land disturbance, emission of dust, noise, and ground vibrations, the latter arising from movement of machinery and rock blasting [4]. Quarrying poses danger to the workers due to rock fall and machinery, while the dust produced is harmful to their health and the most obvious engineering impact of quarrying is a change in geomorphology and conversion of land use, with the associated change in visual scene [5]. While Air pollution resulting from the activities of mining and mining support companies emanates from high airborne particulate matter, black smoke, noise and vibration resulting from blasting [6]. The dust particle size, concentration, mineral composition and long-term exposure are factors considered in evaluating the health risks involved. The inhalation of the dust causes severe health problems including respiratory and pulmonary problems, while dust deposition causes skin and eye problems [7]. Particulates are the tiny solid or liquid particles that are suspended in air and which are usually individually invisible to the naked eyes [8]. The particulates include soot, smoke, ash from fuel mainly coal combustion, dust released during industrial processes like quarrying and other solids from accidental and deliberate burning of vegetation [9]. Quarrying generates a lot of particulate matter (dust) with diameter 1-75 μm (micron). Particles with aerodynamic diameters less than 50 μm termed Total Suspended Particulate (TSP) matter can become suspended in the atmosphere, and those with aerodynamic diameters less than 10μm termed PM_{10} (inhalable particles) can be transported over long distances and enter the human respiratory system *Montgomery,1992*. While various studies have shown that rock contains crystalline silica and heavy metals, which occur in varying quantities. Granitic rock contains up to71% crystalline silica while limestone and basalts contain up to 40% and 1% of crystalline silica, respectively (HSE UK, 1992).

Dust from mining and quarrying operations if allowed to reach the atmosphere creates an incompatible environment or causes excessive wear on machinery, reduces visibility or increases the rate of accidents and also contributes to sinuous diseases such as pneumonias, fibrosis and scarring of the lungs as a result of repeated inhalation of minerals such as silica, asbestos and coal dust *Health and Safety Council Guidelines,* [10].

2. MATERIALS AND METHODOLOGY

The study was conducted in Akamkpa Local Government Area, located at southern part of Cross River State. It is situated between Latitude 4°55′36″N and 6°0′00″N of the Equator and between 8°5′03″E and 8°55′21″E of the Greenwich Meridian. The Local Government which has a land area of 4,300 square kilometres is bounded to the North by Obubra, Ikom and Etung LGAs, to the South by Odukpani, Calabar Municipal and Akpabuyo LGA, to the West by Biase and Yakkur LGAs and Cameroon Republic to the East Cross River State Diary, 2005 and Cross River State Bureau of lands, 1997. Akamkpa LGA is located in a coastal zone within the humid subtropical region and it is affected by weather systems originating from all sides. It experiences the full influence of the overhead sun throughout the year which provides abundant and constant insulation. Consequently, the atmospheric temperature within the area as observed by Mannion [11] are constantly high and changes slightly with the year and according to Udo [12] the mean daily temperature remain around 37°C all year round excepts during the raining season due to the cooling effects of rains and clouds cover that curtails the amount of insolation (Incoming radiation). Soils of Akamkpa LGA are strongly weathered with coarse to fine sand textures in both the surface and subsurface soils. They are characterized by low contents of organic carbon, total nitrogen, exchangeable bases and high contents of available phosphorus Buktrade [13]. Being soils in the humid climate environment, they are highly leached and therefore acidic in reaction Ogban et al. [14], Bulktrade [13].

Data on quarry generated dust was collected at four different working locations at the quarry using a 224-PCXR4 Sample Pump connected to a cassette holding a 47 mm diameter filter of pore size of 0.8 microns, from 16th to 19th December between 12 noon to 2 pm, reason because if falls within dry season when dust incidents are much in the site and December is among the dusty peak period due to harmattan in the study area. Sample cassettes were labeled for ease of identification. Gummed paper labels were used and affixed on the cassettes at the point and time of collection Apha [15]. The details on the labels included unique sample number, sample point, sample type, date and time of collection Alpha [15].

