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The impacts of rock quarry activities on physicochemical and bacterial diversity of air in Akpuoha and Ishiagu communities of Ebonyi State, Nigeria

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Abstract. *Agwaranze DI, Ogodo AC, Nwaneri CB. 2024. The impacts of rock quarry activities on physicochemical and bacterial diversity of air in Akpuoha and Ishiagu communities of Ebonyi State, Nigeria. Asian J Trop Biotechnol 21: 33-40.* This study aims to evaluate the impacts of rock mining (quarry) activities physicochemical and bacterial diversity of air in two communities, Akpuoha and Ishiagu of Ebonyi State, Nigeria. The physicochemical parameters of the air were determined in situ using hand-held environmental sensor meters (Roca Raton, England), while the diversity of bacteria was determined using the settle plate technique. The results showed that temperature ranged from 28.5-33.4°C, Particulate Matter ($PM_{2.5}$) ranged from 3.0-9.4 µg/m^3, Particulate Matter (PM_{10}) ranged from 3.0-9.6 µg/m^3 and Carbon Oxides (CO_X) ranged from 3.2-8.9 µ/mol, in Ishiagu during the dry season. The same parameters were assessed in Akpuoha during the dry season with values of temperature ranging from 28.8-31.3°C, $PM_{2.5}$ ranged from 4.2-8.7 µg/m^3, PM_{10} ranged from 4.4-9.3 µg/m^3 while CO_X ranged from 3.2-7.4 µ/mol. Values were observed to be highest nearest the quarries but decreased with distances away. The same pattern was observed for the parameters during the rainy seasons in both communities; however, lower values were obtained during the rainy season, with the quarry effects being limited to 100-200 m from the quarry edge. The dry season results indicated a more gradual slope extending to 200-300 m. The bacterial diversity of the air was determined and the bacterial physiological groups determined were Total Heterotrophic Bacterial Count (THBC), Total Pathogenic Bacterial Count (TPBC), Total Coliform Count (TCC), and Total Fecal Coliform (TFC). THBC at Ishiagu and Akpuoha in both seasons had the highest counts, followed by TCC and TPBC, while TFC was the least at each sampling distance. The counts decreased with distance from the Quarry site and increased with plate exposure time. Therefore, all quarry industries should be located away from the immediate vicinity of human settlements.

Keywords: Air quality, bacteria diversity, pathogenic bacteria, physicochemical, quarry

INTRODUCTION

In the simplest terms, rock quarrying is used for making small sizes of stone from bigger rocks. The processes involved in rock quarrying are uniform in most areas, although some quarrying sites may present unique peculiarities. These processes include identifying the site where a large quantity of rock is available below the earth's surface, clearing the rocky land, mining of the rock, drilling, blasting, and then crushing it into smaller particles or desired sizes (Wanjiku 2015). Trucks move back and forth between the processing plants and the pit while transporting rocks to the crushers. The crushers break the stones into various particle sizes as may be determined by the output engineers (Wanjiku 2015).

These quarrying activities along with various other factors like human activities from domestic use of energy and operations of the industries cause alterations in the atmospheric gases, leading to air pollution and its attendant effects on the environment and public health have been reported (Peter et al. 2018; Ezekwe 2019). Air pollution poses serious environmental problems and has been a major concern for developed and developing countries. The effects vary greatly due to varying sources of air pollution (Peter et al. 2018). The dust generated during quarry activities and truck movements falls on land around the sites, plants, and water surfaces (Okafor and Njoku 2021). These dust particles cause air pollution and affect the biodiversity, animals (livestock and wildlife), and humans. Anand (2020) reported that damage is caused to biodiversity due to environmental quarrying. Plants play a significant role in maintaining the oxygen and carbon dioxide balance of the atmosphere through photosynthesis which may be altered due to the settling of dust on the leaves of plants (Enyinnaya et al. 2020; Wang 2020; Okafor et al. 2023).

Generally, the effects of dust emissions from quarries have both micro and regional dimensions. Air pollution and ground vibration from blasting, crushing, and emission of toxic gases negatively impact human health and well-being. The quarrying activities products demand is increasing for agriculture, industries, domestic purposes, and other uses (Owens et al. 1988; Wanjiku 2015). However, the dust generated during quarrying operations is usually suspended in the air over a long period, leading to environmental and health problems (Osuide 1990). Moreover, particulate matter can be transported from the mining point to faraway areas. Once particles of varying chemical compositions are inhaled, they lodge in human lungs, causing lung damage and respiratory problems (Okafor et al. 2023). Salim (2016) stated that dust generated from granite quarrying contains 71% silica; inhaling such dust results in silicosis, which can disable an exposed person and, subsequently, lead to death. According to epidemiological studies, a close-response relationship between exposure to PM_{10} and respiration morbidity and mortality has been established (Maji et al. 2023).

