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Respiratory symptoms and blood eosinophil level in workers exposed to quarry dust in South-Eastern Nigeria

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ABSTRACT

Objectives: We investigated the respiratory symptoms and eosinophil levels of workers exposed to quarry pollutants in Ebonyi State, Nigeria. **Materials and Methods:** A total of 400 workers exposed to quarry dust and 400 age, sex, body mass index-matched unexposed controls participated in this study. Incidences of respiratory and allergic symptoms were investigated. The level of respiratory dust and gas emissions in quarry sites were measured. **Results:** The incidence of respiratory symptoms and mean eosinophil levels were significantly greater in workers exposed to quarry dust compared with controls. Mean levels of respirable dust and certain poisonous gases from quarry sites were significantly higher compared with those of control environments. The hazard index of respiratory irritants was >1. **Conclusion:** The higher incidence of respiratory infections and aggravated inflammatory responses observed in quarry workers may be attributable to the presence of higher level of respiratory system irritants in the quarry sites.

KEY WORDS: Quarry, respirable dust, poisonous gases, pollutants, respiratory symptoms, inflammation, Nigeria

INTRODUCTION

Although industries such as power plants, cement, refineries and petro-chemicals have been identified as major sources of air pollutants, the emission of particulates is quite outstanding from quarries [1]. Quarrying is a form of land use method concerned with the extraction of non-fuel and non-metal minerals from the rock. Sand gravels and lime-stone for building houses and other civil construction are obtained through quarrying of rocks from the earth's crust [2]. Quarrying could be done in diverse methods such as hard rock mining, using rock drills, explosion of dynamite and other sophisticated methods [2]. The negative impacts of quarrying activities include land degradation, swamp creation, deterioration of ground water, erosion of soil, noise and percussions from rock blasting, generation of dust, smoke and fumes; production of noxious gases and ground vibration [1]. The health impacts of working in stone quarrying industry have been well-documented [3,4]. Previous studies [5-8] have associated exposure to air pollutants or dust among quarry workers to chronic bronchitis, emphysema, acute and chronic silicosis, lung cancer, major respiratory symptoms such as non-productive cough, chest pain, catarrh and dyspnea and impairment of lung function. However, there is paucity of information on the possible biomarkers of continuous exposure to quarry dust and air pollutants in Nigeria.

Peripheral blood eosinophilia is generally regarded as a marker of allergy [9]. Allergic manifestations facilitate and increase the number of blood eosinophil count [10]. A number of studies have demonstrated the association between pulmonary function impairment and the number of eosinophil in peripheral blood [10-12]. These literatures therefore suggest that individuals exposed to quarry dust and air pollutants may suffer from different types of allergic pulmonary symptoms, which may induce eosinophilia. However, to the best of our knowledge, the eosinophil count of quarry workers exposed to stone dust has not been studied in Ebonyi state, Nigeria.

The quarry industry in Umuoghara town, Ebonyi State, Nigeria is an unorganized industrial sector which employs at least 1000 workers [13]. The population of these workers exposed to quarry dust includes men, women, under-aged children, pregnant women, young women of child bearing age and even the elderly. Unfortunately this "at risk" population is not aware of the health hazards associated with exposure to the quarry pollutants. More pathetic is the utter disregard of pollution limits by the quarry industries, low knowledge of environmental laws, and the general poor living standards of the workers due to poor remuneration. Similarly, precautionary measures such as wearing of goggles to protect the eyes; vacuum dust extractors or face masks to minimize the inhalation of dust; barrier creams to protect against dermatitis, ear muffs to protect against noise pollution and gas testing to test for poisonous gases are neither provided nor used by these workers.

The present study therefore evaluated the respiratory symptoms and blood eosinophil counts of quarry workers exposed to quarry dust and pollutants in Ebonyi, a South-Eastern state of Nigeria and compared them with their unexposed controls. In addition, we investigated the level of respirable/nuisance dust and poisonous gases within the quarry site and compared them with a less polluted control site in the same local government area.

MATERIALS AND METHODS

Study Area

This cross-sectional study was conducted in the vicinity of a quarry site located in Umuoghara community, Ezza North Local Government Area of Ebonyi State, Nigeria. The Umuoghara community and its environs are endowed with large deposits of granite, a good material for quarrying, which is responsible for the presence of quarrying companies operating around the area. The temperature of this area ranges between 29°C and 35°C. A preliminary close observation indicated a very dusty and polluted quarry environment resulting from activities from processing and crushing plants, blasting activities at the drilling sections, haulage of crushed rocks, exhaust fumes from many sources including heavy duty vehicles, power generating plants etc.