The sampling media used to collect the dust samples at the quarries were membrane filters of pore size 0.8 micron, fitted in 47 mm diameter cassettes sealed on both ends. The Universal Sample Pump, model 224-PCXR4 was used for dust sampling. In every location the dust collection pumps were set at 2L/min and were each connected to a cassette containing a filter. The set of dust sampling equipment was each stationed at the four cardinal directions from the source of dust at successive distances of 0 m, 25 m and 50 m away from the crusher. The pumps were allowed to run for two hours at every collection point.

The cassettes containing the dusty filters were carried to the DOSHS where they were again desiccated in order to remove any moisture that the filter may have collected during dust sampling. Using a digital weighing balance placed in an enclosed room the final weight of the dusty filters was taken. The difference between the dusty filter and the blank one gave the weight of the dust sample. The dust concentration was calculated using a standard procedure formula.

The dust samples collected from the quarry were then transferred to the Geological Department laboratory of the University of Calabar for analyses. The samples were analysed using the standard analytical procedures. The samples were analysed for their chemical composition, any radioactive elements and heavy metals including using an XRF and AAS. A dry analysis for any radioactive elements was done using the XRF while the AAS was used to analyse the chemical composition and concentration of the dust samples. The dust samples were digested using hydrochloric acid + nitric acid (aqua-regia), and then fed into the AAS and computerized results read against the standard solution.

3. RESULTS AND DISCUSSION

Fig. 2 shows the concentration of dust particles at different working areas of the Akamkpa quarries. The highest (92.5 mg/m^3) concentration of dust was recorded at the rock crushing site. This was followed by the quarry pit where dust concentration of 58.75 mg/m^3 was recorded while at the dust concentrations at the garage and the office area were 45 mg/m^3 and 10 mg/m^3 respectively. On average, a dust concentration of 51.56 mg/m^3 was recorded in the study area. All the working areas except offices had dust concentrations that exceeds the time weighted average limit of 10mg/m^3 [16], for total dust, and 5 mg/m^3 for respirable dust (New Zealand Workplace Exposure Limit). A similar study on impact of granite quarrying on the health of workers [17], showed similar results of higher concentrations of dust at crushing than in the pit 65.03 mg/m^3 and 44.09 mg/m^3, respectively. Drilling and crushing of rock are peak points in dust production.

Dust deposits lead to scarring and inflammation which clogs passageways, obstructing airflow and causing chronic bronchitis (MHSA (Information Service, 2007). Particulate air pollution is associated with a range of effects on health (from particles less than 10 µm in diameter, known as PM_{10}) including effects on the respiratory and cardiovascular systems, asthma and mortality [1]. Current research suggests that asthma is caused by a combination of genetic and environmental factors but that particulate matter inhalation increases the severity of asthma (NASA, 2001).

3.1 Concentration of Detected Harmful Elements/Compounds

Table 1 shows the concentrations of harmful elements and or compounds in the sampled dust particles. Silicon dioxide, chromium and lead were the three detected threats in the dust particles. A mean concentration of 0.62 mg/m^3 silicon dioxide was recorded in the dust particle, while 5.92 mg/m^3 and 9.24 mg/m^3 of chromium and lead respectively, were recorded. It was further shown that the mean concentration of silica was higher than the limit of 0.2mg/m^3 for respirable silica set by Occupational Safety and Health Association [16]. Horwell et al. [18], reports that Respiratory Crystalline Silica (RCS) jeopardizes state of the human wellbeing, a fact reiterated by the National Institute for Occupational Health (Esswein et al 2013). Also in 1987, International Agency for Research on Cancer (IARC) branded Silicon dioxide as plausible cancer-causing agent [19], but until 1997 that Silicon dioxide was termed Group 1 cancer-causing agent [19].

The concentrations for chromium and lead were also comparatively high, the workers were therefore at high risk of developing respiratory problems and silicosis from exposure. Inhalation of these high levels of lead exposed workers to kidney and brain damage while inhalation of chromium-laden dust exposed the workers to the risk of damage to the livers and the kidneys as well as skin irritation [20].

