# Air Quality in the Quarry Working Environment in Edo State, Nigeria

Erah FO[1], Okojie OH[2]

[1]Consultant, Department of Community Medicine, Irrua Specialist Teaching Hospital, Irrua, Edo State, Nigeria. [2]Professor/Consultant, Department of Community Health, University of Benin Teaching Hospital, P.M.B 1111, Benin City, Edo State, Nigeria.

**ABSTRACT**

**Aim:** To estimate the concentration of dust (air quality) in the quarry industry in Edo State with a view to protecting workers in this industry from respiratory problems.

**Methods:** The study was carried out in Edo State which is in the South-South geopolitical zone of Nigeria. The quarry locations have natural deposits of large stones and the substances quarried in the sites include granite, limestone, and dolomite.[4]The study was conducted using a cross-sectional analytical study design. Total population of all eligible quarry sites (six) who met the inclusion criteria were recruited for the study. Measurement of total dust concentration with the aid of a dust meter (CEL-712 Microdust pro) in workplace environment in six dust producing sites and control environment were carried out. Observational check list was used in both the quarries and control sites. Data were analysed with the aid of IBM SPSS version 20.0 software.

**Results:** The TSP, $PM_{10}$ and $PM_{2.5}$ were higher in all the quarries than the WHO recommended limits. The mean values of TSP, $PM_{10}$ and $PM_{2.5}$ of 5.22 ±3.38mg/m$^3$, 1.27 ±0.67mg/m$^3$ and 0.54 ±0.34mg/m$^3$ respectively were higher in the quarries when compared to the mean values of TSP, $PM_{10}$ and $PM_{2.5}$ of 0.01±0.08mg/m$^3$, 0.02±0.01mg/m$^3$ and 0.02±0.01mg/m$^3$ respectively in the control sites and the mean values in the control sites were within normal values while those in the quarry working environment were above WHO recommended limits.

**Conclusion:** The concentration of particulate matter in the quarry working environment in Edo State is unacceptably high and efforts should be made by all concerned to keep the quarry working environment safe for the workers.

**Key words:** Dust, Concentration, quarry workers, environment.

## INTRODUCTION

The quarry industry began when man started using stone to build homes and monuments. The industrial revolution in the western countries created an unprecedented demand for stone as wooden harbours could no longer sustain the huge increase in shipping. Stone harbours were constructed at every major seaport, and the cities that dramatically expanded around these lucrative regions required even more stones to build houses, prisons, town halls and courts.[1]

The act of quarrying is carried out by different methods using different equipment such as hand tools, explosives, power saws, by channeling and wedging according to the purpose for which the stone is extracted.[2] Crushers and channeling machines which are gasoline or electric driven engines, tractors and heavy duty vehicles are equally used.[3]

An estimated 13-20 million people from over 50 developing countries are directly engaged in artisan mining.[2,4] The quarrying job involves exposure to inhalation of dust. Individuals

***Correspondence:**
Erah Francis O, Consultant Public Health, Department of Community Medicine, Irrua Specialist Teaching Hospital, Irrua, Edo State, Nigeria. Email: francozenith@yahoo.com, mobile: +2348033546812.

working in dusty environment face the risk of inhaling particulate materials that may lead to adverse respiratory effects.[5] Inhalation of air borne particles and the use of machines/equipment exposes the workers in the quarry industry to a lot of health hazards. Quarry workers in developing countries are often exposed to dust though they may not be aware of its dangers.[6] Many workers in the quarry industry do not have sufficient knowledge of the impact of dust in their lungs and their overall health conditions.

Determining the nature of dust in the quarry work environment gives the information on the hazards the workers are exposed to. This information will form the basis for recommendation to the appropriate authorities on the need to keep the work environment safe for its workforce. Finding from this study will equally assist the management of these quarries in doing everything possible to minimize dust generation and offering health education to its workers on the need to wear the provided respiratory protective equipment when necessary; also undue exposure to dust in the work place can be prevented entirely. Therefore, the findings from this study will enable policy makers in the quarry industry to proffer solution to the problem of work-related respiratory impairment.

