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Assessment and Modeling of Air Quality in Selected Areas Around the Quarry Sites in Abia State

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ABSTRACT

This study focused on the assessment and modeling of air quality in selected quarry sites located in Lokpaukwu, Umunneochi Local Government Area of Abia State. Ambient air samples were taken in the major activities areas of the quarry site, such as the generator house, the weight bridge, the primary crusher, the secondary crusher, the administration block and the site main gate. The data obtained were subjected to statistical analysis. A model equation was developed by multiple regression analysis, thereafter was calibrated, verified, validated and compared with well-known standard. The particulate matters considered in the model are Suspended Particulate Matter, PM_{10}, $PM_{2.5}$ and $PM_{1.0}$. The study revealed a positive correlation between the observed and predicted pollutants concentration. From the results, the error of estimate gotten is within the specific range of statistical analysis. Eluama quarry site recorded $120.28 ug/m^3$ as the highest predicted concentration in January, 2015 and $54.07 ug/m^3$ as the lowest predicted concentration in May, 2015. Eziama quarry site recorded $104.22 ug/m^3$ as the highest predicted concentration in March, 2015 and $59.05 ug/m^3$ as the lowest predicted concentration in July, 2015. The result shows that the level of concentration of the particulates in air will be highest during the dry season and lowest during the rainy season. The highest predicted concentration of the pollutants recorded is $120.28 ug/m^3$ which is below the permissible limits of NESREA and WHO ($150 ug/m^3$ and $250 ug/m^3$). Overall, the model performance is satisfactory and this would provide reliable results in predicting or determining the air quality in Quarry Sites.

Keywords: Air quality, correlation coefficient, Modeling, Particulate Matter, Regression.

1.0 INTRODUCTION

Environmental quality is an important direct and indirect determinant of human health. Deteriorating environmental conditions are a major contributory factor to poor health and poor quality of life and hinder sustainable development (WHO, 1997).

Dust from mining and quarrying operations if allowed to reach the atmosphere creates an incompatible environment or causes excessive wear on machinery, reduces visibility or increases the rate of accidents and also contributes to Siniuous diseases such as Pneumoniasis, Fibrosis and scarring of the lungs as a result of repeated inhalation of minerals such as silica, asbestos and coal dust (Health and Safety Council Guidelines, 2008).

Quarry is the exploitation of various lithological materials given by nature to mankind. It is a place from which dimension stones, rocks, construction aggregates, riprap, sand, gravel or slate have been excavated from the ground (Ukpong, 2012: Nartey, 2012). The quest for harnessing the materials that abound in our environment will continue to increase due to the need for urbanization, road and rail construction, airport and beautification of infrastructural facilities around us. Quarrying as we know is a good source of income and revenue for both the government and individuals. There are several quarries spread across the southern part of Nigeria with a total annual yield of 1,954,263.83 tons of granite dust and 1,604,822.71 granite aggregates. The quarry and mining industry in Nigeria contributed 8.7% of Gross Domestic Product (GDP) with a sum of N5.37 Trillion in 2021 according to National Bureau of Statistics (NBS, 2022).

Unfortunately, these quarry industries cause significant impact on the surrounding environment. In fact, the extraction process normally depends on heavy machines and explosive, where both processes are associated with air pollution, water pollution, soil pollution, noise pollution, damages to biodiversity and habitat destruction (Lameed and Ayodele,2010: Ogbonaya and Phi-Eze, 2020)

Particulates are the tiny solid or liquid particles that are suspended in air and which are usually individually invisible to the naked eyes. The particulates include soot, smoke, ash from fuel (mainly coal) combustion, dust released during industrial processes like quarrying and other solids from accidental and deliberate burning of vegetation. Quarrying generates a lot of particulate matter (dust) with diameter 1 - 75μm (micron). Particles with aerodynamic diameters less than 50 μm termed Total Suspended Particulate (TSP) matter can become suspended in the atmosphere, and those with aerodynamic diameters less than 10μm termed PM_{10}(inhalable particles) can be transported over long distances and enter the human respiratory system (Montgomery, 1992).

TSP is the concentration of all particles in the atmosphere. Particles with aerodynamic diameters less than 2.5 µm (respirable particles) are most effective at scattering light and have a great effect on visibility or visual intrusion, impairment and the earth's radiation balance. PM_4 and $PM_{2.5}$ if inhaled penetrate deeply into the lungs and are capable of making their way to the air sacs deep within the lungs where they may be deposited and cause respiratory problems Air pollution also causes damage to man-made materials and structures, changes the weather and interferes with comfortable enjoyment of life, property or human activities (Charlson,1992).

