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IMPACT OF PARTICULATE MATTER AS AN AIR QUALITY POLLUTANT RELEASED FROM QUARRY ACTIVITIES IN AKAMKPA, CROSS RIVER STATE, NIGERIA

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ABSTRACT: *This study examines the impact of particulate matter ($PM_{2.5}$) and (PM_{10}) as an air quality pollutant released from quarry operations at a quarry site in Akamkpa, Cross River State, Nigeria. Rock quarrying is the practice of obtaining quarry materials, typically rocks, from above or below land surfaces and crushing or grinding them into fragments to produce various rock sizes. For air quality assessment, concentrations of the air pollutants were measured at different locations within and around the quarry site, from a height of 1.5m above ground level. Highly sensitive digital portable meter was used for the measurement of $PM_{2.5}$ and PM_{10}. The Inverse Distance Weighted model (IDW) tool in ArcGIS was used to perform a spatial interpolation analysis on the data measured from the field monitoring during the dry and wet seasons. The findings indicate that during the dry season, $PM_{2.5}$ and PM_{10} concentrations ranged from 292µg/m^3 to 127.33µg/m^3 and from 377.67µg/m^3 to 222.67µg/m^3 respectively, while during the wet season, they ranged from 239.67µg/m^3 to 92.00µg/m^3 and from 276.33µg/m^3 to 124µg/m^3. The findings suggest that residents of the study area should limit their exposure, especially during the dry season.*

KEYWORDS: Akamkpa, Rock Quarry, Particulate Matter, Air Quality, Pollutants.

INTRODUCTION

Rock quarrying is the practice of gathering quarry materials, typically rocks, from above or below the land surface and crushing or grinding them into fragments to produce various rock sizes (Enoh, 2016). It involves the mining of nonmetallic rocks such as granite, slate, marble, sandstone, and limestone, as well as rock salt, ironstone, phosphate, and slate.

Rock quarrying products are increasingly demanded for various purposes, including industrial, domestic, recreational, institutional, agricultural, and other purposes, so as to satisfy the needs of the rapidly growing population of the world. Rock quarrying operations are a significant source of construction materials used in the construction of roads and buildings (Kalu, 2018). It is indeed produced in order to meet the daily demands of the country. Although it is grossly inadequate to meet the present needs of the country, these operations are known to have various environmental impacts.

Like many other anthropogenic activities, the health of people and the environment are significantly impacted by rock quarrying (Okafor, 2006). Rock quarrying activities have lots of environmental impacts, such as air pollution, soil contamination, noise pollution, etc., which have negative effects on the natural environment. Quarry activities may have a negative impact on the environment and human health if appropriate measures are not put in place to forestall environmental degradation.

Emission of some air pollutants has been linked to quarry activities. Among these air pollutants is particulate matter ($PM_{2.5}$ and PM_{10}). Particulate matter (PM) is described as suspended particles in the air that range in size and composition and are the product of numerous anthropogenic activities (Health and Safety Authority, 2021). Particulate matter is the major source of air pollution at quarry sites and has been traced to rock blasting and crushing operations (Morris & Borja, 1998). Thus, several researchers have reported that the local microclimate circumstances will determine the rate of pollution (Hong *et al*., 2017). The suspension and entrainment of dust particles in airflow cause them to spread out. When compared to large dust particles, smaller dust particles disperse widely and deposit slowly across a larger region. This study therefore aims to analyze the impact of particulate matter ($PM_{2.5}$ and PM_{10}) as air quality pollutants released by quarry operations at a quarry site in Akamkpa, Cross River State, Nigeria.

MATERIALS AND METHODS

Description of the Study Area

Geographically speaking, Akamkpa is situated between latitudes 5°14'N and 5°40'N and longitudes 8°12'E and 8°75'E. The area is a local government area, in Cross River State, Nigeria with an estimated population of 149,705 (City Population, 2014). Akamkpa has aerial extent of about 5,003km^2 territories, which includes several areas connected by major and small roadways, and bordered by the Republic of Cameroun, Yakurr, Obubra, Biase and Odukpani Local Government Areas of Cross River State, Nigeria.

