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Assessment of $PM_{2.5}$ Around Rock Quarrying Sites and Residential Communities of Iyuku and Ikpeshi, Estako West, Akoko Edo, Edo State

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Abstract

$PM_{2.5}$ is one of the major air pollutants in our environment today. $PM_{2.5}$ refers to particles with aerodynamic diameter less than or equal to 2.5 micrometer. The aim of the study was to assess the levels of $PM_{2.5}$ generated around selected quarries and residential areas in Iyuku and Ikpeshi.Portable hand held monitor was used to detect the concentration of $PM_{2.5}$ in four main quarry sites (Atmas quarry, Freedom quarry, Mothercat quarry, Abandoned Quarry), two operating on hard rocks and the other two operates on soft rocks, Remote path, one residential community in Iyuku, one Control location and one community in Ikpeshi. The obtained data were statistically analyzed using descriptive statistics, correlation and two way ANOVA. The result revealed that the mean value of $PM_{2.5}$ ranged from 21.40 – 99.80 µg/m^3, during Wet season and 99.80 – 263.20 µg/m^3 in Dry. Temperature ranged from 31.74 – 33.72 during wet season and 35.62-38.40 µg/m^3 in Dry season season across sampling locations. The wind speed ranged from 0.96 – 1.60 µg/m^3 in wet season and from 1.76-2.42 µg/m^3 in the dry season. The results showed that the mean values of $PM_{2.5}$ obtained around the vicinity of soft rocks in both wet and dry seasons were higher than those of the hard rocks. Also, the mean $PM_{2.5}$ concentration across the sampling points and seasons exceeded USEPA limit (35 **µg/m^3***) with the exception of that of Control location (21***µg/m^3***). Further findings revealed a significant difference in the spatial and seasonal distribution of $PM_{2.5}$ concentration obtained from the areas of study with the type of rocks been crushed ($P<0.05$). It was observed that the mean Value of $PM_{2.5}$ obtained within marble quarries (R_S) for both wet and dry season were higher than the mean value of $PM_{2.5}$ obtained around granite quarries (R_H).*

1.0. Introduction

Air pollution has become a growing worry across the world today as a result of its adverse effects on our environment and health, due to an ever increasing need for urbanization, the growth of industrial organizations, improved standard of living and automotive emissions [1] According to [2] premature death is an ultimate impact of air pollution.

Particulate matter is a solid or liquid aerosols suspended in the atmosphere. It comprise of suspended particles in air with varying composition and sizes derived from natural and anthropogenic sources [3]. Particulate matter is regarded as the most significant air pollutant in cities around the world because of its negative effect on the environment and its health impacts. Some of its effect on health includes cardiovascular illness, respiratory irritation, and pulmonary dysfunction [4].The environmental impact of particulates is a function of its size, composition and concentration. Particulate matter is characterized based on its aerodynamic diameter.

$PM_{2.5}$ or fine is a particulate matter with aerodynamic diameter of 2.5 micrometer. Due to its fine or minute size it tends to have a larger surface area and thus have the capacity to absorb other contaminants and be widely dispersed [3]. Hence Fine particulate matter ($PM_{2.5}$) has a greater impact on environmental components and human health [5]. According to global burden of illness estimates, residents in Nigeria have a shorter life expectancy than the regional or global norm because of their exposure to ambient $PM_{2.5}$ pollution [6]. Long-term exposure to ambient outdoor fine particulate matter is the leading environmental health risk factor, with an estimated 4.1 million deaths related to it in 2019 [7].

Quarrying is a foundation of modern civilization. Quarry products are essential in providing shelter, infrastructure and communication [8]. Quarrying activities are a major source of $PM_{2.5}$ emission in our environment [9]. Quarrying involves the searching and the extraction of stone from rocks. Stones like gravel, granite and limestone are extracted from the earth through quarrying and are used for the construction of buildings, roads, and dams [9]. Air pollution arising from diverse extraction processes contributes to the release of particulate matter and other air contaminants. Rock drilling and blasting, Stockpiles of quarry wastes, crushing activity, conveyor movements and haulage trucks exacerbate $PM_{2.5}$ production [10]. According to [11] once fine particulate matter when inhaled accumulates in the lungs and may cause respiratory problems. Because of the abundant mineral resources that characterized Iyuku and Ikpeshi, locals and licensed mining owners has engaged in serious quarrying activities, thus the main pollutants in these areas may be linked to industrial activity, movement of haulage trucks and operations related to quarrying or mining. Presently there is little data on $PM_{2.5}$ assessment in Iyuku. Assessment of $PM_{2.5}$ in the study area would provide information that could help in planning mitigation strategies. The aim of this study is to assess the concentration of $PM_{2.5}$ particles generated around selected quarries and residential areas in Iyuku and Ikpeshi, Estako west and Akoko Edo, Edo State.