Subjects

The study was carried out among adult workers occupationally exposed to dust and air pollutants in the quarry site and their occupationally unexposed controls living in the rural communities of the same local government area but far away from the quarry sites. A total of 400 (240 males and 160 females) quarry workers aged 25-58 years and 400 age, sex, body mass index (BMI)-matched controls participated in the study. The test subjects included stone cutters/crushers and loaders, machine operators and supervisors who have worked for at least 1 year in the quarry site and usually exposed to dust for at least 8 h daily for 5 days in a week. The control subjects were rural men and women who were not occupationally exposed to quarry dust or other known air pollutants such as dust from traffic load, toxic gases from explosions and exhaust fumes from vehicles and generators. Subjects were administered with a structured health and life-style questionnaire based on international models adapted for the study population to obtain their past history of pulmonary diseases and other clinical abnormalities. Exclusion criteria included history of clinical abnormalities of vertebral column and thoracic cage, anemia, diabetes mellitus, hypertension, pulmonary tuberculosis, bronchial asthma, chronic bronchitis, emphysema and other respiratory diseases and history of abdominal or chest surgery [13,14]. In addition, those with the habit of smoking were excluded from the study.

The weight of each subject was measured and recorded in kilograms using a standard weight scale and with the person wearing light clothing and without foot-wear. The height of the subjects were measured and recorded with non-stretchable meter rule. Heart rate and blood pressure measurements were done using electronic heart rate monitor and manual sphygmomanometer and stethoscope respectively by experienced medical personnel. Each participant gave his or her individual informed consent to the study before participation after permission was sought and obtained from their employers. Ethical clearance was obtained from the Ethical Committee of Nnamdi Azikiwe University Teaching Hospital, Nnewi.

Study Design and Procedures

Respiratory symptoms were investigated with the use of a structured questionnaire based on international models as well as by medical examinations (health history and physical examination) by qualified medical personnel. An interpreter was employed to translate the questionnaire to most of the workers who did not understand English language.

Respirable dust monitoring was conducted with the aid of a Suspended Particulate Matter meter that measures the concentration of particulates present in the air (mg/m^3). The readings were taken at four different points (cardinal directions) of major activity areas of the quarry site so as to arrive at a mean value for a specific sampling location [1]. The level of gaseous emissions were also determined at predetermined sample points within the vicinity of the quarry site shortly after rock blasting explosions using Gasman gas monitors for hydrogen sulfide (H_2S), ammonia (NH_3), nitrogen di-oxide (NO_2), carbon monoxide (CO) and hydrogen cyanide (HCN), respectively. These measurements (dust and gaseous emissions) were also repeated at four selected pre-determined sampling locations of a rural control site in the same local government area and the mean values calculated.

Blood samples were obtained from the subjects by venopuncture and collected with both EDTA sample bottles and non-EDTA or plain bottles. The blood samples were stored under cold temperature and later analyzed for total white blood cell and eosinophil counts using Auto-Analyzers in the Departments of Hematology and Chemical pathology of Nnamdi Azikiwe University Teaching Hospital, Nnewi.

Data Analysis

Descriptive data are presented as means ± standard deviation for continuous variables and percentages for categorical variables. Comparative analysis between the mean values of two continuous variables was done using independent sample *t*-test. Chi-square test was used to test for the differences between proportions and percentages. All statistics were done using IBM/SPSS for Windows (Version 20.0, IBM Corporation, New York, USA). Statistical significance was set at $P < 0.05$.

RESULTS

Demographic and baseline data for males and females indicated no significant differences in age, height, body weight and BMI between the test subjects exposed to quarry pollutants and their unexposed controls [Table 1].

The mean respirable dust at all the selected sampling locations was higher than the Occupational Safety and Health Administration (OSHA) permissible level of 5 mg/m^3. Our data also indicated that the mean levels of respirable dust from the selected locations of the site (drilling, 6.43 ± 0.66; crushing, 6.22 ± 0.34; loading, 5.85 ± 0.35; administration, 5.32 ± 0.34) were significantly higher ($P < 0.001$) when compared with the mean values of the control site [0.96 ± 0.12, Table 2]. Furthermore, the hazard quotients of the respirable dust in all selected locations were >1 thus indicating a possible adverse effect to pulmonary health.

