Original Article

Environmental Assessment and Adherence to Occupational Safety Regulations in Stone Quarries in Gusau Metropolis, Zamfara State, Northwest Nigeria

***Shehu A[1], Raji MO[2], Ka'oje AU[2], Azees AS[3], Akogwu HS[4], Daninna MZ[4], Bello MM[2], Abdul'aziz MD[2], Illo HG[2], Attahiru A[5], Abubakar AB[1], Yakubu M[1].**

[1] *Department of Community Medicine, Federal Medical Centre Gusau, Zamfara State.*
[2] *Department of Community Medicine, Usmanu Danfodiyo University Teaching Hospital Sokoto.*
[3] *Department of Community Medicine and Primary Care, Federal Medical Centre Abeokuta, Ogun State.*
[4] *Department of Family Medicine, Federal Medical Centre Gusau, Zamfara State.*
[5] *Department of Community Medicine, University of Abuja Teaching Hospital, Abuja.*

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***Correspondence:** Shehu Abdullahi
Email: abdulshehu78@gmail.com

ABSTRACT

Hazards generated in the process of quarrying stones include noise and particulate matter (PM) among others. This study measured environmental hazards and adherence to occupational safety and health (OSH) regulations in stone quarries in Gusau in a cross-sectional study conducted in the quarries of Gusau in August 2022. Environmental assessment was conducted using a noise level meter, and air quality detector. A checklist was used to assess adherence to OSH regulations in the quarries and data were presented in tables. Ethical clearance was obtained from Zamfara State Ministry of Health. The mean $PM_{2.5}$, PM_{10} and noise levels for the quarries were 75.0 ± 9.8µg/m3, 186.7 ± 8.7 and 102.7 ± 6.2 dBA respectively. The average afternoon temperature was 40.9 ± 2.2 ^{0}C. There was poor adherence to OSH regulations in the quarries. This study revealed the presence of unhealthy and poor levels of PM, noise beyond the recommended exposure limit (REL) and poor adherence to OSH regulations in quarries in Gusau. Regulatory authorities and quarry employers should educate and enforce adequate safety training of the workers on the risks of hazards they are exposed to, and ensure adequate implementation of the regulations in all the quarries.

Keywords: Adherence, Environmental assessment, Occupational safety regulations.

INTRODUCTION

Quarrying is the process of extraction from rocks of any useful stone for construction and building purposes.[1] Quarrying generates a lot of small dry particulate matter (PM) ranging in size from 1 to 100µm in diameter.[2] Particles with diameters less than 5µm get to the lung's alveoli and those less than 2.5µm can cause visual disturbance and impairment.[2] The WHO states that there is no known PM threshold level below which no damage to health is observed.[3] Therefore, the WHO global guideline limits aimed to achieve the lowest concentrations of PM possible: Fine particulate matter ($PM_{2.5}$) 5µg/m^3 annual mean or 15µg/m^3 24-hour mean.[3] Coarse particulate matter (PM_{10}) 15µg/m^3 annual mean or 45µg/m^3 24-hour mean.[3] In a study in Congo, workplace dust measurements showed abnormally high levels of $PM_{2.5}$ (205 ± 13.2µg/m^3 vs. 31.3 ± 10.3µg/m^3 in control sites; $p < 0.001$).[4] Similarly, another study in Ogun state, Nigeria among quarry workers showed that the highest mean PM_{10} levels among the selected quarries vary between 26.03±1.36mg/m^3 and 11.03±1.52mg/m^3.[5] It was also shown that PM_{10} levels declined significantly ($p<0.05$) with distance from the drilling and crushing locations at each of the quarry sites. At 25metres away from the quarry sites, the mean PM_{10} levels reduced drastically to 4.85±0.20mg/m^3 and 3.67±0.40mg/ m^3.[5]