Microorganisms like bacteria and fungi contribute to nutrient cycling, waste bioremediations, and soil pollutants. Reports have indicated that the community of microorganisms in the soil occupies the majority of biodiversity below the ground (Zhou et al. 2023). These bacterial communities significantly contribute to the ecosystem biomass, nutrient-cycling biodiversity, and energy flows (Nielsen et al. 2015; Jiao et al. 2019). Moreover, the activities of these bacterial communities are also affected by climate change (global warming), greenhouse gases (Dove et al. 2021; Zhou et al. 2023), and other particles released during mining activities, including rock mining and crushing. Hence, the composition of the soil bacteria can also be altered during mining and quarry activities which could affect their performance and beneficial roles in an environment. Pathogenic bacteria can be exposed to humans, the environment, and air by rock mining activities, which could be of public health importance. Therefore, this study aimed to evaluate the effect of stone quarrying activities on the physicochemical and bacterial diversity of Ishiagu and Akpuoha in Ebonyi State, Nigeria.

MATERIALS AND METHODS

Description of study areas

Ishiagu is located in the Ivo Local Government Area in Ebonyi State, Nigeria, at latitudes 50 52' to 50 60' N and longitudes 70 30' to 70 37" E. The area is situated in the tropical rainforest zone of Nigeria, but due to intensive human activities, it is rapidly becoming a Guinea savanna. Geologically, Ishiagu is part of the Cross River Basin and lies in the well-known Calabar Trough and it's a well-known quarry mining area. Ishiagu is a semi-urban area endowed with several mineral resources, especially lead and zinc ores, including granite. Akpoha is a typical rural community located in Afikpo South LGA and also situated at the southern elbow of Ebonyi State; unlike Ishiagu, Akpoha is located in typically Guinea savanna and has more rainfall, as it lies nearly at the bank of the Calabar River. It is also in the Calabar trough zone and endowed with the same resources as Ishiagu (Peter et al. 2018; Okafor et al. 2023). It is a new mining area. Both study sites have two main seasons – rainy and dry seasons.

Collection of samples

Air samples were collected from the Crushed Rock quarry site (Ishiagu) at various distances: 0 (edge of company premises), 100, 200, and 300 meters away from the company site. Similar sampling distances were used at Akpuoha, where Julius Berger Nigeria Limited operates. Passive air sampling was conducted using the settle plate method for microbial analysis. Petri dishes containing solidified media were exposed to the air (one meter above the ground) at various time intervals ranging from 10, 20, and 30 minutes at the distances mentioned earlier (0, 100, 200, and 300 meters).

Determination of the physicochemical parameters of the air

The air quality was determined in situ using hand-held environmental sensor meters (Roca Raton and England). The meter was switched on at the various sampling points and allowed to stabilize within 1-5 minutes before taking the readings at eye level. Three readings were taken at each sampling point, and the mean was recorded as the value for that particular sampling point. Parameters measured include NO_X, SO_X, CO_X, and CH_4 (Nitrogen Oxides, Sulphur Oxides, Carbon Oxides, and Methane). Others were hydrogen sulphide (H_2S), Ammonia (NH_4), and particulate matter ($PM_{2.5}$ and PM_{10}), including Wind Direction (WD) and temperature. These readings were collected during the rainy and dry seasons according to the various sampling points and communities.

Determination of bacteria diversity/air quality around the quarry sites

The media used for the microbiological analysis were Nutrient Agar, Eosin Methylene Blue Agar, McConkey Agar, and Blood Agar. The various media were for the various bacteriological physiological groups (bacterial community profile) tested. These were prepared according to the manufacturer's instructions and used for air sampling. Passive air sampling was carried out using the settle plate method. Petri dishes containing solidified media were exposed to the air at various time intervals ranging from 10, 20, and 30 minutes at the distances mentioned earlier (0, 100, 200, and 300 meters). The plates were kept about 1-2 m above the ground level and at least 10 m away from obstructions (Agwaranze et al. 2020). This was incubated at 37°C for 24 h, and the number of colonies observed on each culture plate was counted to ascertain the Total Heterotrophic Bacterial Count (THBC), Total Pathogenic Bacterial Count (TPBC), Total Coliform Count (TCC) and Total Fecal Coliform (TFC).

RESULTS AND DISCUSSION

Figure 1 shows that the temperature values ranged from 27.4-31.7°C in Akpuoha and 27.8-32.7°C in Ishiagu (Figure 2) during the rainy season; there were slight differences in dry, but were not statistically significant. However, there were significant variations according to sampling distance from each quarry site, as the temperature values decreased away from the site edge. The highest values were the nearest site, and the lowest was the farthest from the site. The effects were up to 100 m as the values at

200 m and 300 m were statistically different from the edge and the 100 m from the site ($P < 0.05$). Additionally, the wind direction was observed northeast at the study site.