## METHODS

### Study area

The study was carried out in Edo State which is in the South-South geopolitical zone of Nigeria. It is bounded by Kogi State to the north, Delta State to the south which also forms the eastern border, and Ondo State forms the southwest border. It has a total land area of 19,187.93 square kilometers. The 2006 population and housing census (priority table IV) puts the population of Edo State at three million, two hundred and thirty three thousand, three hundred and sixty six (3,233,366) people with a male/female ratio of nearly 1:1 (1,633,946: 1,599,420).[7] The projected population of Edo State for 2016 is four million, two hundred and twenty thousand, four hundred and fifty five (4,220,455) with a growth rate of 2.7.[7] The State has tropical climate with distinct dry and rainy seasons. The temperatures range from 27 to 44 degrees Centigrade with annual rainfall of 150 cm. The State consists largely of flat lands with tropical rain forest in the South and guinea savannah in the North. It lies at an elevation level of about 500 feet in the south and up to 1800 feet in the north. Edo State has eighteen Local Government Areas (LGA) and quarry industries are located in three LGAs namely: Etsako West LGA (quarries located in Imeke and Iyuku), Akoko-Edo LGA (quarries located in Ikpeshi) and Ovia South West LGA (quarries located in Evbonogbon).[9] The natural deposits of large stones in these areas necessitated the establishment of quarry industries in these locations.

The substances quarried in the sites include granite, limestone, and dolomite. The state is blessed with other abundant natural resources including crude petroleum oil, marble, lignite, kaolin, etc.[8] There is the presence of various industries such as cement factory, flour mill, beverage industries (bottling and brewing) and other agro-allied industries, construction and civil works, woodwork and numerous small scale industries. The religions of the people include Christianity, Islam and African Traditional Religion (ATR). Large proportions of Moslems are in the northern part of the state. The occupations of the people are farmers, artisans, civil servants, traders, quarry workers and students. The major ethnic groups include Benin, Esan, Afemai and other indigenous and non-indigenous tribes. The proportion of people living below poverty line in Edo State is high and ranges between 40% and 83% with poverty highest among women, children, youth, unemployed and people living with HIV/AIDS.[10]

### Study Design

The study was conducted using a cross-sectional analytical study design.

### Study Population

The study population included workers from dust producing environment in six quarry sites in Edo State with the study carried out over a period of ten months. Six control sites free of quarry activities from University of Benin, Benin City, Nigeria were also recruited for the study.

**Selection criteria**

A total population of 6 (six) eligible quarry sites in the study area who met the inclusion criteria were recruited for the study. The control sites were 6 locations within the University of Benin where there was no quarrying activity or were free of any dust production and selected by the researcher to be used as control.

**Data collection method**

**Quantitative Method of Data Collection**

**Dust sampling.**

Measurement of total dust concentration in workplace environment in six dust producing sites and control environment were carried out in accordance with the National Institute for Occupational Health and Safety (NIOHS) guideline. A portable direct reading dust meter (CEL-712 Microdust pro) for particulate monitor manufactured by CASELLA CEL with serial number 1739934 was used. It achieves accurate and repeatable dust concentration measurement using forward light scattering techniques. It offers graphical presentation of concentration trends, internal data logging, simple and clear user interface and digital calibration methods to suit any dust sampling scenario and is expressed in milligram per cubic meter ($mg/m^3$). The instrument uses a modulated beam of Infra-Red light projected into a measurement chamber. Under clean air conditions, all light is prevented from reaching the receiver by a light stop. When dust particles enter the sample volume, the light beam is scattered forward within a narrow angle to receiver. Excellent linearity is achieved up to $2500mg/m^3$ when a comparison is made between micro-dust measurement and simple gravimetric measurement. The equipment exhibits its highest degree of sensitivity for particle sizes within the respirable domain; It also determined inhalable Particulate Matter (PM), as well as Total Suspended Particle (TSP). It has particle sensing range of 0.1 to $250mg/m^3$ (the machine could be adjusted to any of the following ranges 0.001 to $2.5mg/m^3$; 0.01 to $25mg/m^3$; 0.1 to $250mg/m^3$ and 1 to $2500mg/m^3$) and could operate effectively between temperatures of 0 to $50^0C$. The equipment has TSP, $PM_{10}$ and $PM_{2.5}$ accessories. $PM_{10}$ is about one-seventh of the width of a strand of human hair while forty $PM_{2.5}$ could be placed on the width of a strand of human hair. For each measurement to be taken, the appropriate accessory has to be attached before taking the measurement. $PM_{10}$ and $PM_{2.5}$ requires the attachment of a pump which attracts dust of less than ten microns to the instrument. The equipment was calibrated before use in accordance with the manufacturer's instructions. Each reading was taken for 20 minutes at each work area. Prior to the test, the respondents were informed of the test procedure and the purpose of the test. The dust sampling (measurement of TSP, $PM_{10}$ and $PM_{2.5}$) was conducted in the quarry work environment and the control environment. In the six quarry sites, the dust sampling was done at the drilling/crushing site, 50 meters away and 100 meters away from the sites and three reading taken at each location. For the control environment, the dust sampling was done at six different locations with three readings taken at each location.