2.0. Materials and Methods

2.1 Study Area

The study was conducted in Ikpeshi, Akoko Edo local government and Iyuku Etsako West Local government in Edo State which are located in the South-South region of Nigeria within the tropical rain forest belt, on the geographical coordinates of latitude N 07° 08’ 45.0" longitude E 006° 11’ 04.0" and latitude N 07° 09'45.36" and longitude E 006° 15' 07.20" respectively. Characterized by two distinct seasons all year round: wet and dry, with an estimated mean daily temperature range of 26.1 - 32°C, average relative humidity of 79% and average annual rainfall of 2025mm. The wet season extends between March and October, while the dry season commences in November and stops in February, with a temporary break in August known as “August break” [12]. The samplings were conducted from 22nd October, 2021 to 22nd December, 2021 and from 10th January 2022 to March 2022 that spans for Six (6) months.

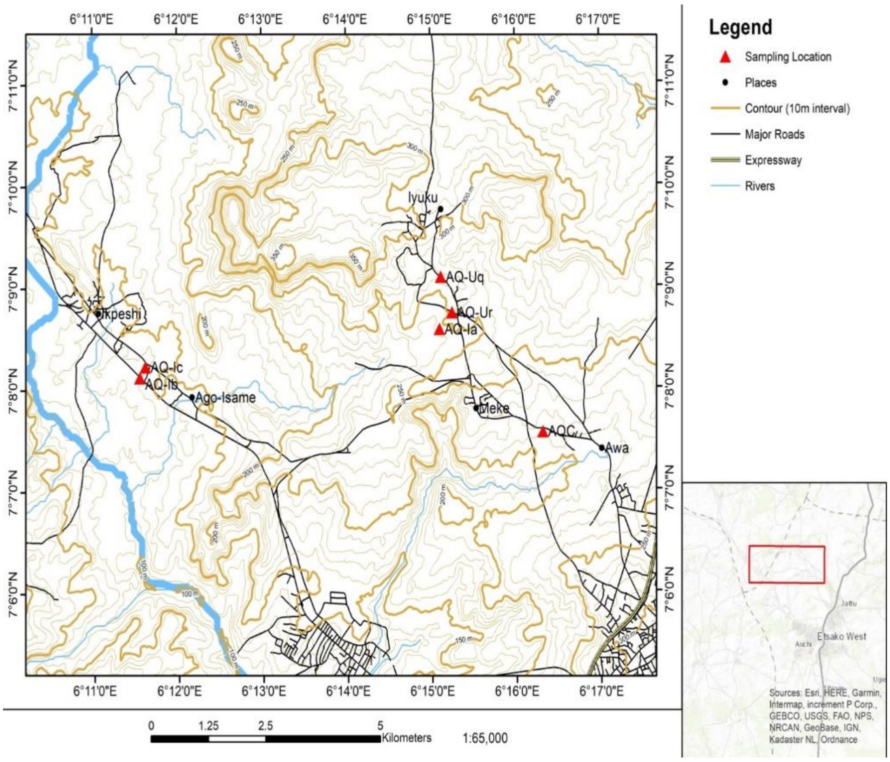

Fig. 1: Sample Location Map of the Study Area

2.2 GEOLOGY OF THE STUDY AREA

In Iyuku, both sedimentary and basement complex rocks are present. Iyuku is located between latitude 07° 08' 22''N to 07° 10' 00''W and longitude 06° 14' 18''E to 06° 161' 00'' E. The lithology of the sedimentary rocks is cretaceous sandstones which are from the Lokoja-Basange formation. These sandstones form a quarter of the sedimentary basin in iyuku. The study area is a part of the southwestern basement complex in Nigeria with extensive igneous rocks like granite and pegmatite. Iyuku granite represents the youngest group of rocks of Precambrian age in the southwestern Nigeria Basement complex. The granites are Syn-to-late tectonic and most of their activity took place during the waning phase of the Pan-African orogeny. Iyuku granite occurs as massive ridges and fragmented boulders [13]; [14].