Figures 3 and 4 show the air's wind speed and H_2S values around the two study sites. At Akpuoha, the wind speed values ranged from 1.6 to 2.4 m/s, while at Ishiagu, they ranged between 1.8 to 2.6 m/s. Ishiagu values were non-statistically higher than those from Akpuoha ($P>0.05$). However, the sites had similar values; the highest ones were nearest the site and decreasing away from it. H_2S values ranged from 0.5 to 1.9% in Akpuoha and 0.4 to 3.7% in Ishiagu, with the highest values obtained nearest to the site and lowest farthest away. The effects were within 0 to 100 m but decreased significantly after 200 to 300 m. Values from 0 to 100 m of Akpuoha were significantly lower than those from similar spots at Ishiagu ($P<0.05$).

The results showed the values of $PM_{2.5}$, PM_{10}, NH_4, CH_4 and CO_X in the two study sites: $PM_{2.5}$ values ranged 2.5 to 4.2 µg/m^3 (Akpuoha) and 2.7 to 4.7 µg/m^3 (Ishiagu), PM_{10}, ranged from 2.2 to 7.55 µg/m^3 (Akpuoha) and 2.3 to 8.3 µg/m^3 (Ishiagu). The decrease in the value of PM_{10} was steeper than $PM_{2.5}$ in both sites as $PM_{2.5}$ was more gradual; the other parameter values are shown in those figures. In all the parameters, values obtained at the 0 m (edge) were not significantly different from those at 100 m ($P<0.05$) but differed from those at 200 and 300 m away, indicating that distance from the sites influenced those values.

Values obtained for SO_X and NO_X are shown in Figures 7 and 8 for Akpuoha and Ishiagu, respectively. Values for SO_X at Akpuoha ranged from 0.02 to 0.04 at 0 m (edge) and 100 m, while SO_X was not detected at 200 and 300 m; this was quite similar to 0.2 to 0.5 observed at Ishiagu. SO_X was not detected at 200 and 300 m; there was no statistical difference between values at Ishiagu and Akpuoha. Values of NO_X showed that of 200 and 300 m; there were no statistically significant differences both in distances and sites, but values of 0.09-0.06 in Ishiagu at 0 and 100 m were significantly higher than 0.07 and 0.04 observed at Akpuoha ($P>0.05$). This still showed the influence of distance on the results (Figures 5 and 6).

Temperature values during dry seasons for Akpuoha ranged from 28.5 to 31.3°C, while that of Ishiagu was 28.8 to 33.4°C (Figures 9 and 10). The values gradually decreased at each site, with the effects shown at 200 m away from the site. Only values at 300 m were significantly different from the rest ($P < 0.05$).

Wind speed ranged from 1.2 to 1.9 m/s (Akpuoha) and 1.5 to 2.0 m/s (Ishiagu). Values obtained for temperature were statistically higher in the dry season than rainy season, while the wind speed showed the reverse being higher during the rainy season than dry season. H_2S values are shown in Figures 11 and 12, which indicate higher values nearest the site and lowest away. Values obtained in the dry season were slightly lower than those in the rainy season.

Figures 13 and 14 show the values of $PM_{2.5}$, PM_{10}, NH_4, CH_4, and CO_X; the values of $PM_{2.5}$ and PM_{10} were higher than those of the rainy season and extended to 200 m sampling spot at both sites. On the other hand, values of NH_4 and CH_4 were lower than in three rainy seasons at each sampling point and site. Values obtained for CO_X during the dry season were higher than those of the rainy season, except at the control (300 m). The decrease in values of site edge (0 m) to 200 m was quite gradual, unlike the rainy season.

Results obtained for SO_X and NO_X are shown in Figures 15 and 16; SO_X values did not change significantly on the sites and pattern seasons. Values remained fairly the same, only reported at edge (0 m) and 100 m. Values for NO_X were statistically higher during rainy than during dry seasons, especially at 0 m and 100 m ($P < 0.05$) (Figures 15 and 16).

The air bacterial diversity is shown in Figures 17 and 18 (rainy season) and 19 and 20 (dry season). The bacterial physiological groups determined were Total Heterotrophic Bacterial Count (THBC), Total Pathogenic Bacterial Count (TPBC), Total Coliform Count (TCC), and Total Fecal Coliform (TFC). THBC at Ishiagu ranged from 3.0 to 21.5 cfu/10 minutes, 50 to 31.5 cfu/20 minutes, and 9.0 to 38.0 cfu/30 minutes. The TPBC had a range of 2.0 to 5.5 cfu/10 minutes, 2.0 to 8.5 cfu/20 minutes, and 3.5 to 10.0 cfu/30 minutes. For TCC, the ranges were 2.0 to 9 cfu/10 minutes, 2.5 to 10.5 cfu/20 minutes, and 3.0 to 13.0 cfu/30 minutes. The results for TFC show 2.0 to 5.5 cfu/10 minutes, 2.5 to 7.5 cfu/20 minutes, and 2.5 to 9.0 cfu/30 minutes. THBC had the highest counts, followed by TCC and TPBC, while TFC was the least at each sampling distance.