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The vegetation of the study area is primarily disturbed lowland forest. Large species of commercial trees have been heavily exploited. Solid minerals such as granite rocks present in the area have prompted the activities of quarrying within this region. Other solid minerals, such as limestone and kaolin have not yet been commercially exploited in Akamkpa (Kekerete, 2014).

In Akamkpa, the rainfall shows a bimodal distribution with peaks in June–July and September. The area has a 26–27ºC annual average temperature, with a peak of 35ºC from February to April. Given its location in the rainforest, yearly rainfall is at least 2000mm, with the months of July and September experiencing the highest amounts.

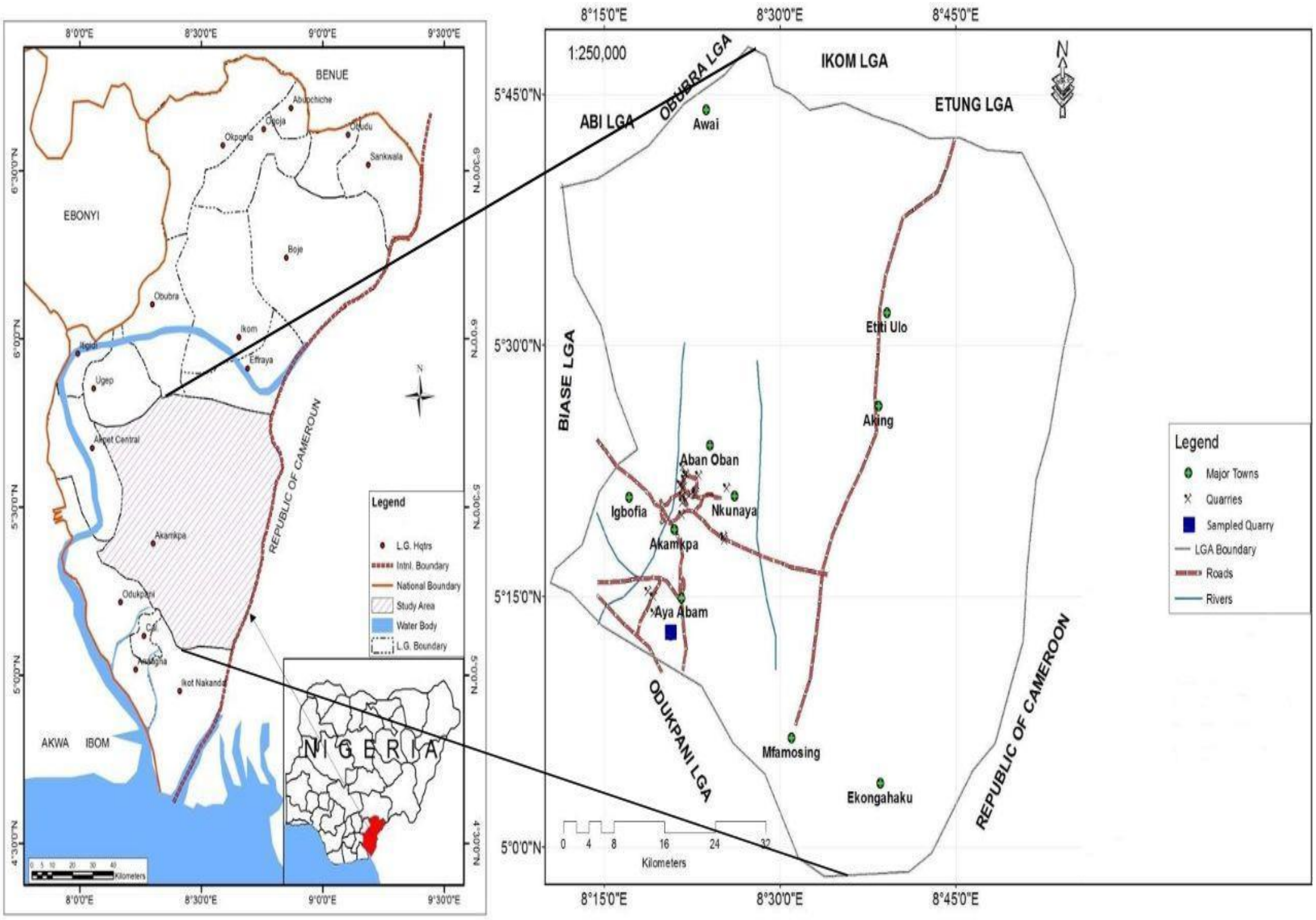

Figure 1: The Study Area

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$PM_{2.5}$ and PM_{10} Measurement

For air quality assessment, concentrations of the air pollutant were measured at different locations from a height of 1.5m above ground level. Highly sensitive digital portable meters were used for the measurement of $PM_{2.5}$ and PM_{10}. These pollutants were measured at different locations within and around the quarry site, during peak hours (operational hours) of the day. This data represents the test data. $PM_{2.5}$ and PM_{10} were also measured in an area where no quarry activity takes place, during the same hours. This represents the control data. The control location is approximately three (3) kilometers away from the closest quarry site and 500 meters away from the closest human settlement. Measurements were taken in the dry season (December, January and March) and in the wet season (May, July and September).

Meteorological Data Acquisition for Air Quality