2.3 Sampling Locations

In accordance with the objectives of the study, four (4) main quarry sites were selected; two (2) operating on hard rocks (RH) granite and the other two operates on soft rock (RS) dolomite and calcite. Two (2) residential communities one close to each quarry site in the Iyuku and Ikpeshi, A walk path to mothercat quarry and one control location. The locations were geo-reference with a Google Earth map. The samplings were conducted from 22nd October, 2021 to 22nd December, 2021 and from 10th January 2022 to March 2022 that spans for Six (6) months with 5- days intervals to examine seasonal variations. A total of 192 samples were measured from all determined sampling stations. After which daily mean levels of PM2.5 was averaged and computed as shown in Table 1 and Table 2.

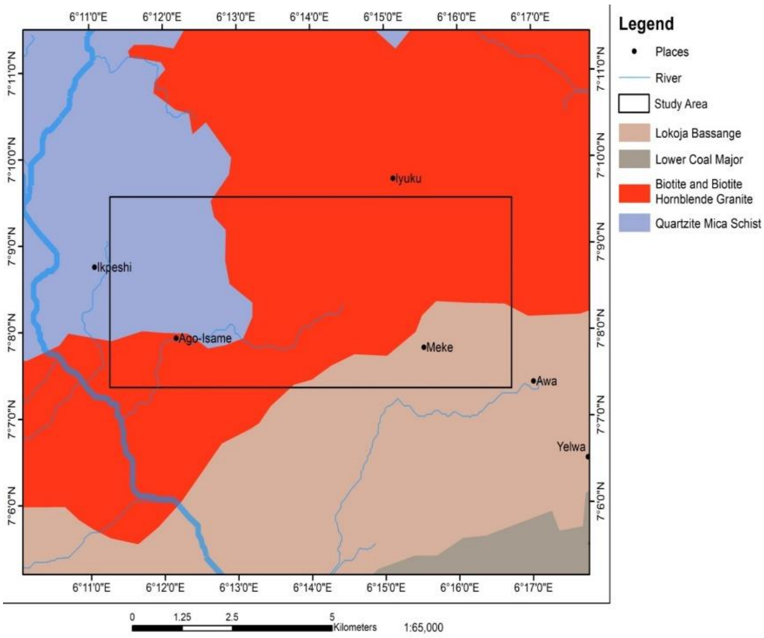

Fig.2: Geologic Map of the study area

Table 2. Showing the details of each sampling location

Location	Location Code	Coordinates	Traffic	Description
ATMAS Quarry	AQ-Ia	**N 070° 08' 34.7''** **E 0060° 15' 05.7''**	Moderate	Operate on soft rocks, and sampling point at the entrance
Freedom Group	AQ-Ib	**N 070° 08' 07.1''** **E 0060° 11' 32.6''**	Moderate	Operate on soft rocks, and sampling point at the entrance
Ekpeshi community	AQ-Ic	**N 070° 08' 13.5''** **E 0060° 11' 36.5''**	Moderate	A residential environment with various activities
Mother cat quarry	AQ-Um	**N 070° 08' 34.7''** **E 0060° 15' 05.7''**	Low	Operate on hard rocks, and sampling point at the entrance
Remote path to Mothercat	AQUr	**N 070° 08' 44.4''** **E 0060° 15' 14.7''**	Low	A remote environment with less residential settlement.
Abandon quarry	AQ-Uq	**N 070° 09' 05.4''** **E 0060° 15' 06.8''**	Moderate	Non-active hard rocks quarry, and sampling point at the entrance
Ijiku Community	AQ-Uc	**N 070° 09' 05.4''** **E 0060° 15' 06.8''**	Moderate	Residential environment, sampling opposite market square
Control	AQC	**N 070° 07' 34.0''** **E 0060° 16' 18.9''**	Nil	A remote environment with no human activities

2.3.1 Particulate Matter ($PM_{2.5}$) Sampling

Portable hand-held air quality monitor (L529K) is a seven (7) in one active sampling device that is calibrated to detect In-situ values for $PM_{2.5}$, The sampler uses light scattering method in determining the $PM_{2.5}$ concentration. It has a display screen which gives the active values for $PM_{2.5}$ measure at each location.

2.3.2 Meteorological Parameters

The meteorological information were collected using a Portable hand-held air quality monitor (L529K) a seven (7) in one multifunctional meter equipped with a hygrometer for determination of the relative humidity and a thermometer for temperature determination. The wind speed was measured using a portable hand held anemometer BTMETER (BT-100). Air temperatures and humidity were measured simultaneously during the survey at an operating conditions of 0 to 50 °C, the thermometer measures within a range of -10°C to 130°C with a sensitivity of 0.1°C and an accuracy of ± 1%; the hygrometer records relative humidity within a range of 10 to 95% with a sensitivity of 0.1% and an accuracy of ± 4%; while the anemometer measures in a range of 0.3 to 30.0 ms-1, a sensitivity of 0.10ms-1 and an accuracy of ± 1%.

