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Assessment of Drinking Water and Air Quality around Selected Quarries in Southeastern Nigeria

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***Abstract*— This study investigated the effects of quarry operations inSoutheastern Nigeria on potable water indices, air quality and noise level in the quarry environs. Standard analytical methods were used to determine physicochemical parameters, heavy metal levels and microbial indices in drinking water, followed by determination of air quality and noise levels within the vicinity ofselected Rock Quarries(QR 1, 2 & 3). Results for physicochemical indices for drinking water samples indicated non-compliance with WHO and NSDWQ permissible limits for aesthetic parameters such as appearance, taste and odour. Values recorded for pH ranged between 6.05 and 6.45 while turbidity values ranged from 6.50 ± 2.66to 17.78 ± 1.95 NTU. Bacteriological results indicated total coliform count of 1.00 ± 0.58, 0.75 ± 0.48 and 0.75 ± 0.48Cfu/100ml for Quarries 1, 2 and 3 respectively. Mean concentration of selected heavy metals in water samples collected from Quarries 1,2 and 3 was in the order: Na>Fe>Mn>Cu>F>As. Results for Fe and Mnin the water samples were above permissible values of 0.3 ppm and 0.4 ppm for Fe and Mn respectively. While Sulphur dioxide (SO2), Methane (CH4), Carbon monoxide (CO) and Hydrogen Sulphide (H2S)levels in ambient air were below detection limits, significantly high PM2.5 and PM10 values were recorded within the vicinity of the rock quarry sites. Noise level at the Quarries varied slightly, with the highest noise level recorded at Quarry 2. Findings reveal that activities at the rock quarries have adverse impact on the environment and further confirm that there are significant health risksto residents within the quarry sites.There is therefore, the urgent need for policy makers, relevant government agencies and quarry operators to instigate measures that would minimize exposure of drinking water, ambient air and residents to environmental pollutants.**

***Index Terms*— Air quality, Drinking water, Noise pollution, Quarry, Water quality.**

I. Introduction

Quarrying and stone cutting are economically important activities all over the world. It is a growing and successful industry in Nigeria. About seven percent of Nigeria's GDP is generated by the mining and quarrying sector [1]. Mining and quarryingoperations in Nigeria generally involve the processes of extraction of naturally occurring stone or minerals such as coal, ores, crude petroleum and natural gas from the earth. [2]. Quarrying products are increasingly demanded for construction, industrial, domestic, agricultural and other purposes so as to satisfy the needs of the rapidly growing population.

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Although quarrying and stone cutting industries have a great role in improving the economic situation, these activities are normally associated with environmental and health impacts[3]. The gains from the sector in form of increased investment are being achieved at great environmental, health and social costs to residents within the quarry locations.Quarrying raises various environmental concern such as land pollution, emission of dust, noise and ground vibrations, the latter arising from movement of machinery and rock blasting which is necessary to break down the rocks from the ground for subsequent processing into aggregates [4]. Suspended particulate matter from quarry sites is a noteworthy source of air contamination, the seriousness of which relies on factorssuch as local climate, particle load in the air, size and chemistry of the particles [5]. Quarries and stone cutting industries cause ecological disturbance, destruction of natural flora, pollution of air, land and water, instability of soil and rock masses, landscape degradation [6].Particulate materials in the form of smoke, dust and vapor generated during quarrying operations are usually suspended over a long period in the air. Such particulate matter in the air are capable of being transported from the point of generation to remote areas [7]. Once particles of varying chemical compositions are inhaled, they lodge in human lungs thereby causing lung damages and respiratory problems [8]. Dust and emissions generated during quarrying can lead to chronic health effects such as decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants. Fine rock and mineral dust of many kinds have been shown to be carcinogenic when inhaled [9]. Inhalation of dusts have potentials to affect the respiratory and cardio-vascular systems and cause pneumoconiosis[10-12].