Figure 18 shows the bacterial colony count and diversity at Akpuoha. The bacterial dynamics in counts, distance, and exposure time followed the same pattern as those observed at Ishiagu. THBC had the highest counts at each sampling point, the highest at edge (0 m), and the least at 300 m. The same pattern was observed in TPBC, TCC, and TFC, which had the lowest counts. In all cases, plates exposed for 10 minutes had the lowest counts, followed by those exposed for 20 minutes, while those exposed for 30 minutes had the highest counts. Observations showed that the counts decreased extensively after 100 m. Spots indicate that the effects of the quarry did not spread out much beyond 100 m.

Figures 19 and 20 show the bacterial dynamics during the dry season. The same trends observed during the rainy season regarding plate exposure time and distance from the quarry sites on bacterial physiological groups were repeated during the dry season. However, observations showed higher bacterial counts and spread to 200 m sampling points, with only the counts at 300 m being statistically significantly low.

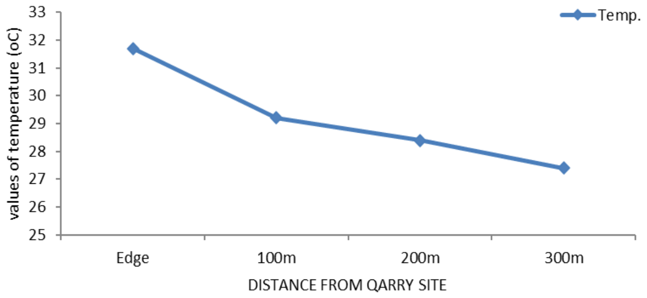

Figure 1. Temperature (°C) variations of air at the Akpuoha Quarry site, Nigeria during the rainy season

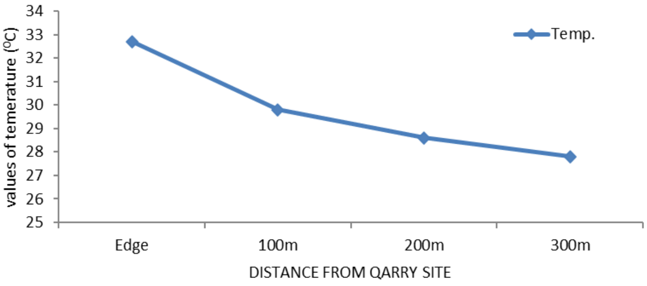

Figure 2. Temperature (°C) variations of air at Ishiagu Quarry site, Nigeria during the rainy season

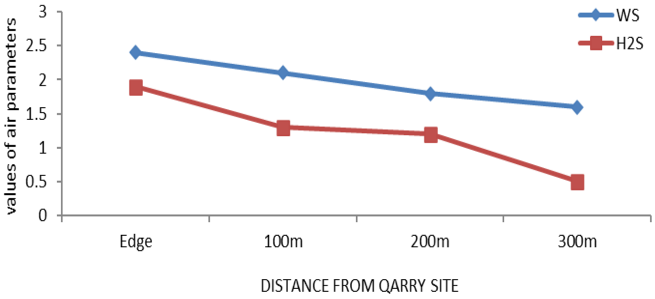

Figure 3. Wind Speed (m/s) and Hydrogen Sulfide concentrations (%) of air at Akpuoha, Nigeria during the rainy season. WS: Wind Speed, H_2S: Hydrogen Sulphide

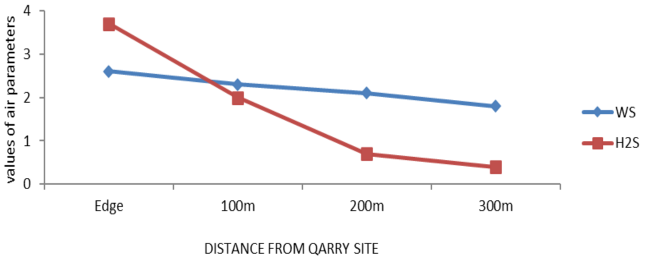

Figure 4. Wind Speed (m/s) and Hydrogen Sulfide (%) of air at Ishiagu, Nigeria during the rainy season

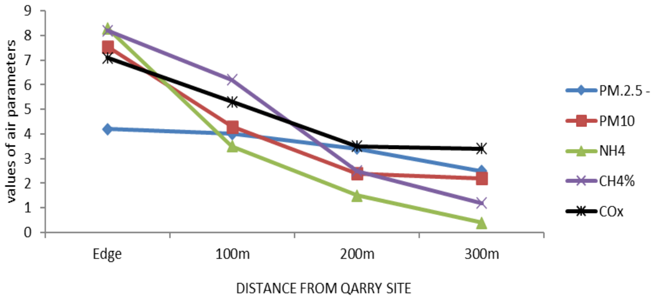

Figure 5. Particulate Matter $PM_{2.5}$, Particulate Matter PM_{10} (µg/m^3) Ammonium, Methane (%) and Carbon Oxides of air at Akpuoha, Nigeria during the rainy season