2.4 Statistical Analysis

Statistical analysis of the obtained data was performed using descriptive statistics with the help of Microsoft Office Excel 2013 software the association between different parameters were done using correlation and regression statistical model.
Finally, the level of data significances was done by determining the p-value by two-ways analysis of variance (ANOVA) using Microsoft Excel 2013 statistical package software.

3.0 Result and Discussion

The results of $PM_{2.5}$ and meteorological parameters obtained in Iyuku and Ikpeshi, Edo State in both wet and dry seasons is presented in Table 1, Table 2.

Particulate Matter 2.5 ($PM_{2.5}$)

The mean concentration of $PM_{2.5}$ ranged from **21.40 – 178.60 µg/m^3**, during Wet season and 99.80 – 263.20 **µg/m^3** in Dry **as** presented in Table 1, Table 2. The highest mean concentration of 263.60 µg/m^3 was obtained at AQ-Ib and the lowest mean concentration of 21.40 µg/m^3 was obtained at AQC during the dry and wet season respectively. Fig 7 Comparing the determined concentrations of $PM_{2.5}$with standard set by WHO [15] and [16] USEPA (35 µg/m^3), it was observed that the obtained result from all the sampling locations as revealed in Figure 7 violated the [15] WHO and [16] USEPA regulatory limits of 25 µg/m^3 and 35 µg/m^3 in both wet and dry seasons with the exception of $PM_{2.5}$ particles obtained from Control location (AQC) in the wet season. that was in compliance with the limit set by WHO and However, these sampling locations AQ-**I$_a$**, **AQ-I$_b$**, **AQ-I$_c$**, **AQ-U$_m$**, **AQ-U$_r$**, **AQ-U$_q$**, **and AQ-U$_c$** violated both the WHO and USEPA regulatory limits.

3.1. Temperature and Relative Humidity

Temperature influences evaporation and high humidity enhances the production of water vapour. Generally, higher temperatures will promote lower relative humidity conversely lower temperatures will bring about high relative humidity. Table 1 and 2, Figure 3and figure 5 shows the seasonal and spatial variations of temperature at the sampling locations during the sampling period. The wet season mean temperature range was 31.74 – 33.72^{o}C while the dry season mean temperature range was from 35.62 – 38.40^{o}C. The lowest mean temperature (31.74^{o}C) was obtained at location AQ-Ia during the wet season and the highest (38.40^{o}C) was obtained at AQ-Uc during the dry season sampling period. While Relative Humidity ranged from 62.00 – 73% and 49.20 – 55.60% for both wet and dry season as reported in Table 1and 2. The lowest mean relative humidity (49.20%) was obtained at AQ-Uc during dry season sampling and the highest (68.20%) was obtained during the wet season at AQ-Um. Figure 1 and Figure 2 indicate the temperature plot trend. Findings show that wet season temperatures was lower than in dry season, but reverse was the case for the relative humidity. This observation confirms the report of [17] that stated that temperature is generally higher during the dry season when compared with wet season and relative humidity is generally higher during the wet season when compared with dry season.

3.2. Wind Speed

The values of average wind speed ranged from 0.96 -2.42 m/s in wet season and from 1.76-2.42m/s during the dry season at the different locations during the sampling period are shown in Figure 5 and figure 6. The highest and lowest wind speed was obtained at location AQ-Uq with an average value of 2.42m/s in the dry season and 0.96m/s in the wet season respectively.

Table1. Summary of both meteorological and $PM_{2.5}$ concentration obtained during the wet season sampling

Location	Temperature (°C)	Humidity (%)	Wind speed (m/s)	$PM_{2.5}$ (µg/m³)
AQ-I_a	31.74 ± 1.80	64.80 ± 6.18	1.04 ± 0.18	98.40 ± 43.36
AQ-I_b	32.46 ± 1.59	62.00 ± 5.87	1.26 ± 0.44	178.60 ± 79.83
AQ-I_c	32.64 ± 2.25	64.20 ± 3.11	1.60 ± 0.51	81.80 ± 31.02
AQ-U_m	32.26 ± 1.98	68.20 ± 6.91	1.52 ± 0.68	104.30 ± 30.63
AQ-U_r	33.66 ± 3.46	68.00 ± 6.04	1.32 ± 0.61	84.60 ± 30.65
AQ-U_q	33.72 ± 3.22	67.20 ± 4.44	0.96 ± 0.30	116.20 ± 16.15
AQ-U_c	33.58 ± 3.01	65.60 ± 5.32	1.20 ± 0.29	71.00 ± 22.05
AQC	32.26 ± 1.68	73.00 ± 3.54	1.54 ± 0.44	21.40 ± 2.41