Environmental safety laws and guidelines have been adopted by Governments of nations in order to protect the environment from such hazards. However, operators of quarries have abused these laws in order to maximize profit.According to Omosanya and Ajibade[13], the abuse is on a large scale inNigeria. The situation is further worsened by the exposure of quarry workers to particulate pollution due to the general non-use of protection gadgets predisposing them to several respiratory ailments.

There has been a considerable increase in mining activities, particularly quarry operations in Abakiliki, Southeastern Nigeria including use of heavy machines that emit gases that are harmful to the environment. This has drastically exposed residents of communities where quarry operations are carried out to various environmental impacts. The aim of the present study is to investigate the effects of quarry operations in Abakiliki, Southeastern Nigeria, on potable water indices, air quality and noise levels. Quality analysis of drinking water collected from the Quarry locations was carried out to ascertain its microbiological, physical and chemical properties and establish that they are all within permissible limits for safe drinking water. Finally, we provide recommendations to help reduce environmental damage caused by quarry operations is reduced to the barest minimum.

II. MATERIAL AND METHODS

A. Study Area

Abakaliki in southeastern Nigeriais located 64 kilometres (40 mi) southeast of Enugu. It lies between latitudes of 6.3231oN and longitudes of 8.1120oE.The quarry sites in the present study are located in Umuaghara Community in Ezza-North Local government area. Abakaliki, as in the past, is a center of agricultural trade including such products as yams, cassava, rice, and both palm oil and palm kernels. It is also known for its local lead, zinc, salt, and limestone mining or quarrying. The last known population of Abakaliki was 915,438(in 2019). This was 0.253% of total Nigerian population. If population growth rate would be same as in period 2006–2015 (+15.31%/year), it is estimated that the population of Abakaliki as at the end of 2021 will be about 1,179,280.

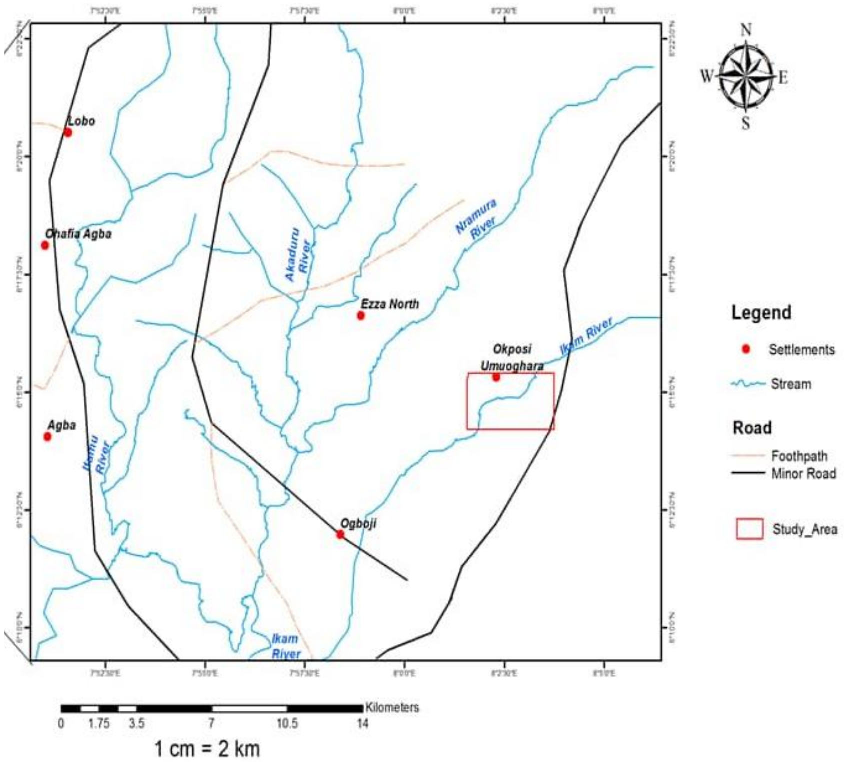

Figure 1. Map showing the study area.

B. Methods

WaterSampling:

Water samples were collected at five sampling points for each of the Quarry sites, approximately 20cm below the surface. The samples were subjected to physicochemical analysis. The samples were collected using sterilized plastic containers and preserved in ice chest box before taking to the laboratory for analysis.