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Noise generated during the stone quarrying process is a major occupational hazard for quarry workers.[6] The National Institute of Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) for occupational noise exposure is 85 dBA, as an 8-hour time-weighted average (85 dBA as an 8-hour TWA).[7] Exposures at or above this level are considered hazardous.[7] A study conducted in a total of 25 enterprises with open quarries in China reported a median noise level of 92 dBA, and, only 30.4% (17/56) of the workplaces met the national noise standard.[8] A cross-sectional study conducted among workers in five quarry workplaces in Ghana showed that workers were exposed to noise levels ranging from 85.5 dBA to 102.7 dBA which is above the normal permissible limit.[9] A cross-sectional study conducted in quarries in Ikere-Ekiti, Southwest Nigeria, observed that the noise level in the quarries reached a maximum of 106.2 dBA.[10] Exposure to noise by quarry workers may result in accidents due to work exhaustion, noise-induced hearing loss and other detrimental effects of high noise levels on human health.[11] The estimated cost of noise in developed countries ranges from 0.2 to 2% of the gross domestic products, this is higher for developing countries.[12] Extreme heat weather exposure may result in heat cramps, heat exhaustion, heat syncope and extreme cold weather may lead to hypothermia and frostbites among others.[13]

Availability of OSH regulations is one of the commonest factors that enable workers to adhere to OSH practice.[14] In Zaria, it was found that no preventive measure was available in the quarries.[15] Despite the challenges inherent in the quarry, the sector remains an important contributor to the global economy and was one of the most important contributors to the state's and nation's economy in Nigeria.[2]

Quarry workers may have an idea of the health effects of noise from explosives or heavy machines but may have a low-risk perception of the noise they produce while quarrying stones manually. Similarly, dust with PM size <5μm is colourless, odourless, non-irritating, and does not cause immediate health effects, hence may go unnoticed by the quarry workers in the workplace.[2] Likewise, the quarry workers work under heavy sunlight without a shade, helmet or hat, and sometimes under extreme cold weather without protection. Consequently, the workers may not protect themselves, or demand OSH measures. In addition, studies conducted among quarry workers in Nigeria did not measure these environmental hazards quarry workers are exposed to in the quarry workplaces.[15] This study bridged the gap by measuring these environmental hazards; air quality ($PM_{2.5}$ and PM_{10}) level, noise level, and ambient temperate.

Although there were studies conducted on the awareness, knowledge and use of PPE, there were no readily available studies on the availability of OSH regulations in the quarries. This study was therefore set up to assess the availability of OSH services in the quarries in Gusau metropolis. The findings from the study generated facts that were used for advocacy to the relevant stakeholders for improved working conditions in the quarries.

MATERIALS AND METHODS

Study Area

The study was conducted in Gusau, Zamfara State, Nigeria. Gusau is populated by Hausa and Fulani indigenes.[16] Occupations in the state are farming, stone quarrying, cotton ginnery, trading and others.[16,] Zamfara state was created from Sokoto state on 1st October 1996 with its capital in Gusau town.[16] It is situated in the North-Western region of Nigeria and occupies 39,762 square kilometres.[16] Gusau LGA has a population of 528,400 while Gusau city, the capital of Zamfara State has an area of 3,364 km (2,090 m²) and a population of 383,162 as of the 2006 census.[16]

Study Design

This was a cross-sectional study that was conducted in Gusau in August 2022.

Data Collection

There were three quarry sites in Gusau metropolis. All the three quarries were enlisted for the study. Each of the three quarries was divided into two sections (i.e., quarrying and administrative areas) making up a total of six areas. The environmental assessments (air quality, sound level, and ambient

temperature) were conducted in each of the six (6) quarry quadrants. For air quality, sound level, and temperature measurement, three readings each were taken and averages of the three readings each were recorded respectively for each of the six areas. In all the selected quarries, the principal researcher measured noise level using a sound level meter (TSI Quest SE 400 series), both air quality and ambient temperature using a portable digital air quality monitor (KC3YR3) and recorded in the appropriate section on the checklist.

The study instruments were checklist for workplace assessment, sound level meter, and air quality detector. The checklist was used by the principal researcher to assess the safety and health status of the selected quarries. These included general workplace conditions, hazard identification, and regulations on safety and health. The checklist was adapted from a Quarry Mining Inspection Checklist and an International Labour Organization (ILO) document on occupational safety and health.[17, 18] Sound level meter was held at about 1.5m from the workers during stone quarrying and crushing and at 1.5m away from reflecting stone surfaces.[19] Three readings were taken at an interval of one minute each and the mean value was used. The NIOSH recommended exposure limit for occupational noise exposure is 85 dBA as an 8-hour Time Weighted Average.[20] Exposures beyond this level are considered hazardous.[20] Air quality detector was placed within the breathing zones of the quarry workers in each of the quarry quadrants.[21] The average 24-hour values for $PM_{2.5}$ and Pm_{10} were obtained for all the quarries (quarry and administrative areas) designated for the study. The WHO global guideline limits for $PM_{2.5}$ level was graded as good (0.0-12.0 $\mu g/m^3$), moderate (12.1-35.4 $\mu g/m^3$), unhealthy for sensitive groups (35.5-55.4 $\mu g/m^3$), unhealthy (55.5-150.4 $\mu g/m^3$) and very unhealthy (150.5-250.4 $\mu g/m^3$), while PM_{10} was graded as good ($\leq$150 $\mu g/m^3$), and poor (>150 $\mu g/m^3$).[22] The outdoor temperature of the selected quarries was taken also using the air quality detector at a different time of the day.[23] The lowest and highest temperatures of each of the quarries were recorded in the checklist. Three readings were taken at an interval of one minute each and the mean value was recorded in the checklist appropriately.