(WHO 2005) **25 µg/m³**

(USEPA 2009) **35 µg/m³**

Table2. Summary of both meteorological and $PM_{2.5}$ concentration obtained during the dry season sampling

Location	Temperature (°C)	Humidity (%)	Wind speed (m/s)	$PM_{2.5}$ (µg/m³)
AQ-I_a	35.62 ± 1.79	55.60 ± 4.04	1.76 ± 0.40	244.20 ± 80.91
AQ-I_b	36.04 ± 1.75	51.60 ± 5.32	2.08 ± 0.41	263.60 ± 85.55
AQ-I_c	36.92 ± 1.57	50.00 ± 6.32	1.76 ± 0.60	108.60 ± 37.49
AQ-U_m	38.12 ± 1.95	50.00 ± 4.85	2.20 ± 0.68	166.80 ± 52.20
AQ-U_r	37.86 ± 2.01	50.80 ± 3.70	2.14 ± 0.47	121.00 ± 34.98
AQ-U_q	38.34 ± 1.83	49.20 ± 3.83	2.42 ± 0.65	138.40 ± 31.13
AQ-U_c	38.40 ± 1.85	51.20 ± 7.53	2.12 ± 0.41	99.80 ± 20.85
AQC	38.22 ± 1.68	51.20 ± 6.98	2.08 ± 0.47	43.80 ± 11.56