**Qualitative data collection method**:

**Observational check list**

Observational check list was used to observe the environmental conditions of the quarries and control sites. The observational checklist included assessment of quarry environment, observation of workers to see how workplace hazards are minimized or prevented and the placement of health and safety posters, display of factory act within the premises of the industry, availability of fire-fighting equipment, provision of first aid, and use of Personal Protective Equipment (PPE).

**Data Management**

Data from the questionnaire were coded and entered into an electronic spread sheet. Analysis was done with the aid of IBM SPSS version 20.0 software, and discrete data were presented as tables, diagrams and proportions (percentages). Students' T test for test of association between two independent means and Analysis of Variance (ANOVA) for the means of particulate matters in six quarry locations and control sites was done. Where the expected frequency in more than 20% of cells was less than 5, or any cell had an expected cell count less than 1, Fishers' exact test was used to test for association between the variables. Statistical level of significance was set at $p < 0.05$.

**Ethical Issues**

Ethical approval to conduct this research was sought and obtained from the University of Benin Teaching Hospital Research Ethics Committee.

**Establishment Approval**

Approval to carry out this study in the quarry sites was obtained from the managements of the various quarry sites in Edo State. All the details of the study (like dust sampling in the various quarries and control sites) were dully explained and communicated to the authorities in the various sites. For anonymity, the quarry sites were labelled A-F.

**Study Limitations**

Differentiating between particulate matter generated sorely from quarries and other pollutants from smoke and other outdoor pollutants was difficult in this study.

## RESULTS

**Table 1: Mean levels of particulate matter (mg/m$^3$) in the quarries**

| rticulate matter | Drilling/Crushing site | 50 m away | 100 m away |
|---|---|---|---|
| QUARRY A | | | |
| TSP | 2.154 ± 0.093 (ME) | 1.266 ± 0.198 (LE) | 0.570 ± 0.079 (LE) |
| PM10 | 0.964 ± 0.182 (LE) | 0.964 ± 0.307 (LE) | 0.323 ± 0.067 (LE) |
| PM2.5 | 0.326 ± 0.147(LE) | 0.223 ± 0.133 (LE) | 0.187 ± 0.032 (LE) |
| QUARRY B | | | |
| TSP | 3.323±1.315 (ME) | 1.002±0.202 (LE) | 0.115±0.061 (LE) |
| PM10 | 1.306±0.503 (LE) | 0.393±0.237 (LE) | 0.113±0.067 (LE) |
| PM2.5 | 0.637±0.094 (LE) | 0.327±0.128 (LE) | 0.081±0.032 (LE) |
| QUARRY C | | | |
| TSP | 9.327±1.975 (HE) | 1.444±1.318 (LE) | 1.158±0.529 (LE) |
| PM10 | 0.855±0.682 (LE) | 0.435±0.274 (LE) | 0.346±0.364 (LE) |
| PM2.5 | 0.460±0.266 (LE) | 0.216±0.187 (LE) | 0.120±0.001 (LE) |
| QUARRY D | | | |
| TSP | 4.226±2.611 (ME) | 1.743±1.216 (LE) | 0.964±0.165 (LE) |
| PM10 | 1.682±0.524 (LE) | 0.922±0.173 (LE) | 0.699±0.188 (LE) |
| PM2.5 | 0.988±0.118 (LE) | 0.115±0.034 (LE) | 0.468±0.272 (LE) |
| QUARRY E | | | |
| TSP | 2.779±1.159 (ME) | 1.068±0.114 (LE) | 0.759±0.056 (LE) |
| PM10 | 0.946±0.210 (LE) | 0.726±0.249 (LE) | 0.356±0.269 (LE) |
| PM2.5 | 0.077±0.001 (LE) | 0.271±0.242 (LE) | 0.124±0.075 (LE) |
| QUARRY F | | | |
| TSP | 9.507±0.766 (HE) | 4.119±0.166 (ME) | 1.148±0.247 (LE) |
| PM10 | 1.847±1.209 (LE) | 1.179±0.224 (LE) | 0.454±0.123 (LE) |
| PM2.5 | 0.732±0.086 (LE) | 0.413±0.435 (LE) | 0.232±0.159 (LE) |