Data analysis

Data collected were transferred into Statistical Package for Social Sciences (IBM SPSS) software version 25 for data analysis. A descriptive analysis of all the variables was performed on the data. Categorical data were summarized using frequencies and percentages, while quantitative data were summarized using mean and standard deviation.

The measurement variables were mean values of $PM_{2.5}$ and PM_{10}, mean values of sound pressure, mean temperature levels in the quarries and proportion of quarries that adhered to OSH. Categorical variables (proportion of quarries that adhered to OSH) were reported using frequency and percentages; quantitative variables such as air quality ($PM_{2.5}$ and PM_{10}) level, sound level, and ambient temperature in the workplace were reported using mean and standard deviation and the data were presented in tables. The Independent t-test statistics were performed to compare the mean difference of noise and PM between the quarry working areas and the administrative resting areas.

Ethical Consideration

Ethical approval was obtained from the Health Research Ethics Committee of the Ministry of Health of Zamfara State (ZSHREC01122021). Permission was sought from the leaderships of all the quarries after explaining the purpose of the study and guaranteeing confidentiality.

RESULTS

The mean value of $PM_{2.5}$ from the quarry areas of the quarries was 75.1 ± 9.8$\mu g/m,^3$ while that of the administrative areas of the quarries was 30.7 ± 1.5$\mu g/m^3$. The mean $PM_{2.5}$ of the quarry areas was statistically significantly higher than the mean $PM_{2.5}$ of the administrative areas (p=0.002). The mean value of PM_{10} for quarry areas of the three quarries was 186.7 ± 8.7$\mu g/m,^3$ while the administrative areas of the quarries had PM_{10} levels of 36.0 ± 2.0. The mean PM_{10} of the quarry areas were statistically significantly higher than the mean PM_{10} of the administrative areas (p<0.001). The sound level of

the quarry areas of the quarries ranged from 95.8 to 107.9 dBA with a mean of 102.7 ± 6.2 dBA. The sound level of the administrative areas ranged from 54.2 to 71.1 dBA with a mean of 62.7 ± 8.5 dBA. The mean noise level of the quarry areas was statistically significantly higher than the mean noise level of the administrative areas (p=0.003) (Table 1).

The minimum and maximum morning temperatures of the quarries inspected were 29.8 ^{0}C and 35.4 ^{0}C respectively and the average morning temperature was 33.5 ± 2.0 ^{0}C. However, the minimum and maximum afternoon temperatures of the quarries inspected were 38.4 ^{0}C and 43.1 ^{0}C respectively and the average afternoon temperature was 40.9 ± 2.2 ^{0}C. The average morning and afternoon temperatures across the three sites were similar (Table 2).

All the 3 (100%) quarries assessed had no written policy on OSH and standard operating procedures (Table 3).

All the 3 (100%) quarries assessed had adequate ventilation and lighting. The administrative areas of the 3 (100%) quarries were generally clean, tidy, comfortable and hygienic for meals, separated from the work area and with favourable weather conditions. None of the quarries had toilets for workers' use nor adhered to policies on safety and health (Table 4).

All the 3 (100%) quarries did not use mechanical devices to ease lifting/moving heavy loads and had no appropriate seats for workers sitting for most of the shift. In all the quarries, 3 (100%), workers were exposed to vibrations from working tools. Similarly, in all the quarries, the settings of the workplace predisposed workers to injury (Table 5).