(WHO 2005) **25 µg/m³**

(USEPA 2009) **35 µg/m³**

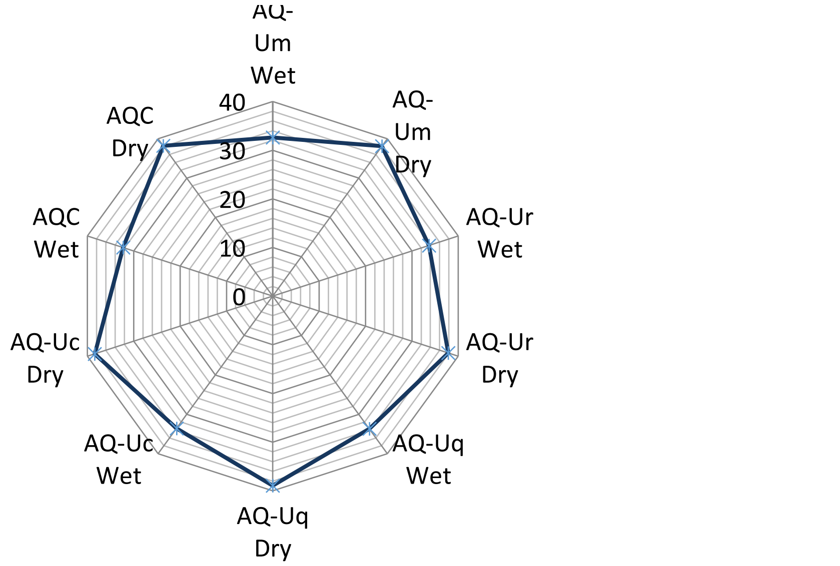

Fig.1. Average temperature at Ikpeshi during the sampling periods

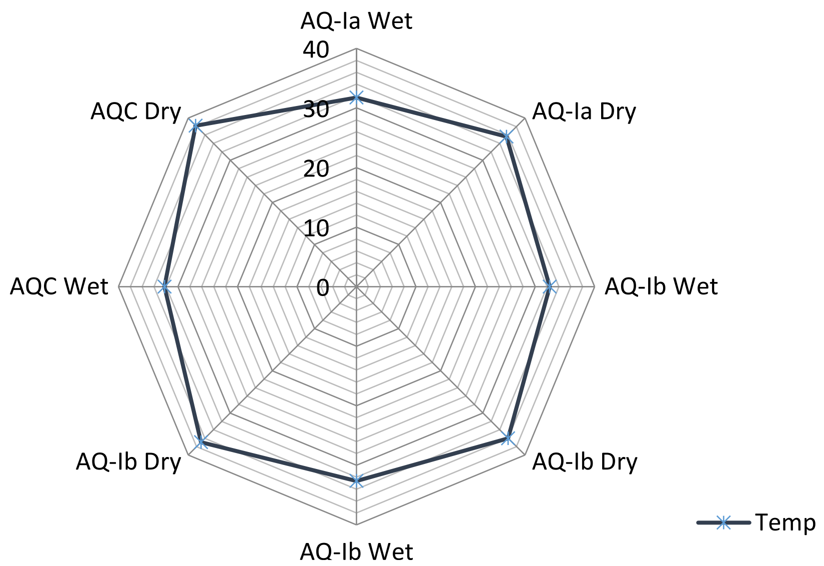

Fig.2. Average temperature at Iyuku during the sampling periods

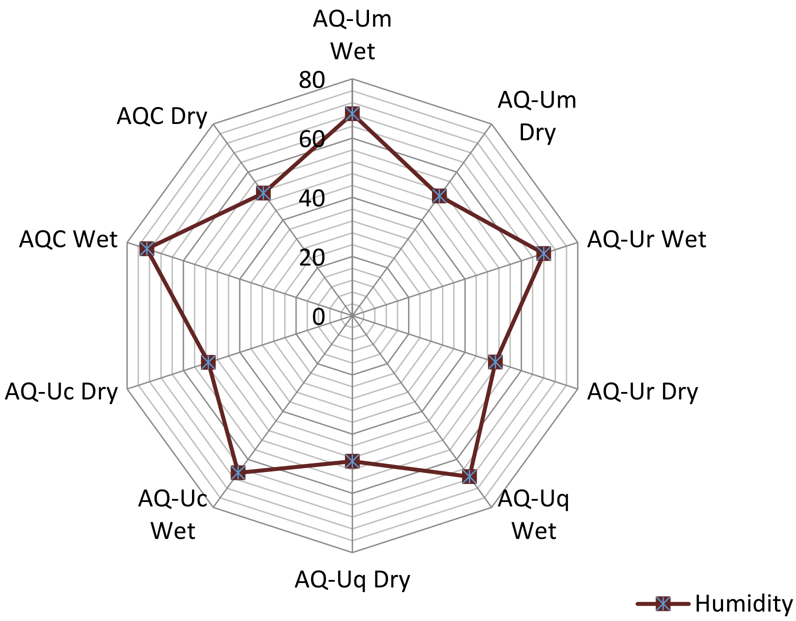

Fig.3. Average Relative Humidity at Ikpeshi during the sampling periods

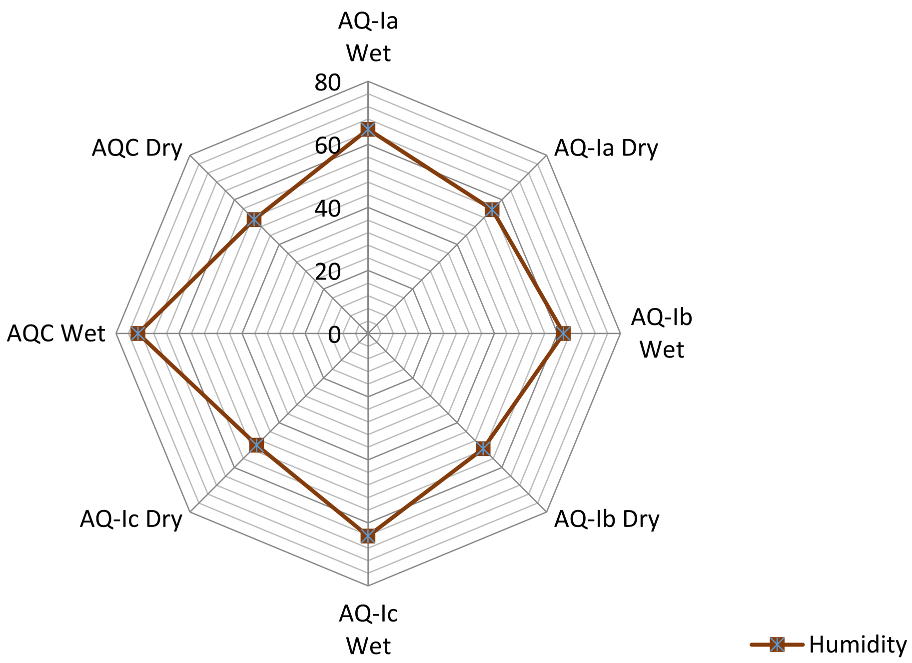

Fig.4. Average Relative Humidity at Iyuku during the sampling periods

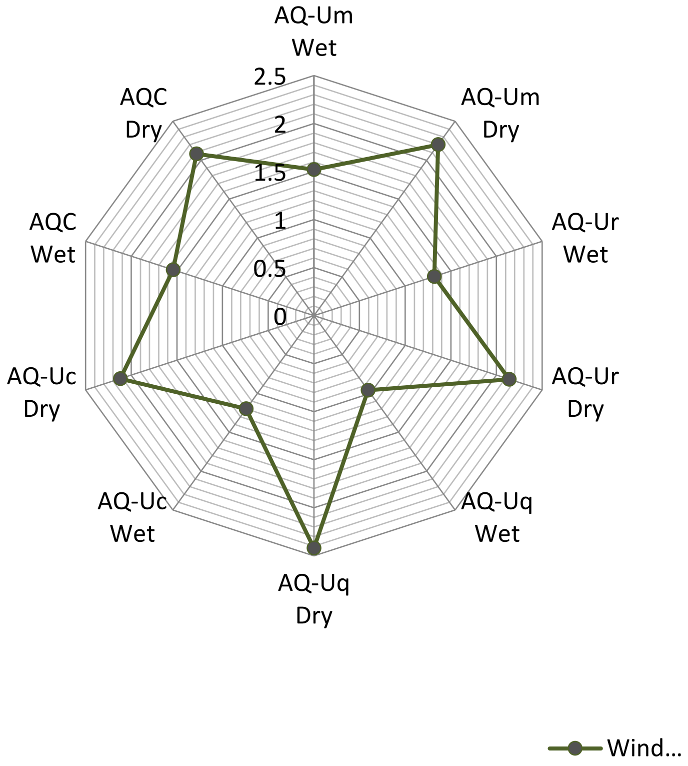

Fig.5. Average wind speed at Ikpesi during the sampling periods

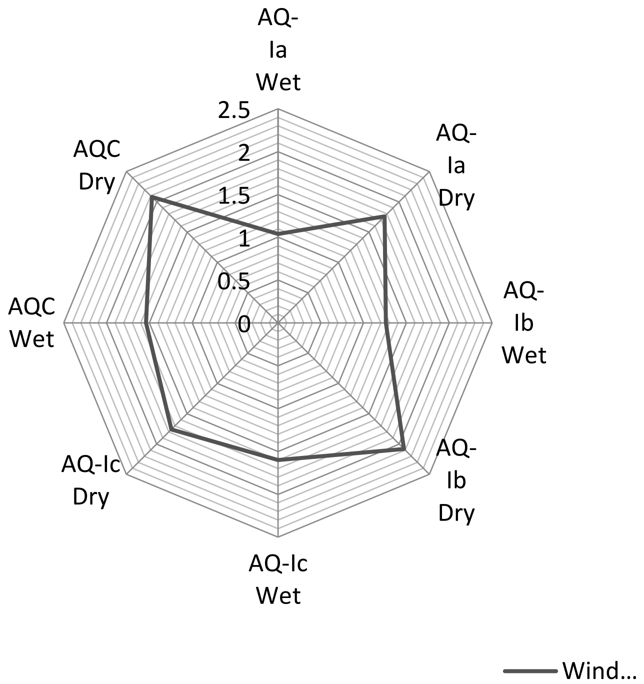

Fig.6. Average wind speed at Iyuku during the sampling periods

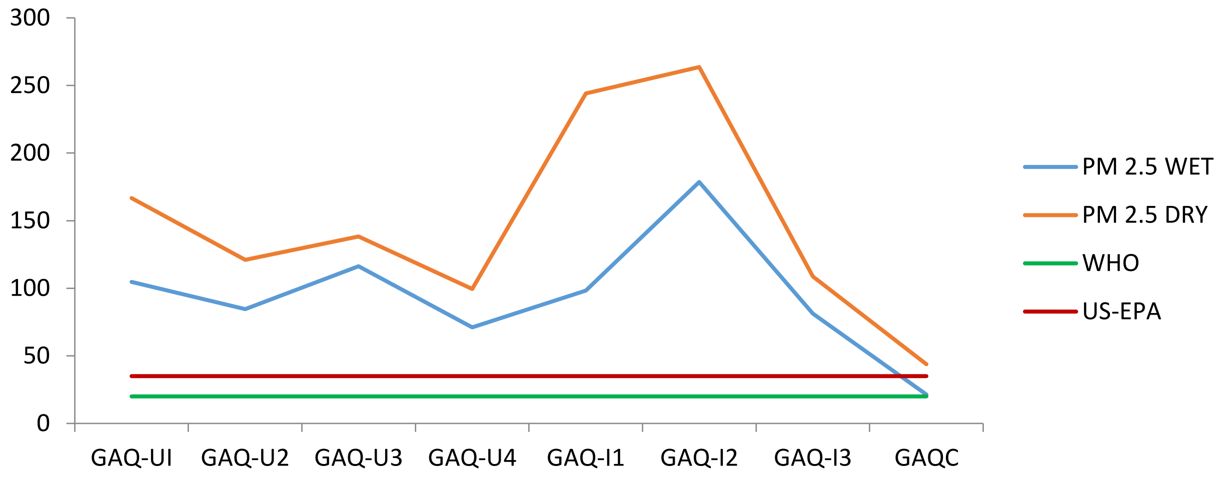

Fig.7. Average seasonal $PM_{2.5}$ concentration comparison along with standards

3.3. Seasonal and Spatial Variation of $PM_{2.5}$ with the Various Rock type

The spatial and seasonal relation table for the obtained $PM_{2.5}$ parameter with the rock type being crushed is presented in Table 3, The table above reveals a significant difference in the spatial and seasonal distribution of $PM_{2.5}$ concentration obtained from the areas of study with the type of rocks been crushed and with $p<0.05$. Comparing the concentration of $PM_{2.5}$ particles obtained around R_H (granite quarries) and $PM_{2.5}$ particles from R_S (marble quarries), it was observed that the mean Value of $PM_{2.5}$ obtained within marble quarries (R_S) for both wet and dry season