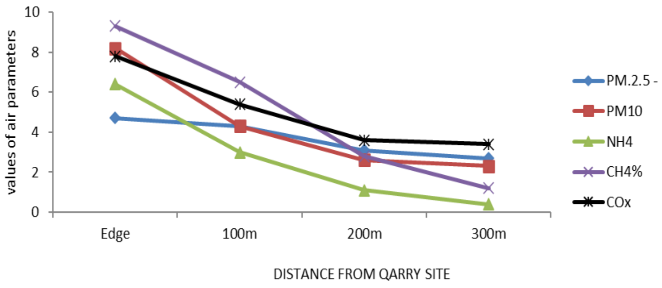

Figure 6. Particulate Matter $PM_{2.5}$ Particulate Matter PM_{10} Ammonium, Methane (%), and Carbon Oxides of air at Ishiagu, Nigeria during the rainy season

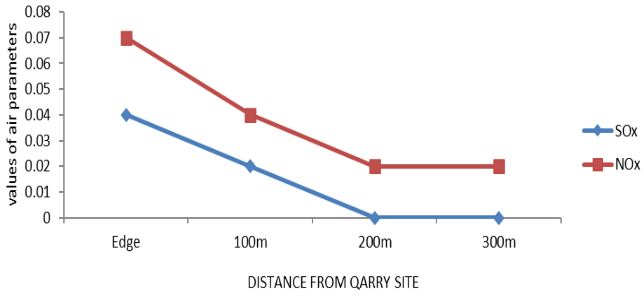

Figure 7. Sulphur Oxides and Nitrogen Oxides (µg/m^3) of air at Akpuoha, Nigeria during the rainy season

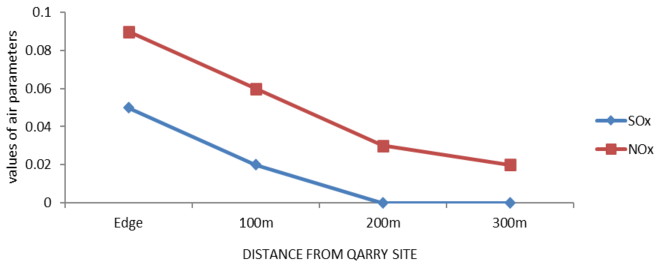

Figure 8. Sulphur Oxides and Nitrogen Oxides (µg/m^3) of air at Ishiagu, Nigeria sample during the rainy season

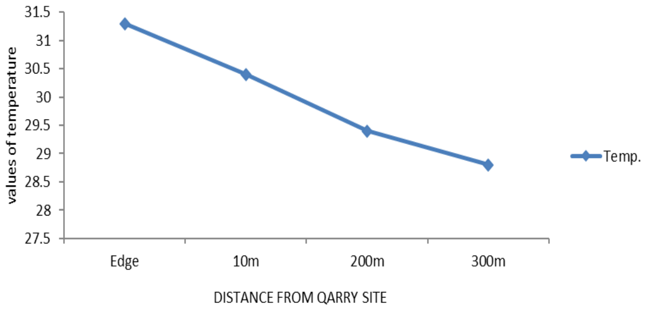

Figure 9. Temperature (°C) variations of air at Akpuoha, Nigeria during the dry season

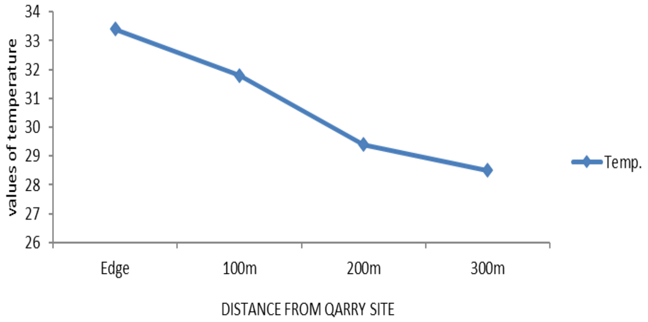

Figure 10. Temperature (°C) of air at Ishiagu, Nigeria during the dry season

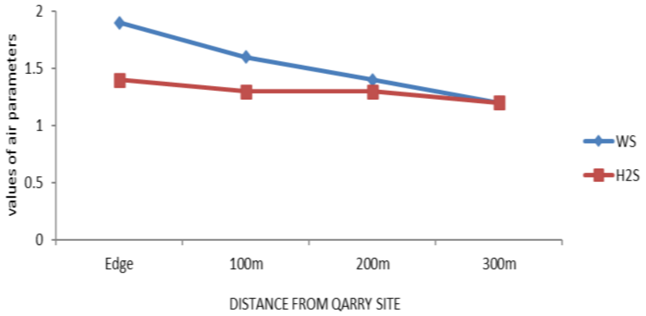

Figure 11. Wind Speed (m/s) and Hydrogen Sulfide (%) of air at Akpuoha, Nigeria during the dry season