Table 1. Experimental Sample grouping - soil and vegetable

Umuoghara Quarries	Quarry 1	Quarry 2	Quarry 3
Water Samples	QR1w	QR2w	QR3w
Ambient Air	QR1a	QR2a	QR3a

Physicochemical& Microbial Analysis:

The color of water samples was determined using visual comparison method. pH was determined in situ; the indicator electrode of a pH meter immersed, allowed for few minutes to let the reading settle and the final reading was recorded. Temperature was determined in situ by dipping the thermometer of 110^{0}C calibration range into the water and the reading is taken after 5 minutes' interval. Conductivity was determined using electronic conductivity measurement set [14]. Total suspended solids (TSS) and total dissolved solids (TDS) was determined using gravimetric method. Turbidity was determined photometrically using a turbidimeter. Total Suspended Solids was determined according to the APHA 2540-D method [15] while Total Dissolved Solid was determined using APHA 2540-C method [16].Analysis for microbial parameters in the water samples were done according to APHA [17] standard methods. The level of metals (Sodium, Potassium, Calcium, Copper, Iron, Zinc and Cadmium) in water was determined using Atomic Absorption Spectrophotometer method [18].

Calcium & Magnesium hardness, Total Dissolve free CO_2, Total Hardness and Bicarbonate were determined by EDTA titrimetric method described by AOAC [19]. Atomic absorption spectrophotometer (UNICAM) was used for the determination of the concentration of (Fe, Mn, F, Na, As, Cu) in the water samples. The method of APHA [20] was used for the determination of sulphate in the water samples. Silica (as $SiO_{2)}$ was determined using ammonium molydate spectrophotometric method. Alkalinity was determined using titrimetric method. Phenol was determined using Method 528. Albuminoid ammonia was determined by the Nessler colour test [21]. Nitrate in water was determined using standard spectrometric techniques. Asbestos fiber concentration in water samples was measured using the method described by USEPA[22].

Air Quality Determination

Air was trapped at five different locations within each quarry site using series of hand-held air quality monitoring equipment and air pollutants measured immediately. An industrial scientific corporation IBRID MX6 Multi-Gas Monitor was used for the detection of CO, SO_2, $NH_{3,}$ $NO_{2,}$ 0_3,H_2S, CH_4 and VOCs.A Krestel hand held weather trucker was used to determine the wind speed, temperature and relative humidity. PM10 AND PM2.5 emissions were measured using Method 201A[23]. An Extech model 407736 sound level meter was used to measure noise level of the locations.

III. RESULTS AND DISCUSSION

Aesthetic parameters

Water samples from the Quarries under study showed observable colours and objectionable taste and odour at the time of sampling. Colour in drinkingwater may be due to the presence of coloured organic matter, e.g. humic substances, metals such as iron and manganese, or highly coloured industrial wastes. Drinking water should be colourless; changes in the colour of water and the appearance of new colours serve as indicators that further investigation is needed [24].

Table 2. Results for aesthetic, physical and microbial parameters of water quality

	QR1w	QR2w	QR3w	WHO [25];NSDWQ [26]
Appearance	Coloured	Coloured	Coloured	Clear
pH	6.05 ± 0.05^{adh}	6.30 ± 0.12^{adg}	6.45 ± 0.10^{bdg}	6.5-8.5
TDS (mg/l)	0.13 ± 0.06^{adg}	0.19 ± 0.06^{adg}	0.41 ± 0.16^{adg}	500
TSS (mg/l)	12.75 ± 0.63^{adg}	16.00 ± 2.38^{adg}	12.75 ± 1.44^{adg}	25
Taste	Objectionable	Objectionable	Objectionable	unobjectionable
Conductivity (µs/cm)	14.80 ± 1.03^{aeg}	12.00 ± 0.41^{bdg}	12.30 ± 0.27^{adg}	1200
Total Coliform (CFU/100ml)	1.00 ± 0.58^{adg}	0.75 ± 0.48^{adg}	0.75 ± 0.48^{adg}	0
Turbidity (NTU)	6.50 ± 2.66^{adg}	17.78 ± 1.95^{adg}	15.25 ± 4.77^{adg}	5
Temp (^{o}C)	30.00 ± 0.00^{adg}	30.00 ± 0.00^{adg}	30.00 ± 0.00^{adg}	25

Values are means ± Standard Error Mean (SEM). Values with different superscript are statistically different at (P < 0.05). QR = Quarry, WHO = World Health Organization, NSDWQ = National Standard for Drinking Water Quality.