Table 1: Average Air and Noise quality levels in the quarries

Sites	Quarry area	Administrative area	T-statistics	P-value	95% Confidence interval
	Air quality - PM $_{2.5}$ (µg/m^3)				
Samaru	78.1 ± 2.6	32.0 ± 0.3	30.40	<0.001	41.80 - 50.20
Damba	82.9 ± 3.4	29.1 ±0.8	26.78	<0.001	48.40 - 59.60
Lalan	64. 0 ± 3.8	31.1 ± 0.4	14.96	<0.001	26.88 – 39.12
Average	75.0 ± 9.8	30.7 ± 1.5	7.70	0.002	28.36 – 60.31
	Air quality - PM $_{10}$ (µg/m^3)				
Samaru	194.0 ± 2.8	38.1 ± 0.4	95.53	<0.001	151.47 – 160.53
Damba	189.1 ± 3.3	33.9 ± 0.9	78.48	<0.001	149.52 – 160.48
Lalan	176.9 ± 2.6	36.2 ±0.7	90.70	<0.001	136.68 – 145.32
Average	186.7 ± 87	36.0 ± 2.0	29.12	<0.001	136.29 – 165.03
	Noise level (dBA)				
Samaru	95.8 ± 2.2	62.7 ± 2.9	15.75	<0.001	27.27 – 38.93
Damba	104.5 ± 1.9	54.2 ± 3.1	23.96	<0.001	44.47 – 56.13
Lalan	107.9 ± 2.1	71.1 ± 2.5	19.52	<0.001	31.57 – 42.03
Average	102 ± 6.2	62.7 ± 8.5	6.61	0.003	23.22 – 56.91

Table 2: Average ambient temperature at the quarry sites

Sites	Average Temperature (^{0}C)	
	Morning	Afternoon
Samaru (quarry area)	35.4	43.1
Samaru (admin area)	33.7	39.7
Damba (quarry area)	34.9	42.7
Damba (admin area)	33.4	38.4
Lalan (quarry area)	33.6	42.8
Lalan (admin area)	29.8	38.8
Average (Mean ± S.D)	33. 5 ± 2.0	40.9 ± 2.2

Table 3: Assessment of adherence to OSH policy

Variables	Frequency	Percentage
Availability of written policy on OSH	0	0
Compliance with a written policy on OSH	0	0
Standard operating procedure pasted at the workplace	0	0
Available instructions on the use of PPE	0	0
Workplace inspection by labour inspectorate in the last 1 year	0	0

Table 4: Assessment of general work condition

Variables	Frequency	Percentage
*Factory, generally clean and tidy	1	33.3
Presence of adequate signs: to encourage good safety practices, and housekeeping, and to warn persons of hazards in the work area	0	0
Availability of a separate, clean, comfortable and hygienic place for meals separate from the work area	3	100
Availability of properly equipped first-aid kits with a full list of contents	0	0
Availability of trained staff on how to provide first aid in case of an accident	0	0
Presence of an accident register in the quarry	0	0
Presence of toilets for workers to use	0	0
Adequate ventilation	3	100
Adequate lightening	3	100
Comfortable weather/temperature	3	100
A workplace free from dust	0	0
A workplace free from noise	0	0

Table 5: Assessment of Adherence to workplace health safety measures in the selected quarries

Variables	Frequency	Percentage
Mechanical devices in use to ease the lifting/moving of heavy loads	0	0
Appropriate seats (with lower back support) and footrests were provided for those workers sitting for most of the shift	0	0
Workers not subjected to vibrations	0	0
Workers do not inhale, ingest or absorb dust into the body	0	0
Absence of work process that could cause burns to workers	0	0
Workers not exposed to smoke in the quarries	0	0
Injury or strain cannot arise from the design and organization of the workplace	0	0

DISCUSSION

The efficiency of workers in their workplaces is determined by their state of health.[24] Exposure to hazards in workplaces affects workers' health and plays a role in the morbidities that may develop from these exposures.[25] Despite this reality, hazards generated in the course of work in the quarry workplaces are not measured.[26] In addition, OSH regulations to guide against these workplace hazards may also not be adhered to. [26] This study assessed environmental hazards and adherence to OSH regulations in the stone quarries in Gusau, Zamfara State.