Table 3 indicates the mean levels of some poisonous gases within the quarry and control sites. The mean levels of hydrogen sulfide, carbon monoxide, and hydrogen cyanide were below the recommended (permissible) level, whereas the values of ammonia and nitrogen dioxide gases were higher than the recommended (permissible) level. On the other hand, the mean levels of all the gases from selected sampling points within the quarry site were significantly higher ($P < 0.01$) compared with the control sites.

Table 4 shows the hazard quotient and hazard index of the respiratory irritants. Data indicated that the hazard quotients for respiratory dust (1.19), ammonia gas (3.14), and nitrogen oxide gas (4.8) were >1. The hazard index of all the respiratory irritants was 10.5 thus indicating aggregated adverse hazard effects of the quarry pollutants on the respiratory health of quarry workers.

As shown in Table 5, subjects exposed to quarry pollutants had significantly greater ($P < 0.001$) presence of sputum production (28% vs. 13.5%), runny nose (45% vs. 25.5%), persistent cough (36.5% vs. 19%), sneezing (56.7% vs. 29%), wheezing (34.5% vs. 17%), chest tightness (17% vs. 6.5%) and breathlessness (29.5% vs. 15.2%) compared with the unexposed control group. The most prevalent respiratory symptoms in both test subjects and controls were frequent sneezing, runny nose, cough and wheezing.

In Table 6, the test subjects indicated significantly higher ($P < 0.01$) mean eosinophil count (359.3 ± 88.87 cell/mm^3) compared with the controls (292.5 ± 75.84 cells/mm^3). Data also indicated that the mean white blood cell count in the test subjects (7.45 ± 13.77 × 10^3 cells/mm^3) was insignificantly higher ($P = 0.256$) when compared with that of controls (6.06 ± 8.49 × 10^3 cells/mm^3).

DISCUSSION

The principal findings of the present study indicated that the incidence of respiratory symptoms of frequent sneezing, wheezing and unproductive cough were significantly higher among the test subjects exposed to quarry pollutants compared to their control population. In addition, the mean eosinophil count of quarry workers was also significantly greater than those of the unexposed control group.

Regarding infective indices of exposure to quarry pollutants, this study showed significantly higher prevalence of specific respiratory symptoms such as sputum production, runny nose, persistent cough, frequent sneezing, wheezing, chest tightness, breathlessness when compared with controls. A previous study [6] has also reported higher prevalence rate of specific respiratory symptoms of dry cough (7.28%), sneezing (11.52%), chest pain (8.09%) and breathlessness (2.7%) among workers exposed to dust emitted from crushing of granite when compared to the controls. The most prevalent respiratory symptoms in test subjects exposed to quarry pollutants were frequent sneezing (56%), runny nose (45%), cough (36%) and wheezing (34%). Olusegun *et al.* and Urom *et al.* [1,6] also reported a high prevalence of catarrh or "runny nose" (20%, 26%) in the respondents exposed to granite dust in Calabar and Abeokuta, Nigeria respectively. Similarly, Olusegun *et al.* and Nwibo *et al.* [1,13] reported high prevalence of cough (26%, 40.5%) in the respondents exposed to quarry dust in Umuoghara and Abeokuta in Nigeria respectively. Frequent sneezing and wheezing are strong indices of allergy and respiratory tract irritation. Cough with sputum production is strongly indicative of infective processes and overwhelmed antioxidant in the respiratory system might be a strong contributing factor. Similarly, we observed higher but insignificant white blood cell

Table 1: Demographic and baseline characteristics of test subjects and their controls according to gender

Variables	Males			Females		
	Controls (*N*=240)	Test subjects (*N*=240)	*P* value	Controls (*N*=160)	Test subjects (*N*=160)	*P* value
Age (years)	41.34±7.64	41.72±8.86	0.265	37.36±6.42	37.55±6.85	0.265
Height (m)	1.72±0.08	1.71±0.06	0.148	1.64±0.05	1.63±0.05	0.112
Weight (kg)	74.31±8.75	74.08±7.58	0.208	68.56±6.95	68.88±6.54	0.138
BMI (kg/m2)	25.24±2.38	24.95±2.16	0.203	25.36±2.46	25.14±2.23	0.214

Data are means and standard deviations. BMI: Body mass index

Table 2: Mean levels of respirable dust (mg/m³) at selected locations of the quarry site compared with the control site

Sampling locations	Respirable dust (mg/m³)	Hazard quotient
Drilling section	6.43±0.66*	1.28
Crushing section	6.22±0.34*	1.24
Loading section	5.85±0.35*	1.17
Administrative section	5.32±0.34*	1.06
Control site	0.96±0.12	0.19