Table 3. Results for some chemical aspects of water quality

Water	QR1w	QR2w	QR3w	WHO [25]; NSDWQ [26]
Phenol	3.47 ± 0.27 ^{a,d,g}	3.50 ± 0.29 ^{a,d,g}	3.42± 0.27 ^{a,d,g}	0.0
Bicarbonate (mg/l)	43.03± 2.33 ^{a,b,g}	35.30± 7.45 ^{a,d,g}	36.2±7 6.77 ^{a,d,g}	N.S
Silica (mg/l)	6.01± 0.06 ^{a,d,g}	6.29 ±0.24 ^{a,d,g}	3.06 ±1.77 ^{a,d,g}	10
Albuminoid NH_3	BDL	BDL	BDL	N.S
Nitrates (mg/l)	3.06± 1.53 ^{a,d,g}	1.74± 1.53 ^{a,d,g}	0.41± 0.00 ^{a,d,g}	50

Dissolved free CO_2 (mg/l)	18.7±5 0.25 a,d,g	44.50± 26.25 a,d,g	14.78± 2.96 a,d,g	N.S
Magnesium Hardness (mg/l)	0.80± 0.23 a,d,g	0.40± 0.04 a,d,g	0.62± 0.19 a,d,g	20
Calcium Hardness (mg/l)	13.50± 0.87 a,d,g	26.48± 12.84 a,d,g	12.73± 0.77 a,d,g	600
Asbestos(mg/l)	0.00± 0.00 a,d,g	0.37± 0.18 a,d,g	0.33± 0.17 a,d,g	N.S
SO_4 (mg/l)	1.56± 0.16 a,d,g	1.67± 0.20 a,d,g	1.33± 0.22a,d,g	500
Alkalinity (mg/l)	41.50± 8.69 a,d,g	44.50± 8.59 a,d,g	70.25± 11.36 a,d,g	N.S

Values are means ± standard error mean (SEM). Values with different superscript are statisticallysignificant at (p<0.05).

Table 4. Result for some metals in drinking water samples

WATER	**QR1w**	**QR2w**	**QR3w**	**WHO [25]; NSDWQ [26]**
Fe (ppm)	1.58 ± 0.53a,d,g	2.43 ± 0.25a,d,g	2.05 ± 0.14a,d,g	0.3
Mn (mg/l)	0.60 ± 0.17a,d,g	0.58 ± 0.19a,d,g	0.72 ± 0.17a,d,g	0.4
F(mg/l)	0.20 ± 0.07a,d,g	0.15 ± 0.05a,d,g	0.11 ± 0.06a,d,g	1.5
Na (mg/l)	14.95 ± 1.70a,d,g	13.50 ± 1.50a,d,g	16.00 ± 1.35a,d,g	<20
Arsenic	BDL	BDL	BDL	0.01
Cu (ppm)	0.33 ± 0.13a,d,g	0.18 ± 0.08a,d,g	0.33 ± 0.13a,d,g	2

Values are means ± Standard Error Mean (SEM). Values with different superscript are statistically significant at (P < 0.05). QR = Quarry, BDL=Below Detection Limits; WHO= World Health Organization; NSDWQ=National Standard for Drinking Water Quality.