To ascertain air quality, measurement of meteorological parameters is important, as they can influence the presence and concentrations of pollutants found in the atmosphere. Meteorological parameters explain the variations in air quality obtained at given times, seasons, and specific locations. As such, there were measurements of some meteorological parameters at the different locations where $PM_{2.5}$ and PM_{10} were measured. These meteorological parameters include temperature, relative humidity, atmospheric pressure, wind direction, and wind speed. The measurements were carried out using *in-situ* portable equipment.

$PM_{2.5}$ and PM_{10} Data Analysis and Presentation

Air quality was measured with applicable equipment for both dry and wet seasons. The data were compared with United States Environmental Protection Agency (USEPA) standards for $PM_{2.5}$ and National Environmental Standards and Regulations Enforcement Agency (NESREA) standards for PM_{10}. Air Quality Index (AQI) was also used as an indicator to check the concentration of particulate matter as it relates to health concerns. The Inverse Distance Weighted model (IDW) was used to show the dispersion of the air pollutants at each global coordinate point.

RESULTS

The findings indicate that during the dry season, $PM_{2.5}$ and PM_{10} concentrations ranged from 292µg/m^3 to 127.33µg/m^3 and from 377.67µg/m^3 to 222.67µg/m^3 respectively, while during the wet season, they ranged from 239.67µg/m^3 to 92.00µg/m^3 and from 276.33µg/m^3 to 124µg/m^3. Table 1 and Table 2 show results of the Mean±Std of $PM_{2.5}$ and PM_{10} in dry season and wet season respectively.

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Table 1: Mean±Std of $PM_{2.5}$ and PM_{10} in Dry Season

	0m (Onsite) Mean± Std	100m Mean± Std	200m Mean± Std	400m Mean± Std	600m Mean± Std	800m Mean± Std	1000m Mean± Std	Control Mean± Std	p-value	Standard
$PM_{2.5}$ (µg/m^3)	292.00^a± 10.82	135.67^d ± 10.97	127.33^d ± 7.02	142.33^c ± 13.65	160.67^b ± 7.02	156.67^b ± 13.01	163.00^b ± 9.54	109.00^e ±7.00	p<0.05	50.0 (USEPA)
PM_{10} (µg/m^3)	377.67^a± 10.02	234.67^c ± 4.73	222.67^c ± 13.05	246.33^c ± 17.04	280.67^b ± 9.29	241.67^c ± 12.01	297.33^b ± 21.50	197.00^d ± 5.29	p<0.05	150.0 (NESREA)