HE=High Exposure (−5mg/m$^3$), ME= Moderate Exposure (2 - 4.99mg/m$^3$), LE= Low Exposure (0-1.99mg/m$^3$).

The Total Suspended Particles (TSP) in the quarries were within moderate exposure limit of 2 - 4.9mg/m$^3$ (the mean TSP in quarry A was 2.154mg/m$^3$, quarry B was 3.323mg/m$^3$ and quarry E was 2.779mg/m$^3$) except in quarry C and quarry F were the TSP were in high exposure of greater than 5mg/m$^3$ (9.327mg/m$^3$ and 9.507mg/m$^3$ respectively). The mean TSP in the crushing sites range from 2.154mg/m$^3$ to 9.507mg/m$^3$. The mean TSP decreased at 50 meter and 100 meter away from the crushing and drilling sites (1.266mg/m$^3$ and 0.570mg/m$^3$ respectively). The $PM_{10}$ and $PM_{2.5}$ at drilling/crushing sites were all within the low exposure limit of 0 – 1.99mg/m$^3$. The mean values for $PM_{10}$ and $PM_{2.5}$ range from 0.855mg/m$^3$ to 1.847mg/m$^3$ and 0.077 mg/m$^3$ to 0.988mg/m$^3$ respectively. These values were higher than the WHO guideline for $PM_{10}$ and $PM_{2.5}$ of 50 ug/m$^3$ (0.05mg/m$^3$) and 25ug/m$^3$ (0.025mg/m$^3$) respectively.

**Table 2: Mean levels of particulate matter (mg/m$^3$) in quarry and control environment**

| Particulate matter (mg/m$^3$) | Quarry sites | Control sites | t-test | p-value |
|---|---|---|---|---|
| TSP | 5.22 ± 3.38 | 0.01 ± 0.08 | 6.410 | <0.001 |
| $PM_{10}$ | 1.27 ± 0.67 | 0.02 ± 0.01 | 7.868 | <0.001 |
| $PM_{2.5}$ | 0.54 ± 0.34 | 0.02 ± 0.01 | 6.516 | <0.001 |

The mean levels of TSP in the quarry was much higher than that in the control and this association was statistically significant (p = <0.001). The mean levels of $PM_{10}$ and $PM_{2.5}$ were higher in the quarry than in the control and this association was found to be statistically significant (p = <0.001, p = <0.001 respectively).

**Table 3: Spatial variation of particulate matter (mg/m$^3$) for quarry and control environment (Analysis of variance)**