Table 5. Results for Ambient Air Quality

	QR1a	**QR2a**	**QR3a**	**WHO [25]; NSDWQ [26]**
PM 2.5	0.06± 0.02 a,d,g	0.09± 0.02 a,d,g	0.10 ±0.02 a,d,g	0.01
PM 10	0.35± 0.15 a,d,g	0.50± 0.04 a,d,g	0.45± 0.03a,d,g	0.02
CO_2(ppm)	497.64± 33.62 a,d,g	535.50± 35.62a,d,g	489.38± 28.79a,d,g	N.S
NO_2(ppm)	0.13± 0.01 a,d,g	0.10± 0.01 a,d,g	0.08± 0.02 a,d,g	0.04
CH_4 (ppm)	BDL	BDL	BDL	N.S
VOC	2.04± 0.38 a,d,g	2.43± 0.61 a,d,g	0.74± 0.09 a,d,g	N.S
SO_2(ppm)	BDL	BDL	BDL	0.02
CO (ppm)	BDL	BDL	BDL	10
NH_3(ppm)	0.30± 0.04a,d,g	0.21± 0.04 a,d,g	0.26± 0.05 a,d,g	0.2
H_2S (ppm)	BDL	BDL	BDL	0.008
0_3 (ppm)	0.29± 0.01 a,d,g	0.31± 0.01 a,d,g	0.28± 0.02 a,d,g	0.1
RH (%)	9.14± 0.45 a,e,h	25.8±5 1.88 b,d,g	31.41± 2.06 b,d,g	N.S

WS (m/s)	5.99± 1.06 ^{a,d,g}	5.74± 0.25 ^{a,d,g}	5.85± 0.35 ^{a,d,g}	
TEMP (^{O}C)	38.25± 0.70 ^{a,d,g}	35.20± 1.37 ^{a,d,g}	32.75± 1.81 ^{a,d,g}	N.S
NOISE (db)	79.26± 6.67 ^{a,d,g}	85.01± 1.81 ^{a,d,g}	73.81± 4.52 ^{a,d,g}	85

Values are means ± Standard Error Mean (SEM). Values with different superscript are statistically significant at (P < 0.05). QR = Quarry N.S = Not stated; WHO = World Health Organization;

It is standard requirement that good quality water should be free of objectionable taste and odour.Odours in water are caused mainly by the presence of organic substances. The observable water colouration and objectionable taste and odour observed in the Quarry water samples is indicative of increased biological activity or water pollution caused by continuous rock quarrying activities.

Surface water temperature:

Surface water temperature recorded a mean value of 30^{0}C for the rock quarries under study (Table 1). This finding of high temperature is similar to temperature ranges reported by Duru et al. [27]in a study on the impact of organic wastes on water quality of Woji Creek in Port Harcourt Nigeria. The high water temperature values recorded can be attributed to the heat from the sun which increased the surface water temperature. Statistical analysis showed significant difference between the dry and wet seasons temperature.

pH: pH values ranged between 6.05 and 6.45 for water samples collected from the Quarry sites and these values fell within the permissible standards of 6.5-8.5 set by WHO [25].

***Turbidity**:*

Turbidity values ranged from 6.50 ± 2.66 to 17.78 ± 1.95 NTU during the study period. Water samples collected from Quarry 1 recorded higher turbidity. Turbidity values in this study seem to fall below the range of 2NTU to 47NTU reported by Asonye et al., [28] in a study of some physico-chemical characteristics and heavy metal profiles of Nigerian rivers, streams and waterways. Turbidity is an indication of water pollution; turbidity is caused by the presence of suspended matters like clay, silt and micro-organisms which makes water cloudy [29]. *Water hardness* is the total calcium and magnesium ion concentration in a water sample and is expressed as the concentration of calcium carbonate. Results for Magnesium Hardness (mg/l) were within regulatory recommendations.

Microbial Count

Results presented in Table 2 show total coliform count of 1.00 ± 0.58, 0.75 ± 0.48 and 0.75 ± 0.48CFU/100mlfor Quarries 1, 2 and 3 respectively. Total coliform count in this study was observed to be higher than WHO/NSDWQ permissible limits of 0.00Cfu/100ml for safe drinking water. This finding corroborates previous report by Kokcha and Chatrath[30] in a comparative study of physicochemical parameters of quarry and drinking water where heavy presence of total coliform bacteria was observed in quarry water. Total coliform bacteria should be absent in drinking water; their presence in water indicates that water is not treated properly and is not suitable for drinking purpose WHO [25]. Values for Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and Electrical Conductivity (EC) fell below WHO/NSDWQ regulatory standards for safe drinking water.