Table 2: Mean±Std of $PM_{2.5}$ and PM_{10} in Wet Season

	0m (Onsite) Mean± Std	100m Mean± Std	200m Mean± Std	400m Mean± Std	600m Mean± Std	800m Mean ±Std	1000m Mean± Std	Control Mean± Std	p-value	Standard
$PM_{2.5}$ (µg/m^3)	239.67^a ±9.07	103.67^b ±6.66	98.33^b± 5.51	92.00^b± 6.24	97.00^b± 9.00	94.33^b ±6.11	100.67^b ±4.51	94.00^b± 6.56	p<0.05	50.0 (USEPA)
PM_{10} (µg/m^3)	276.33^a ±8.74	182.33^b ±7.51	183.33^b ±15.04	193.67^b ±10.79	173.33^b ±11.72	127.33^c±17.16	124.00^c ±7.55	104.00^d ±6.56	p<0.05	150.0 (NESREA)

Particulate Matter and Air Quality Index (AQI)

The Air Quality Index (AQI) measures daily air quality. The AQI scale used for indexing the real-time pollution is based on the latest USEPA standard. The AQI is an index for reporting air quality. It also serves as an indicator of the quality of the air and its health effects. The AQI was used as an index for comparison with the values obtained in the study area for $PM_{2.5}$ and PM_{10}. Table 3 shows the USEPA standard for $PM_{2.5}$ and PM_{10}.

Table 3: USEPA $PM_{2.5}$ and PM_{10} AQI

AQI Category	AQI Value	24-hr Average $PM_{2.5}$ concentration (µg/m^3)	24-hr Average PM_{10} concentration (µg/m^3)
Good	0 – 50	0 – 15.4	0 – 54
Moderate	51 – 100	15.5 – 40.4	55 – 154
Unhealthy for sensitive group	101 – 150	40.5 – 65.4	155 – 254
Unhealthy	151 – 200	65.5 – 150.4	255 – 354

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Very unhealthy	201 – 300	150.5 – 250.4	355 – 424
Hazardous	301 – 500	250.5 – 500.4	425 – 604

From the AQI scale, the mean value of $PM_{2.5}$ during the dry season at 0m (onsite) signifies hazardous, and 100m, 200m, 400m and the control locations signify unhealthy. At 600m, 800m and 1000m, the mean values signify very unhealthy in the AQI scale. In the wet season, the mean value of $PM_{2.5}$ at 0m (onsite) signifies very unhealthy, while 100m, 200m, 400m, 600m, 800m, 1000m and control locations signify unhealthy in the AQI scale.

For PM_{10} in the dry season, the mean value at 0m (onsite) signifies very unhealthy in the AQI scale. Mean values at 100m, 200m, 400m, 800m and control locations indicated unhealthy for sensitive groups, while at 600m and 1000m, the mean values signify unhealthy in the AQI scale. In the wet season, the mean value at 0m (onsite) signifies unhealthy in the AQI scale. Mean values at 800m, 1000m and control locations indicate moderate, while mean values at 100m, 200m, 400m and 600m signify unhealthy for sensitive groups in the AQI scale.

Spatial Dispersion of $PM_{2.5}$ and PM_{10} in the Study Locations

Figure 2–5 shows the spatial dispersion of $PM_{2.5}$ and PM_{10} in dry and wet seasons in the study locations.