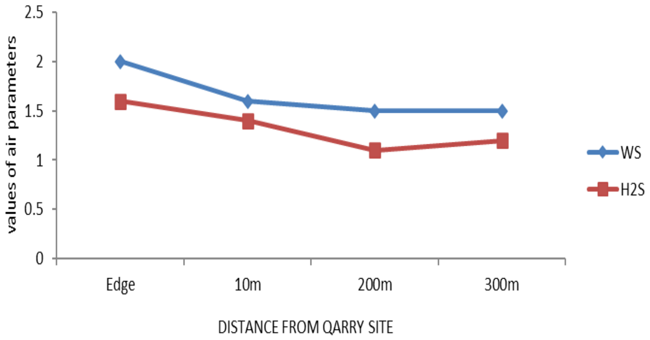

Figure 12. Wind Speed (m/s) and Hydrogen Sulfide during the dry season (%) according to the distance at Ishiagu, Nigeria

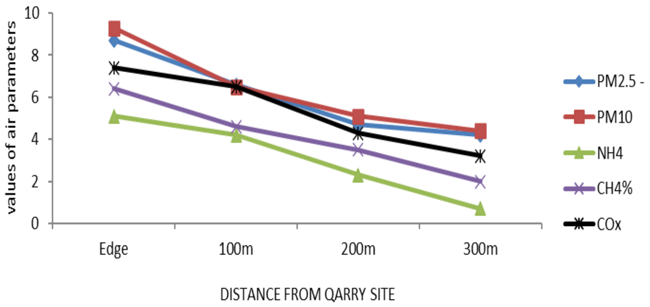

Figure 13. Particulate Matter PM$_{2.5}$, Particulate Matter PM$_{10}$ (μg/m^3) Ammonium, Methane (%), and Carbon Oxides of air at Akpuoha, Nigeria during the dry season

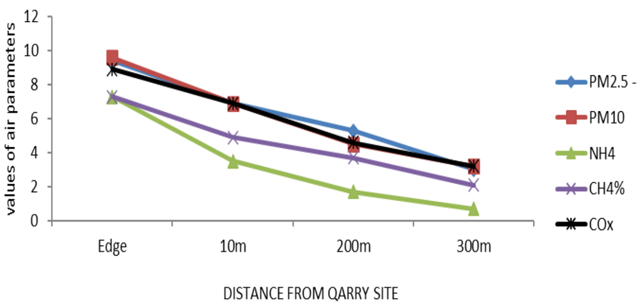

Figure 14. Particulate Matter PM$_{2.5}$, Particulate Matter PM$_{10}$, Ammonium, Methane (%), and Carbon Oxides of air sample during the dry season at Ishiagu, Nigeria

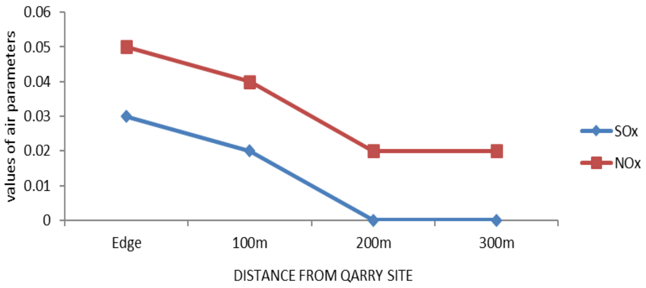

Figure 15. Sulphur Oxides and Nitrogen Oxides of air sample during the dry season (%) at Akpuoha, Nigeria

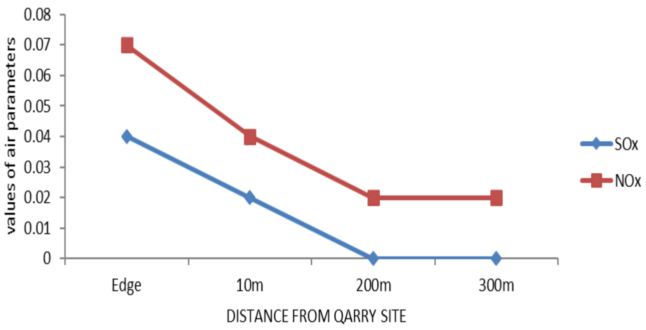

Figure 16. Sulphur Oxides and Nitrogen Oxides (μg/m^3) of air sample dry during the rainy season (%) at Ishiagu, Nigeria

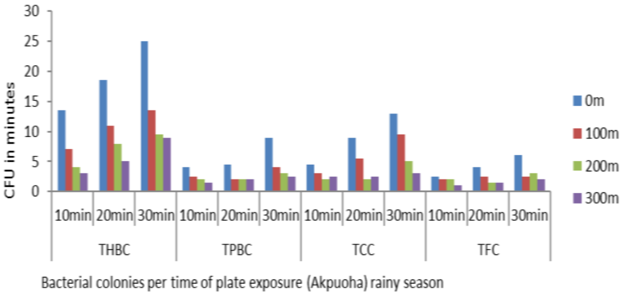

Figure 17. Total Heterotrophic Bacterial Count, Total Potential Pathogenic Bacterial Count, Total Coliform Count, and Total Fecal Count during the rainy season at Akpuoha, Nigeria