In this study, the mean values of $PM_{2.5}$ and PM_{10} in the quarry work areas were high and said to be unhealthy for fine ($PM_{2.5}$) and poor for coarse (PM_{10}) particulate matter. These PM values in the quarry work areas exceeded the normal limits of $PM_{2.5}$ (35 μg/m$^{3)}$ and PM_{10} (150 μg/m^3) set by USEPA (United States Environmental Protection Agency).[22] Similar findings in Ebonyi Southeast, Nigeria, reported high concentrations of $PM_{2.5}$ (69.00 ± 1.41 μg/m^3) and PM_{10} (2,829.50 ± 12.02 μg/m^3).[27] Exposure to high levels of particulate matter may predispose the workers to an increased risk of respiratory symptoms and cardiopulmonary morbidities.[28] The levels of $PM_{2.5}$ and PM_{10} in the administrative areas were however lower than the USEPA normal limit and therefore, the surrounding communities may likely not suffer adversely from air pollution since the PM level was low in the administrative areas.[22]

From this study's findings, the impulsive noise levels measured in the quarry areas were undesirably high and greater than the NIOSH recommended exposure limit of 85 dBA.[20] Similar findings were reported in Kano, North-west Nigeria 96.0 to 101.4 dBA, Abia, South-east Nigeria 69.8 to 96.0 dBA and Malaysia, 91.8 dBA.[19, 29, 30] The impulsive sound levels assessed in this study may be the cause of the similarity in noise generated. Another factor might be noise suppression in the other studies because their methods for mining stone were largely mechanical. Some workers may have noise-induced hearing loss as a result of the excessive noise level generated. There could be stress, sleep disturbances, hearing loss, and elevated blood pressure among the workers as a result of this noise pollution.[31,] Lower proportions of noise levels were reported in the administrative areas. These administrative areas had permissible noise levels of less than 85 dBA as recommended by NIOSH.[20] The importance of this is that nearby populations may not be negatively impacted by noise. A similar finding of 69.8 dBA was reported in the administrative areas of quarry workers in Abia, Nigeria and 67.3 dBA in Sabah, Malaysia.[29,30]

The average morning and afternoon temperatures across the three sites were similar to the temperature (12.2^{0}C to 40.6^{0}C) of Gusau metropolis.[32] This finding is comparable with a study conducted in India among quarry workers which reported a range of 36.1 to 43.2^{0}C.[23] The similarity in meteorological conditions between the two nations could be the reason for the temperature similarity. The maximum temperature reported in this study is high and may be due to the heavy sun prominent in northern Nigeria and heat reflection from the rocks. The consequence of this high temperature is that workers might be vulnerable to excessive sweating, thirst/dry mouth, elevated core temperature, decreased working capacity, heat stress and heat-related illnesses.[23]

All the quarries had no written policy on OSH and standard operating procedures, but there was adequate ventilation and lighting both in the quarry and administrative areas. The administrative areas of the quarries were generally clean, tidy, comfortable and hygienic for meals, separated from the work areas and with favourable weather conditions; however, none of the quarries had toilets for workers' use for convenience. Similarly, no provision was made for mechanical devices to ease lifting/moving heavy loads and no appropriate seats for workers sitting for most of the shift in all the quarries. The workers were exposed to vibrations from working tools and were predisposed to injuries. A study conducted in Zaria, Northwest Nigeria revealed that none of the quarry sites instituted any preventive measures, but the worksites had adequate lighting.[15] Another study conducted in Kenya found that none of the quarry companies had any safety measures in place.[33] There were no warning signs and some workers seemed adamant about the risks they faced as they worked, and documentation was essentially non-existent as evidenced by the non-availability of accident/injury records in all the sites visited.[33] The study established that management lacked commitment to workers' OSH and concluded that it was the top contributing factor affecting the implementation of OSH measures in quarries.[33] This study found that there was poor adherence to OSH regulations in the quarries in Gusau. Consequently, the workers despite being exposed to hazards in quarry workplaces had poor adherence to OSH measures and were at increased risk of morbidities and injuries.

CONCLUSIONS

This study revealed the presence of unhealthy and poor levels of PM, noise above REL limit and poor adherence to OSH regulations in quarries in Gusau.

Recommendations

The state regulatory authorities and quarry employers should educate and enforce adequate safety training of the workers on the risks of hazards they are exposed to, and ensure adequate implementation of the regulations in all the quarries.

Limitations of the Study

A limitation of this study is that it may be subjected to observer bias. However, this was minimized by conducting the environmental assessment multiple times and taking the average.

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Conflict of Interest

None was declared by the authors.

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