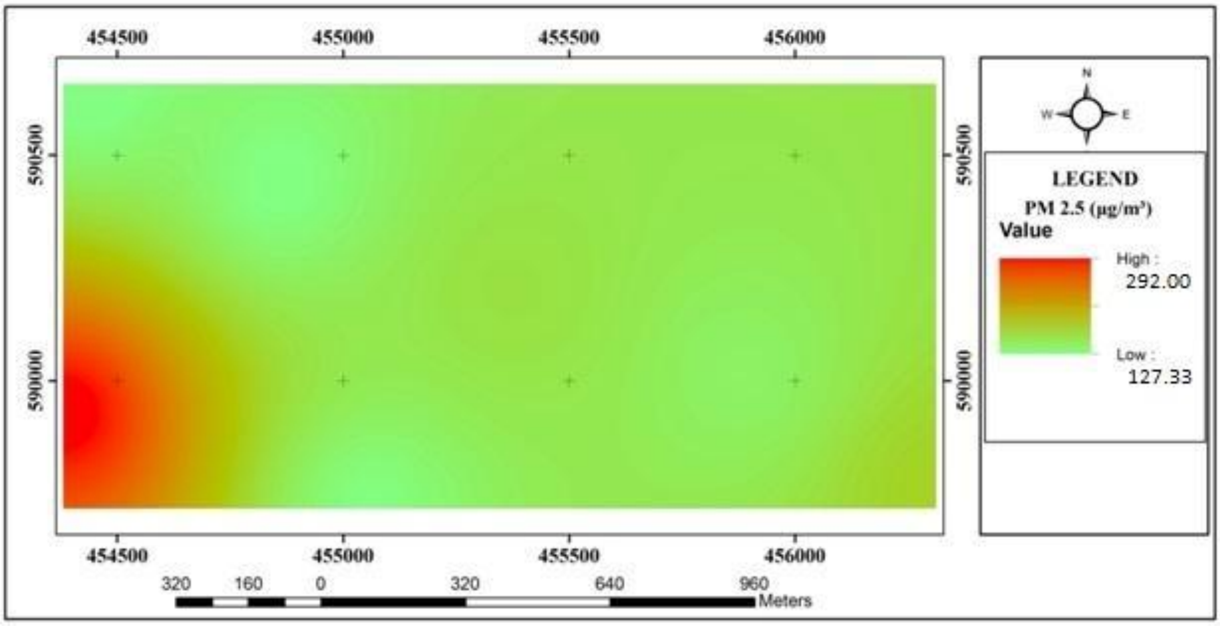

Figure 2: Spatial Dispersion of $PM_{2.5}$ ($\mu g/m^3$) in Dry Season

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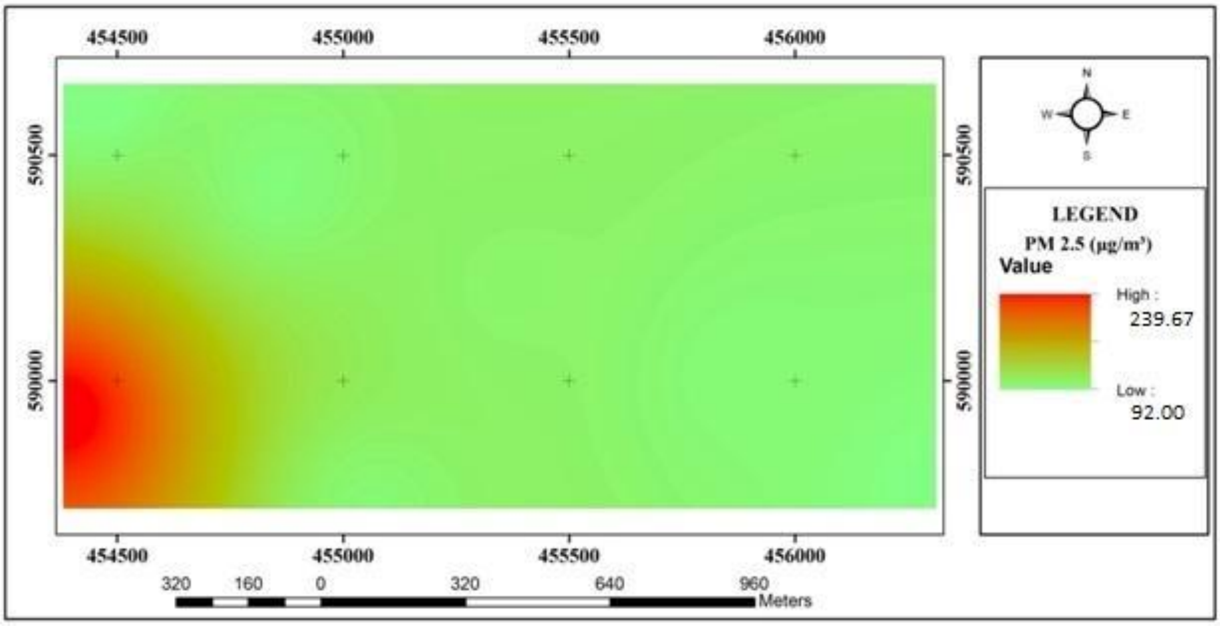