| | | | QUARRY | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Site A | Site B | Site C | Site D | Site E | Site F | F | p-value |
| | $2.15\pm0.0^{a}$ | $3.32\pm1.2^{a}$ | $9.33\pm1.7^{b}$ | $4.23\pm2.1^{a}$ | $2.78\pm1.16^{a}$ | $9.51\pm0.77^{b}$ | 13.72 | 0.000 |
| | $0.96\pm0.18^{a}$ | $1.31\pm0.50^{a}$ | $0.86\pm0.68^{a}$ | $1.68\pm0.52^{a}$ | $0.95\pm0.21^{a}$ | $1.85\pm1.21^{a}$ | 1.244 | 0.348 |
| | $0.33\pm0.15^{ab}$ | $.64\pm0.09^{bc}$ | $0.46\pm0.27^{a}$ | $0.99\pm0.12^{c}$ | $0.08\pm0.03^{a}$ | $0.73\pm0.29^{c}$ | 9.162 | 0.001 |
| ol | | | | | | | | |
| | $0.17\pm0.03^{a}$ | $0.19\pm0.10^{a}$ | $0.12\pm0.02^{a}$ | $0.07\pm0.04^{ab}$ | $0.06\pm0.04^{b}$ | $0.03\pm0.02^{b}$ | 5.257 | 0.009 |
| | $0.03\pm0.00^{ab}$ | $0.04\pm0.01^{a}$ | $0.01\pm0.01^{c}$ | $0.02\pm0.00^{ab}$ | $0.01\pm0.01^{c}$ | $0.01\pm0.00^{c}$ | 6.727 | 0.003 |
| | $0.02\pm0.00^{ab}$ | $0.03\pm0.00^{a}$ | $0.01\pm0.01^{c}$ | $0.02\pm0.00^{bc}$ | $0.01\pm0.00^{c}$ | $0.01\pm0.01^{c}$ | 11.61 | 0.000 |

In the quarry environment, there were significant spatial variation in TSP and $PM_{2.5}$, but there was no spatial variation for $PM_{10}$. There were statistical significant variation in the TSP in sites C and F when compared to other sites and this association was found to be statistically significant (p = 0.001). For $PM_{2.5}$, there were spatial variation in sites D, E and F when compared to other sites and this association was statistically significant (p = 0.001). In the control, there were significant spatial variation in TSP, $PM_{10}$ and $PM_{2.5}$ (p = 0.009, 0.003 and <0.001 respectively) and the source of the difference were in sites C and D (TSP), A and B($PM_{10}$) and B($PM_{2.5}$).

**Table 4: Walk-through assessment of quarry environment (N = 6)**

| FACTORS ASSESSED | Yes | No | Total |
|---|---|---|---|
| | Frequency (%) | | |
| Working environment generally clean. | 2 (66.7) | 4 (33.3) | 6 (100.0) |
| Dangerous areas clearly marked as such. | 6 (100.0) | 0 (0.0) | 6 (100.0) |
| Barriers in place to prevent inadvertent access to dangerous areas | 6 (100.0) | 0 (0.0) | 6 (100.0) |
| Air visibly polluted with dust when in operation. | 6 (100.0) | 0(0.0) | 6 (100.0) |
| Air visibly polluted with dust when machines are not in operation. | 1 (16.7) | 5 (83.3) | 6 (100.0) |
| Attempts seen to reduce dust production. | 5 (83.3) | 1(16.7) | 6 (100.0) |
| Hazard control measures in place. | 6 (100.0) | 0 (0.0) | 6 (100.0) |
| All employees at crushing site seen wearing RPE at work. | 6 (100.0) | 0 (0.0) | 6 (100.0) |
| Workers seen wearing RPE properly | 5 (83.3) | 1(16.7) | 6 (100.0) |
| Presence of health and safety posters. | 5 (83.3) | 1 (16.7) | 6 (100.0) |
| Posters visibly displayed to show good work practice. | 4 (66.7) | 2 (33.3) | 6 (100.0) |
| Factory act visibly displayed within the premises of quarry site. | 6 (100.0) | 0 (0.0) | 6 (100.0) |
| Fire-fighting equipment in place | 6 (100.0) | 0 (0.0) | 6 (100.0) |
| Fire-fighting equipment functional. | 5 (83.3) | 1(16.7) | 6 (100.0) |
| Bathing and toilet facilities available. | 6(100.0) | 0(0.0) | 6 (100.0) |
| First aid materials available. | 6 (100.0) | 0 (0.0) | 6 (100.0) |
| Perimeter fencing and site entrances suitably sited | 5(83.3) | 1(16.7) | 6(100.0) |
| Availability of changing room | 6 (100.0) | 0 (0.0) | 6 (100.0) |