Dust concentration at the quarry was quite high on the average (51.56 mg/m^3), when compared with the limit (10 mg/m^3) of OSHA [16]. The study revealed that the crushing plant had more dust concentration (92.5 mg/m^3) than all the other working areas. Quarry pit had the second highest concentration, followed by garage and the office areas in descending order.

Furthermore, three main harmful elements/ compound were detected in the sampled dust. They were: silicon dioxide with a mean concentration of 0.62 mg/m3, chromium (5.92 mg/m^3) and lead (9.24 mg/m^3).

3.2 Dust Related Disease Symptoms among Quarry Workers

Fig. 3 presents the common dust related diseases that have been suffered by the quarry workers since assuming duty at the quarry. Based on multiple response of the sampled workers, difficulty in breathing was found to be the most pervasive health problem as attested by 60.28% of the sampled quarry workers. This was followed by dry cough with 37.78% of the respondents having suffered from it since assuming duty as quarry workers. Other highly pervasive dust related diseases among the quarry workers were: chest pain (31.94%), sore throat (31.11%), and productive cough (30.28%). Furthermore, 27.5%, 23.61% and 20.83% of the respondents claimed to have repeatedly suffered from other dust related problems such as eye irritation, skin irritation and nasal discharge, respectively, since assuming duty as quarry workers.

In a similar study, Ugbogu, et al. [7], found that the inhalation of the dust causes severe health problems including respiratory and pulmonary problems, while dust deposition causes skin and eye problems. Another similar study on pulmonary problems among quarry workers of stone crushing industrial site at Omuoghara, Ebonyi State, Nigeria [21], gave a similar trend. This study by Nwibo et al. [21], showed 7.4% of the workers had occasional cough, 5.2% were wheezing while 6.4% experienced shortness of breath. The symptoms exhibited by the workers were an indication of risk of developing silicosis and pneumonia [16].

Also, the findings of this study corroborates the works of Ohakwe et al. [7], Olusegun et al. [22]; Johncy et al. [23], Mohapatra et al. [24] and Diaz-Guzman et al. [25], all whom ascribed respiratory inconveniences to micro-particles. Nwibo et al. [21], adds that breathing complication is among medical perils to dust-exposed labourers causing indisposition worldwide. According to Kim et al. [26], dust infiltrates breathing canals to induce complications. The pervasiveness of these diseases among quarry workers in Akamkpa LGA could also be attributed to the high concentration of such harmful dust substances as silicon, chromium and lead in the sampled dust within the study area.