Figure 3: Spatial Dispersion of $PM_{2.5}$ (μg/m^3) in Wet Season

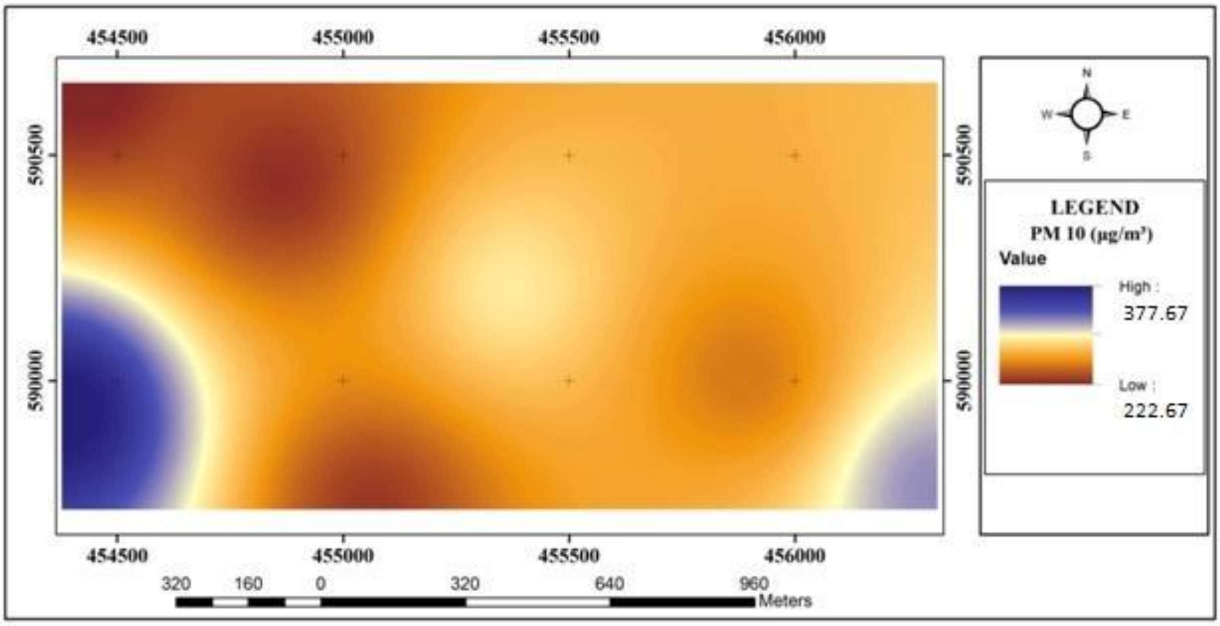

Figure 4: Spatial Dispersion of PM_{10} (μg/m^3) in Dry Season

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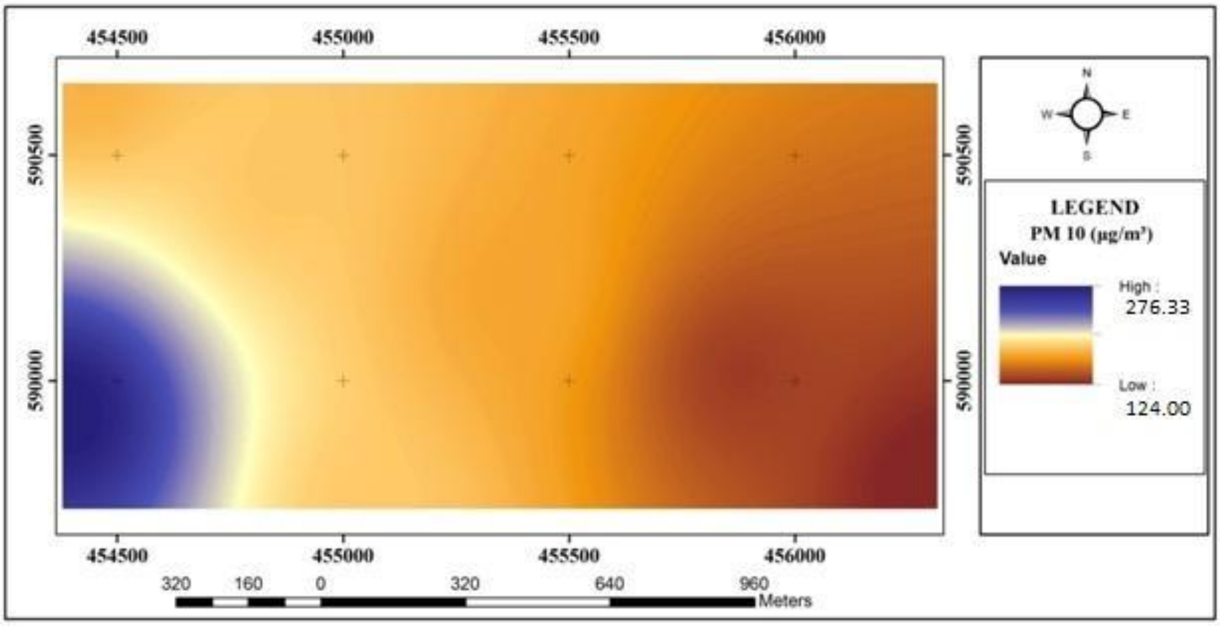

Figure 5: Spatial Dispersion of PM_{10} (µg/m^3) in Wet Season

DISCUSSION

$PM_{2.5}$ recorded values higher than USEPA permissible limit of 50µg/m^3 at all locations with a higher value at 0m (onsite) for both dry and wet seasons, but PM_{10} recorded values higher than NESREA permissible limit of 150µg/m^3 at all locations except at 800m, 1000m and control location during the wet season. The reason for the high values of particulate matter in the study area is because of the quarry activities in the area. Similar results of $PM_{2.5}$ and PM_{10} indicating higher values than the permissible limits are reported in studies by Rock (2015), Babatunde *et al.* (2013), Tasheen (2016), Kalu (2018) and Peter *et al.* (2018). Particulate matter is a major air pollutant emitting from quarry operations, hence the high values above the recommended permissible limits. The sizes of $PM_{2.5}$ and PM_{10} can allow them to be transported by wind easily to distances away from the emission source. This explains the measurement of high values of particulate matter even at different distances away from the emission source.

CONCLUSION AND RECOMMENDATION

This study examines the impact of particulate matter ($PM_{2.5}$ and PM_{10}) as an air quality pollutant released from a quarry site in Akamkpa, Cross River State, Nigeria. Rock quarrying is obtaining quarry materials, typically rock minerals, and crushing or grinding them into different rock fragments. These quarrying activities emit various air pollutants, such as particulate matter into the atmosphere. After emission, the dispersion of these pollutants can be affected by meteorological factors, such as wind, thereby causing them to be impactful even at distances away from the emission source. The study shows that high mean values of particulate matter from these quarry activities were measured at different locations within and

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away from the quarry site. The study recommends that people within the study area should limit their exposure to air pollutants, especially during the dry season.

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