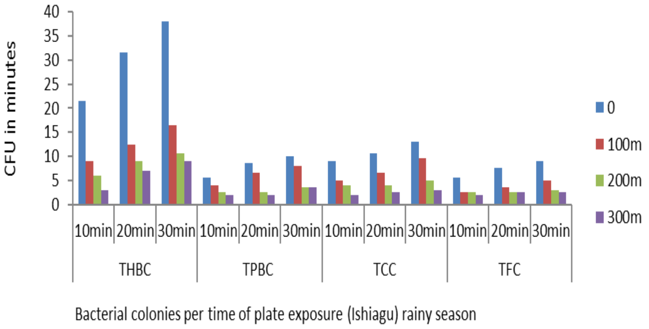

Figure 18. Total Heterotrophic Bacterial Count, Total Potential Pathogenic Bacterial Count, Total Coliform Count, and Total Fecal Count during the rainy season at Ishiagu, Nigeria

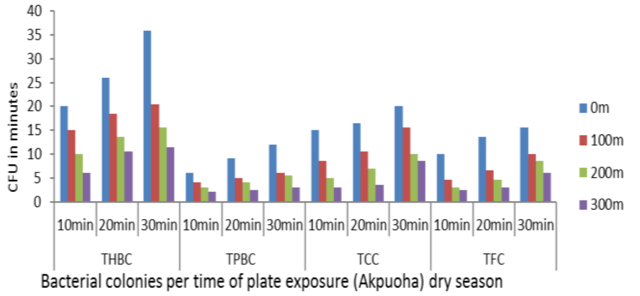

Figure 19. Total Heterotrophic Bacterial Count, Total Potential Pathogenic Bacterial Count, Total Coliform Count, and Total Fecal Count during the dry season at Akpuoha, Nigeria

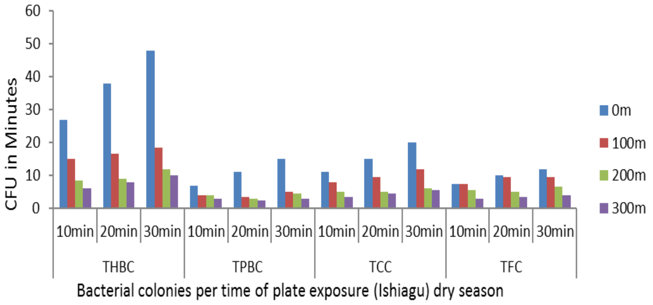

Figure 20. Total Heterotrophic Bacterial Count, Total Potential Pathogenic Bacterial Count, Total Coliform Count, and Total Fecal Count during the dry season at Ishiagu, Nigeria

Discussion

The impact of rock quarry activities on air quality was analyzed in this study. The quality of air inhaled by an individual within his environment determines, to a greater degree, the well-being of that individual. From the air quality of the two communities. It was observed that there was no significant change in the temperature of the two sites sampled (Akpuoha and Ishiagu), as the temperature did not vary significantly at various distances during the rainy season. Again, the wind direction was also the same - South-westerly in both sites. However, particulate matter $PM_{2.5}$ and particulate matter PM_{10} showed remarkable variations based on distance from the quarry but did not vary based on sites; the values decreased with distance from the edge of each quarry. This agreed with Nwaugo et al. (2006) and Abdulkarim et al. (2007) who revealed that particles settle out of the air over distance, and the highest concentration of any substance is nearest the production site. Similarly, Agwaranze et al. (2018) also reported that Ammonium (NH_4), Methane (CH_4), Sulfate (SO_4), and Nitrate (NO_3) had the highest concentration in the production area. Earlier, Chiemeka (2011) revealed that the dust particles from substance quarries containing Phosphate (PO_4), Nitrogen Oxides (NO_x), Carbon Oxides (CO_x), and Sulphur Oxides (SO_x), which are released into the air as dust. These substances, PO_4, NO_x, CO_x, and SO_x, are integral components of the quarry dust particles; hence, their presence increases in the air around the quarry sites. Generally, observations indicate that heavier particles settle out of the air quicker and more easily than lighter ones. This agrees with the observations in this work, where PM_{10} settled out of the air within a very short distance compared to the lighter $PM_{2.5}$ particles. This study revealed that 300 m away from the quarry pits had non-significant concentrations of those substances evaluated. In addition, observations showed higher values at the old quarry pits of Ishiagu compared to Akpuoha. This could be attributed to the persistence of the produced accompanying particles, which settled close to the sampling site. Any little disturbance to those dust settlements could cause the dust to spread to another surface to become airborne again, thereby increasing the quantity of the air content; even though by time, the settled particles are released back into the air. However, not much dust had settled on the surfaces near the new rock quarry sites, which could cause old quarry dust to be higher than the new quarries.