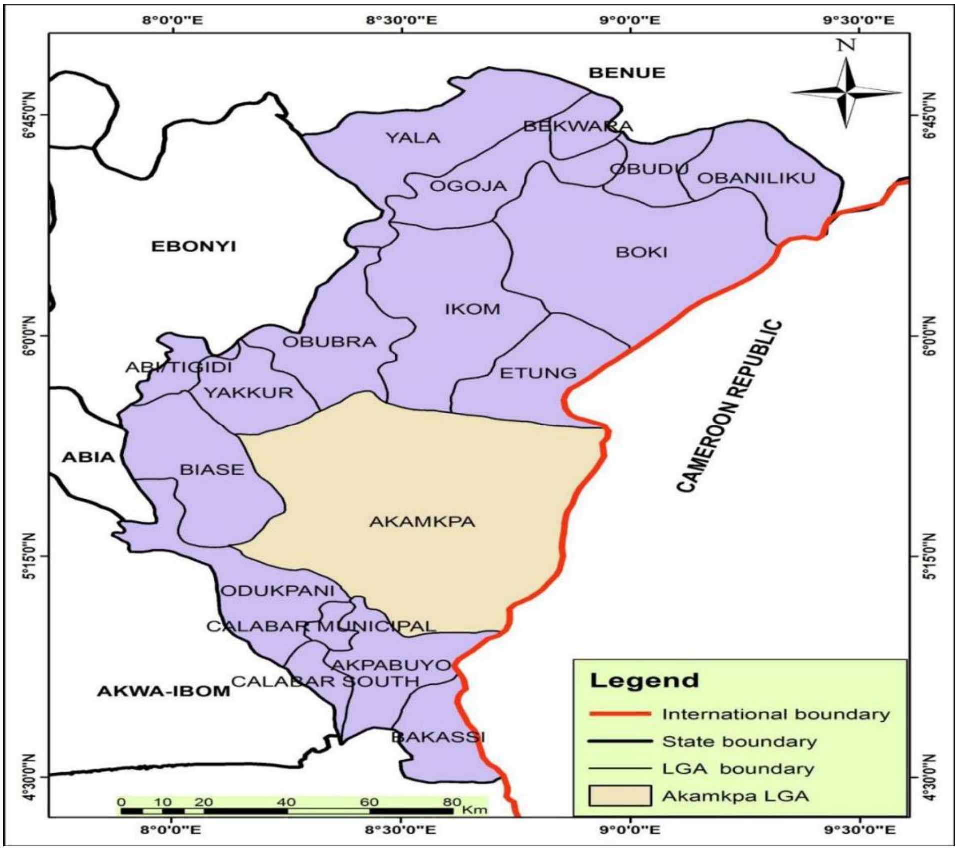

Fig. 1. Map showing study location

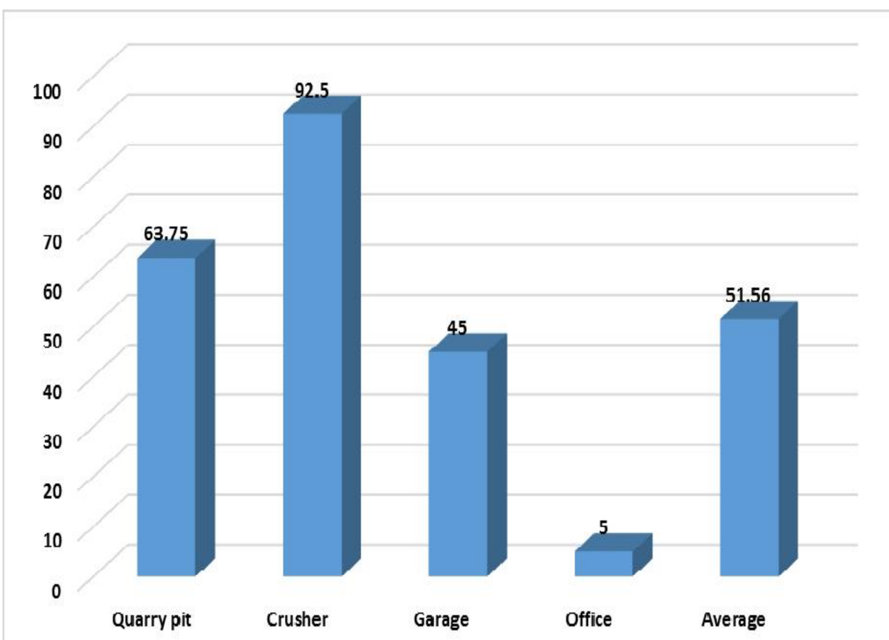

Fig. 2. Dust concentration at akamkpa quarries

Table 1. Concentration of harmful dust elements/compounds

Working Area	Detected Harmful Dust Elements/Compounds (mg/m^3)		
	Silicon dioxide (SiO_2)	Chromium (Cr)	Lead (pb)
Quarry pit	0.85	6.07	11.24
Crusher	1.18	9.14	12.87
Garage	0.28	5.54	9.23
Office	0.17	2.93	3.62
Mean	0.62	5.92	9.24
OSHA Limit	0.2	0.5	0.05