In all the quarries, 6 (100.0%), dangerous areas were clearly marked as such, barriers were in place to prevent inadvertent access to dangerous areas, air was visibly polluted with dust, hazard control measures were

in place, employees were seen wearing RPE, factory act was visibly displayed within the premises of the quarries. The following were seen in place in all 6 (100.0%) quarries: Fire-fighting equipment, bathing and toilet facilities and changing room. The working environment were generally clean in two fifth 2 (66.7%) of the quarries

## DISCUSSION

Findings from this study showed that the Total Suspended Particles (TSP) in two third of the quarries were higher than the World Health Organization (WHO) standard exposure limit for respirable dust of 0.050mg/m$^3$ and 0.025mg/m$^3$ for $PM_{10}$ and $PM_{2.5}$ respectively. These values of particulate matters in the quarries decreased drastically at 50 meter and 100 meters from the drilling and crushing site. This finding is similar to a study done in Abeokuta, Ogun State, Nigeria where the highest mean Suspended Particulate Matter (SPM) levels among the selected quarries was of high limit. SPM levels declined significantly with distance from the drilling and crushing locations at each of the quarry sites[11]. This finding was also supported by another study done in India.[12]All aspects of quarrying are particularly dusty and the environment where this is carried out is polluted with such dust. The observational checklist conducted in the quarries showed that all the quarry environments were polluted with dust and this may explain why the particulate matters in all the quarries were above the WHO recommended exposure limits. This may explain why the highest value of TSP (9.507±0.766mg/$m^3$) in this study was much lower than the finding from a study done in Abeokuta, Ogun State[11] where the highest TSP in the quarries was 26.03±1.36mg/$m^3$. If the workers are not protected by minimizing the amount of dust released into the atmosphere and through use of RPE, the workers are exposed to the undue inhalation which may result to respiratory impairment. It is important to note that the values of the particulate matters (PM) decreased from the crushing site to 100 meter away in all the quarries but the workers who are within the quarries are particularly at risk. Of particular interest is the $PM_{10}$ and $PM_{2.5}$ because these particulate matters usually find their way into the lungs. The workers who are exposed to these dust particles for a long period of time may develop respiratory impairment if deliberate efforts are not made to further minimize the hazard by use of RPE and reduction of dust generation.

In addition, the finding that the $PM_{10}$ and $PM_{2.5}$ were much higher in all the quarries (1.27±0.67mg/$m^3$ and 0.54±0.34mg/$m^3$ respectively) as compared to the control sites (0.02±0.01mg/$m^3$ and 0.02±0.01mg/$m^3$) in this study is similar to a study done in Calabar, Nigeria[13] where particulate matter (PM) level was higher in the dust-emitting sites (1.087±0.243mg/$m^3$) than in the control areas (0.099±0.007 mg/$m^3$). Dust emitting sites such as quarries release particulate matters into the air which can be inhaled by anybody whether worker, contractor, visitors or nearby residents within the community where quarry is carried out. Continuous inhalation without proper protection results in respiratory impairment and other health problems. The implication of this could be that workers in this quarry may be exposed to undue inhalation of these particulate matters which are dangerous to health since the quarry workers depend on quarry for their livelihood and are likely to be exposed to these noxious substances for a long time. The management of these quarries should reduce release of dust particles into the atmosphere and also maximally protect its workers by continuous training and provision of protective equipment. This is further emphasised by the first of Legge's aphorisms which states, 'unless and until the employer has done everything and everything means a good deal, the workman can do next to nothing to protect himself, although he is naturally willing enough to do his share.'

In conclusion, the mean values of all the particulate matters ($PM_{10}$, $PM_{2.5}$ and TSP) were much higher in the quarry crushing sites than in the control sites. The values decreased at 50 meters and 100 meters away from the crushing sites in all the quarries. The mean $PM_{10}$ and $PM_{2.5}$ were above the WHO recommended values of 0.050mg/$m^3$ and 0.035mg/$m^3$ respectively in all the quarry sites.

In view of the above, it is recommended that:

1. The Federal Government through the Ministry of Environment should set air quality standards for particulate matter in the country and ensure that factory inspectors1 monitor its compliance.
2. The Federal Government through the Ministry of Environment should review policy on pollution in quarries with a view to ensuring a safe working environment for quarry workers.

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