*Significantly higher than control ($P<0.001$). OSHA permissible level=5 mg/m³, OSHA: Occupational Safety and Health Administration

Table 3: Mean level of poisonous gases within the vicinity of the quarry site compared with the control site

Gases	Sampling areas		*P* values
	Quarry site	Control site	
Hydrogen sulfide (μg/m³)	4.5±0.7	0.96±0.04	0.002
Ammonia gas (μg/m³)	157.0±17.6	88.0±10.2	0.001
Nitrogen dioxide (μg/m³)	24.0±4.1	11.0±2.5	0.003
Carbon monoxide (mg/m³)	22.0±3.4	12.0±1.9	0.004
Hydrogen cyanide (mg/m³)	5.60±0.83	1.40±0.03	0.002

Table 4: Hazard quotient of the various respiratory irritants prevalent in the quarry site

Quarry pollutants	Measured level	Permissible safe limit	Hazard quotient
Respirable dust (mg/m³)	5.95	5	1.19
Hydrogen sulphide (μg/m³)	4.5	10	0.45
Ammonia gas (μg/m³)	157.0	50	3.14
Nitrogen dioxide (μg/m³)	24.0	5	4.8
Carbon monoxide (mg/m³)	22.0	55	0.40
Hydrogen cyanide (mg/m³)	5.6	11	0.51

Hazard index of all the respiratory irritants=10.5

Table 5: Comparison of the frequency of infective indices of exposure to quarry pollutants between the control and test subjects

Symptoms	Controls *N* (%)	Test subjects *N* (%)	χ^2	*P* value
Sputum production	54 (13.5)	112 (28)	51.97	<0.001
Running nose	102 (25.5)	180 (45)	72.04	<0.001
Persistent cough	76 (19)	146 (36.5)	63.39	<0.001
Frequent sneezing	116 (29)	227 (56.75)	103.0	<0.001
Wheezing	68 (17)	138 (34.5)	29.89	<0.001
Chest tightness	26 (6.5)	68 (17)	19.17	<0.001
Breathlessness	61 (15.25)	118 (29.5)	32.91	<0.001

Multiple responses of respiratory symptoms were allowed for each respondent

Table 6: Mean eosinophil and white blood cell counts in control and test groups

Variables	Test subjects	Controls	*P* value
Eosinophil count (cells/mm³)	359.30±88.87	292.50±75.84	0.001
White blood cell count (10^3×cell/mm³)	7.45±13.77	6.06±8.49	0.256

count in the dust-exposed quarry workers relative to the control group which may be due to the hash, polluted environment and attendant clinical or subclinical respiratory tract or other infections.

It is believed that the higher incidence of respiratory symptoms observed in subjects exposed to quarry pollutants in this study may be due to the presence of higher levels of respirable dust and poisonous gases observed in quarry sites compared to the control environment. Our study indicated that the mean values of respirable dust from different sampling points within the quarry site were significantly higher when compared with that of control site. These findings concurred with previous studies by Olusegun *et al.* [1] and Bada *et al.*, [15] and shows that the quarry workers who inhale these particulate matters and who do not use protection gadgets are predisposed to health risks.

Similarly, the higher hazard quotients of respirable dust above 1 observed at various locations of the quarry site suggest a possible adverse effect to pulmonary health by the respirable dust particles. It has been reported that dust particles may lodge in human lungs when inhaled, thereby causing lung damages and respiratory problems [13,16]. Another study [2] reported an association between chronic exposure to dust generated from crushing granite rocks with impaired lung function and some respiratory and non-respiratory symptoms. High concentration of respirable dust is known to irritate the mucous membranes and may initiate a variety of respiratory problems [13]. Prolonged and excessive inhalation of fine particulates may cause cancer and aggravate morbidity and mortality from respiratory dysfunctions [17,18].

Furthermore, our data indicated that the mean respirable dust in all the sampling points were higher than the OSHA permissible level of 5 mg/m³ [19]. This finding concurred with a previous study [20] which reported higher level of respirable dust compared with the permissible level in a stone crushing unit in Azendarian, Iran. Potential sources of respirable dust in the study area may include the stone cutting/crushing plants, stone grinding machines, blasting activities, haulage of crushed rocks, etc.

The levels of some of the poisonous gases within the quarry site (ammonia and NO_2) were higher than the recommended permissible level. For example, the mean levels of ammonia gas (157 μg/m³) and nitrogen dioxide (24 μg/m³) were higher than the OSHA recommended permissible limits of 50 μg/m³ and 5 μg/m³ (8 h/day weighted average) respectively. In contrast, the mean levels of Hydrogen sulfide gas (4.5 μg/m³), carbon monoxide (22 mg/m³) and hydrogen cyanide (5.6 mg/m³) were lower than their permissible limits of 10 μg/m³, 55 mg/m³ and 11 mg/m³ respectively. In addition, the mean levels of all the gases within the quarry sites were significantly higher ($P < 0.01$) compared with the control sites.