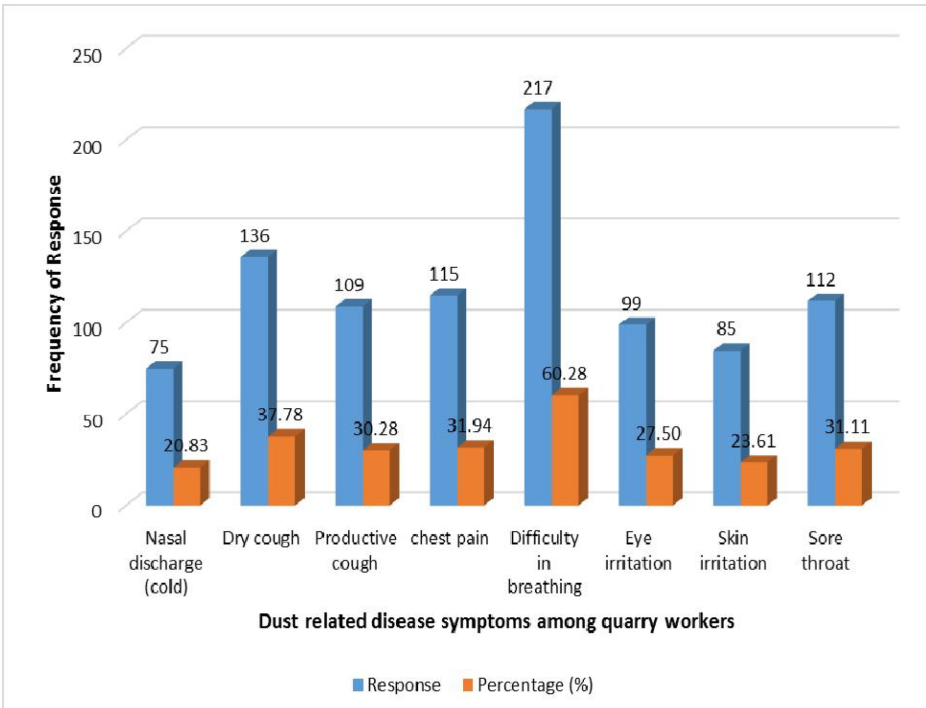

Fig. 3. Common dust related diseases among the quarry workers

4. CONCLUSION AND RECOMMENDATION

This study assessed dust pollution and associated health risks among quarry workers at the Akamkpa Limestone quarries in Cross River State, Nigeria. The aim was to determine the level of air pollution due to dust generated from quarrying activities and expose the health risks posed to workers who inhale such dust on daily basis, Dust samples were also collected using a 224-PCXR4 sample pump and analysed for concentrations and harmful elements/ compounds constituents.

Quality health condition among quarry workers is vital to sustainable quarrying operations. This can only be achieved by evaluating/monitoring of all forms of environmental pollution that poses threats to the workers and devising mitigating measures to them. In line with the findings of this study, it was concluded that drilling/blasting, crushing and road haulage are the main dust generating activities at the quarries and the generated dust are composed of silica, chromium and lead, all of which have human health impacts. Also, the concentration of dust, silica, chromium and lead were higher than limit set by the Occupational Safety and Health Association in 2005. This makes the area quite harmful to human health without protective measures in place. The high concentration of dust generated at crushers and at quarry pit depicts these areas as peak sites and therefore hazard zones.

There is high exposure of the quarry workers to harmful dusts and low use of protective clothing/equipment among them as well. The exposure of workers to the high concentrations and the poor use of protective clothing and gear predispose them to respiratory, skin and eye ailments and silicosis, the ailments which they exhibited.

The study recommends that:

i. Environmental management systems, which include a dust management plan, should be employed at the quarries in order to mitigate dust generation. Particularly during drilling/blasting of rocks and at the crushing plant.
ii. Regular environmental audit and monitoring of quarrying activities should be enforced in order to ensure adherence to the standards and limits of the concentrations of the dust generated from the different stages of their operations.
iii. The quarry workers should be adequately sensitized on adverse health effects of exposure to quarry dust and the importance of using personal protective equipment while at work.
iv. The sector regulators, National Emergency Management Agency (NEMA), Federal Ministry of Environment and the Directorate of Occupational Safety and Health Services (DOSHS), should enhance enforcement and ensure compliance.

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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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/65397