Chemical aspects of water quality & metals

Generally, the mean concentration of the heavy metals in water samples collected from Quarries 1,2 and 3 was in the order Na>Fe>Mn>Cu>F>As. Results for Fe, and Mn were above permissible values of 0.3 ppm and 0.4 ppm for Fe and Mn respectively. Generally, the taste buds in the oral cavity detect inorganic compounds of metals such as magnesium, calcium, sodium, copper, iron, and zinc [25]. Higher concentration of trace elements in water could be an indication of higher dissolution of minerals due to quarrying activities or variations in geo-chemical parameters [31]. Chronic iron overload is characterized by increased iron absorption. Reports have indicated additional medical conditions such as haemorrhagic necrosis and sloughing of areas of mucosa in the stomach with extension into the submucosa [32]. Manganese is an essential element for many living organisms, including humans. For example, some enzymes require manganese (e.g. manganese superoxide dismutase), and some are activated by the element (e.g. kinases, decarboxylases). Adverse health effects can be caused by inadequate intake or over-exposure. By the oral route, manganese is often regarded as one of the least toxic elements, although there are some controversies as to whether the neurological effects observed with inhalation exposure also occur with oral exposure. Several reports of oral exposure to high doses of manganese have described neurological impairment as an effect [33].

Ambient Air Quality:

Sulphur dioxide (SO_2), Methane (CH_4), Carbon Monoxide (CO) and Hydrogen Sulphide (H_2S) concentrations in ambient air were below detection limits (Table 5). Significantly ($p<0.05$) high PM2.5 and PM10 values were recorded within the vicinity of the rock quarry sites. Potential anthropogenic sources of SPM in the study area include fumes from processing/crushing plant, blasting activities, haulage of crushed rocks, welding activities, exhaust fumes from many sources e.g. heavy duty vehicles, power generating plant etc. High concentration of SPM are known to irritate the mucous membranes and may initiate a variety of respiratory problems e.g. cough and asthma. Prolonged and excessive inhalation of fine particulates may cause cancer and aggravate morbidity and mortality from respiratory dysfunctions [34].

Nitrogen Oxide (NO_2), Ammonia (NH_3) and Ozone (O_3) showed significantly ($p<0.05$) higher concentrations as compared to WHO (2017) recommended limits. The oxides of nitrogen 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 NO2 takes place. This finding may have resulted from the use of heavy machines used during quarrying; the heavy duty machinesemit gases that are harmful to the environment. Long term exposure to NO_2 concentrations above 563ppm may cause pulmonary disease and increase susceptibility to bacterial infection in man.

Noise level at the quarries varied slightly. The highest noise level was recorded at Quarry 2. Quarries 1, 2 and 3 recorded noise level consistent with permissible exposure limits expected from such environment. The main sources of noise in the study area included noise from rock blasting site, crush rock processing plants, haulage trucks, diesel power generating plant, heavy duty trucks, welding machines, heavy traffic on the highway traffic hooting and human activities in the neighborhood.

IV. CONCLUSION

Findings from this study revealthat mining activities at the rock quarry sitesand stone industries have adverse impacts on the environment and also, confirmatory that there is significant health risk to residents within the quarry environs. The greatest adverse impact is attributed to particulate matter (dust) generated during quarrying and mining activities, and the negative impact of contaminants on water resources. We therefore recommended thatquarry owners and operators, policy makers, relevant government agencies and other concerned stakeholders shouldcontinuously monitor, control and take necessary policy decisions that would minimize contamination of soil, vegetation, drinking water and ambient air, and ensure reduced exposure of residents to environmental pollutants.

V. COMPETING INTERESTS

The Authors hereby declare that there is no conflict of interests that could possibly arise.

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