Short term exposure to ammonia causes severe irritation of the respiratory tract and may cause burning and tearing of the eyes, runny nose, coughing, chest pain, severe breathing difficulties which are usually delayed in onset and which may cause death. Repeated, long-term exposure to ammonia gas may cause chronic irritation of the upper respiratory tract [21]. The oxides of nitrogen (NO_2) are usually formed at higher temperature combustions e.g. industrial combustion and vehicle engines. NO_2 is readily formed by partial oxidation of nitrogen

and is usually emitted in exhaust pipe or motor vehicles and the manifold of power generating equipment where rapid oxidation to NO_2 takes place. Exposure to nitrogen dioxide may cause severe breathing difficulties which are usually delayed in onset and which may cause death. Recovery may be slow with possible relapse and possible permanent lung damage. Pneumonia, irritation of the eye, nose, throat and skin may occur with acute exposure [21]. Hydrogen sulphide gas is extremely toxic, odorous and corrosive. Inhalation of low concentrations may cause headache, dizziness and upset stomach. At higher concentrations hydrogen sulfide may cause loss of consciousness and death [21]. Exposure to carbon monoxide decreases the ability of the blood to carry oxygen to the tissues. Inhalation of carbon monoxide may cause headache, nausea, dizziness, weakness, rapid breathing, unconsciousness and death [21].

We aggregated the effects of the different respiratory irritants using the hazard index and our finding which indicated a respiratory hazard index >1 suggests that a potential for adverse irritation to the respiratory system may exist in the quarry site. However, there is a need to apply caution in the interpretation of this finding since a hazard index >1 does not necessarily indicate a likelihood of adverse effect. Furthermore, the hazard index cannot be translated to a probability that adverse effects will occur and is not likely to be proportional to risk.

The way the respiratory system responds to inhaled particles depends, to a great extent, on where the particle settles. For example, irritant dust that settles in the nose may lead to rhinitis, an inflammation of the mucous membrane. If the particle attacks the larger air passages, inflammation of the trachea (tracheitis) or the bronchi (bronchitis) or the alveoli (alveolitis) may be seen [22]. It is not clear if the higher mean eosinophil count observed in quarry workers relative to those of unexposed control in the present study is mainly due to inflammatory responses from respiratory system irritants since eosinophil levels can also be elevated during parasitic infections. However, there is growing evidence from large population based studies suggesting that a sizeable proportion of the cases of chronic obstructive pulmonary disease (COPD) in a society may be attributable to workplace exposures to dusts, noxious gases/vapors, and fumes [23-25]. COPD is a disease state characterized by airflow limitation that is not fully reversible. The airflow limitation is usually both progressive and associated with an abnormal inflammatory response of the lungs to noxious particles and gases [26]. It is also noteworthy that cough and sputum production may precede the development of airflow limitation [27]. The present findings therefore suggests that the higher eosinophil level as well as greater prevalence of respiratory symptoms of sputum production and cough among the test subjects compared to their control population, may clinically suggest aggravated inflammatory responses to exposure to quarry pollutants.

CONCLUSIONS AND RECOMMENDATIONS

Long-term exposure to air pollutants produced aggravated inflammatory responses as shown by higher levels of eosinophils and higher incidences of respiratory infective symptoms among the quarry workers compared to their occupationally unexposed controls. There was evidence of significantly higher respiratory dust and chemical gases in the quarry site compared to the control site and a hazard index greater than 1 in the quarry sites. These results suggest that the deleterious pulmonary effects observed in the quarry workers were not only from the respirable dust particles, but also from other hazardous respiratory irritants not previously considered. In the light of the above findings, we therefore recommend that (a) precautionary measures such as wearing of the goggles to protect the eyes, vacuum extractors or face mask to minimize inhalation of dust and barriers to protect the skin should be provided to the workers by their employers; (b) the crushers should be installed inside a reasonably dust tight housing, or the outlet of all crushers, both inlet and outlet of secondary crushers shall be enclosed and ducted to dust extraction and collection system to reduce the air pollutants; (c) environmental impact assessment and comprehensive environmental policies should be mandated for all quarries by the government which should also ensure strict enforcement of such in the location of quarry sites.

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