Observations indicate higher concentrations of air contaminants during the dry compared to the rainy seasons. This could be attributed to two major issues. The waters in the rainy season washed the contaminating substances that did not happen in the dry season. Second, most construction work occurs more during the dry than the rainy seasons. Quarry stones are one of the materials required for the construction; hence, quarry activities occur more during the dry season. Therefore, increased production of quarry products results in increased accompanying wastes. The above observations show the level of air contamination around quarry areas could be influenced by season and distance from the quarry sites. Moreover, a similar observation has been recorded by

Peter et al. (2018) who studied the rainwater effect. This study reported the higher values of air contaminants during the dry than the rainy season, attributed to the rainwater effect. Also, Kalu (2018) reported higher values of air physicochemical parameters in the dry seasons than in the rainy seasons due to rainwater air cleansing.

The study revealed a very gradual decrease of air contaminants during the dry season than the rainy season. This indicates that the wind of the dry season spreads these substances over a long distance before they begin to settle. This phenomenon was unlike in the rainy season, where the rainwaters are regular and easily washed those substances before they are spread out; this results in higher significant differences between the sampling points during the rainy but less so in the dry seasons.

Though higher concentrations of the contaminating substances were reported in the old Ishiagu quarry than in the newest Akpuoha, the differences were not statistically significant. This was because the quarry activities were similar and produced the contaminating substances in similar quantities, whether new or old quarry. This indicates that the main substances are similar or could be from a similar source. Etok et al. (2010) reported that the study area in this work lies within the same plain and trough – the Calabar trough and, therefore, has rock components with a similar composition. Therefore, it is normal to state that rock quarries of similar sites have similar amounts of the substances' components assessed.

Microbial assessment of the air showed similar trends in all the sampling points, though values observed in the old Ishiagu area were higher. This further bolstered the similarity in the origin of the parent material and showed that the rock mined in both sites could come from similar sources or the same source. Nwaugo et al. (2006) and Etok et al. (2010) reported that Total Heterotrophic Bacteria Count (THBC) was, in most cases, higher than all other groups of microorganisms assessed in any given substances or sites. This was attributed to the fact that all other microorganisms of any other physiological group were equally integral to the THBC. From the studies assessed, total heterotrophic bacteria count was the most prominent, followed by the Total Coliform Count (TCC) and Total Fecal Coliform Count (TFC). At the same time, the Total Pathogenic Bacteria Count (TPBC) was the lowest in each site and distance. Generally, it could be inferred that all bacterial species could be found in the THBC while other groups are specialized. The THBC is the most heterogeneous, accounting for the highest number at each site and distance. Again, the presence of the TFC suggests fecal air contamination. Though most TFCs are not spore-formers, several anthropogenic and natural activities could blow some into the air, especially as defecation in bushes around the quarry area becomes common.

The present observations suggest that the microbial groups assessed decreased with distance away from each quarry site. This suggests that the human activities at the sites caused the increase in microbial population as this was observed in both sampling areas. These human activities decreased as the distance from the site increased. Agwaranze et al. (2020) noted a high frequency of airborne bacteria isolates in indoor environments. It could also be noted that human activities include throwing away waste from food, unhealthy sanitary practices, sneezing, and coughing, all of which could send microorganisms into the air. Abu-Allaban and Abu-Qudais (2011) stated that once organisms are airborne, they can be carried over a distance. However, the distances to which these organisms could be spread depend on the substance to which the microorganisms are attached and the prevailing environmental factors besides the microorganisms' nature. Chiemeka (2011) stated that rock dust in Ugwuele, Uturu, contained SO_4, PO_4, and less NO_3, including some trace elements. Therefore, the microbes in the air could leverage these substances for survival, especially under humid environmental conditions. However, following the seasonal effects, many microorganisms were observed to be spread further away during the dry season than in the rainy season. The same reasons that affected particulate matter also applied to the microbial loads. These microorganisms were washed down quickly during the rainy season, thereby reducing their spreading, unlike the dry season, where no rain washed down the particles carrying the microorganisms.

Furthermore, human activities were limited to areas near the mining sites during the rainy season as no people went close to being wet. Similar observations were recorded at the two sites screened, suggesting a similar occurrence, no matter the age of the quarries. This indicates that the most impacted areas were those nearest the site and that the effects waned by the distance; this observation was made during both rainy and dry seasons with similar results. The excavation and blasting processes sent dust particles into the air that quickly came back down to earth. The decline rate depends on size (weight) and environmental factors. This follows, therefore, that most of the airborne particles were found nearest the mining (quarry) sites, but the lighter particles were spread out to areas far away from the site. Further observations indicated that the concentration of various compounds in the rock dust also decreased at longer distances.

In conclusion, this study revealed that the quarry activities in the studied communities significantly affect the physicochemical parameters and bacterial diversity of the air within the surroundings. Concentrations of particulate matter and gases were observed more near the quarry site and decreased with increasing distance from the mining site, irrespectively of wet or dry seasons. Similar observations were recorded for various microbial groups, indicating higher concentrations of bacteria around the sites where human activities occur. Therefore, stone mining and quarrying should be located far from residential areas to reduce air pollution and its impact on human health.

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