were higher than the mean value of $PM_{2.5}$ obtained around granite quarries (R_H). The low mean values of $PM_{2.5}$ around granite quarries in Iyuku compared to $PM_{2.5}$ derived from marble quarries in Ikpeshi might be linked to the type of bonding, type of minerals and the level of induration of the rock materials. This might also be responsible for the significant difference in the spatial distribution of $PM_{2.5}$ as shown in Table 3. Consequently $PM_{2.5}$ pollution due to marble crushing in Ikpeshi is higher than $PM_{2.5}$ generated from granite quarrying in Iyuku. The implication is that workers and residents in Ikpeshi are more likely to be prone to health issues associated with inhalation of $PM_{2.5}$ particles. Generally, the higher mean concentrations of respirable particulate matter observed in the dry season compared to the wet in all sampling stations may be due to the increase in dust generated by operations of quarrying exacerbated by harmattan wind.

Table 3. Seasonal and Rock type particles comparison

Seasonal Variations	RH	RS	*P-value*
Wet Season	94.15 ± 29.59	119.60 ± 67.43	0.000343
Dry Season	131.5 ± 41.96	205.47 ± 97.25	
Spatial	112.83 ± 40.52	162.53 ± 93.10	0.003283

3.4. Mitigation measures

In order to reduce the levels of particulate matter generated in the study areas, it is strongly recommended that wet crushing, water sprays and the use of surfactants should be deployed by quarry workers in addition to the use of nose masks The use of water sprinkling during crushing and drilling is an efficient method of dust emission mitigation [17]. Also, sustainable quarry practices entail that, quarry locations should be sited and positioned in areas with adequate vegetation. The vegetation serves as sinks for emissions emanating from rock quarrying activities.

4.0. Conclusion and Recommendation

The findings of this research have provided information concerning the levels of particulate matter within rock quarrying and residential communities of Ikpeshi and Iyuku Edo State. Rock quarrying no doubt increases the socio economic base of a nation [8]. In the US crushed stone, sand and gravel production account for half of industrial minerals and constitute a $29 billion per year business [8].In fact major materials required for buildings, construction and some medical supplies are derived from rocks. However, a significant drawback in its operations is the release of particulate matter, a designated WHO environmental hazard. In this study it was observed that the concentration of $PM_{2.5}$ particles in both wet and dry season were beyond the [14]; [15] permissible limit of 25 μg/m^{3}and 35 μg/m^3. Also the distribution of $PM_{2.5}$ particles is influenced by the type of rock that is been crushed. It is therefore recommended that stringent regulatory measures be emplaced by government agencies by ensuring that quarry owners and operators functions and adheres to international best practices.

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