Air pollutants such as dust are unhealthy particles (solids, liquid gas mixtures) that are liable to harm both living and non-living things. The main source of airborne particulate matter include the following activities: site clearing, road construction, top soil stripping and dumping, open pit drilling and blasting, stripping, loading and haulage. When air quality is monitored, the most common measure of the concentration of suspended particles is the PM index which is the amount of particulate matter that is present in a given volume of air (Akabzaa, 2000).

The activities of the stone quarrying in some parts of Abia State has generated some environmental issues which needs to be investigated so that mitigation mechanism can be recommended and awareness created on health hazards of the quarrying activities. The objectives of the study was therefore to determine air pollutants at the selected quarry sites, to develop a model that predicts the concentration of the pollutants, to calibrate, verify and validate the model, to compare the air quality parameters with well-known standards and to predict the impact of the pollutants in the communities.

2.0 Literature Review

2.1 Quarry

Quarrying is the process of extracting, removing and disposing quarry resources found on or underneath the surface of a private or public land. It serves as a source of livelihood to sand and gravel industry (Nduka, 2003).

A quarry is a type of open-pit mine from which rock or minerals are extracted. Quarries are generally used for extracting building materials, such as dimension stone, construction aggregate, riprap, sand, and gravel. They are often collocated with concrete and asphalt plants due to the requirement for large amounts of aggregate in those materials. Searching, locating and extracting materials used for construction activities pose some problems to the environment which normally result in the damaging of the immediate environment and atmosphere. Rock-quarrying and stone crushing is a global phenomenon, and has been major sources concern everywhere in the world, including the advanced countries.

Quarrying activity is a necessity that provides much of the materials used in traditional hard flooring, such as granite, limestone, marble, sandstone, slate and even just clay to make ceramic tiles. However, like many other man-made activities, quarrying activities cause significant impact on the environment (Okafor, 2006). Explosives are employed in rock blasting to extract material for processing; this produces noise and air pollution. Also, it destroys the wildlife's natural habitat. Whilst a quarry is in use, the effects on the local environment are more than just the loss of wildlife's habitats and the obvious visual impact. Unwanted sound or noise such as that produced by airplanes, traffic or industrial machinery is considered a form of pollution. Noise pollution can cause hearing loss, stress, high blood pressure, sleep loss, distraction and lost productivity. While high frequency sounds tends to be more hazardous and more annoying to hearing than low- frequency sounds. The initial source of noise on a new mine or quarry is the preparatory works for the site. Noise is an inevitable consequence of the working of minerals. The extraction process for any material will contain a number of noise generating processes (Umeham, 2001). The noise impact of quarry mining will arise from the earth moving machines/equipment, power generating sets, machines and vehicular traffic. Noise is known to affect workers' productivity, scare away wildlife and distorts birds' sanctuary. In most cases, there will be a need to remove soil and overburden to expose the mineral. The mineral will need to be excavated and then transported from the quarry site for further processing or direct use. These activities require the use of powered machinery for excavation and transportation of materials within the site. Processing plant, on site can often include the use of crushing and grading plant. There will also be noise generated from the blasting of rock. The process of blasting can give rise to vibrations, noise, dust and fumes. Vibration from blasting of rock can give rise to destruction of houses (Ekechukwu, 2010).

The biggest negative impacts of quarrying on the environment are the damage to biodiversity (Anand, 2006). The damage caused to plants by pollution include necrosis (dead areas on leaf structure) chlorosis (loss or reduction of chlorophyll leading to yellowing of leaf), epinasty (downward curvature of the leaf due to higher rate of growth on the upper surface), and abscission of leaves (premature fall). This will no doubt affect the physiological activities of the plants most especially those around the quarry sites such that as in photosynthesis and respiration. The implication of these is that some of the plants may have retarded growth, while others may be eliminated (Lameed and Ayodele et al., 2010). Furthermore, active and abandoned mines and quarries have been a source of negative environmental effects which have led to erosion, formation of sinkholes, and contamination of soil, groundwater, and surface water, and also the loss of biodiversity. All these problems arise from contamination of the chemicals used in mining and the neglect of environmental awareness while operating the mines and quarries (Ogunwole, 2015). The bio-physical effects are associated with the environmental impacts because the fact that many of the quarry sites are uncontrolled and that insufficient techniques of mining are used, it produces a degradation of both land and stone reserves. In many cases there is lack of resource allocation planning in quarry land, a situation that results to quarry sites being located haphazardly without any proper development and guidance. In the end there is a myriad of mineral surface workings that show a lack of resource and environmental management (Savery, 1997). Another effect is that quarries can contribute to air pollution in a number of ways that include; ammonium nitrates form the fuel mix used in blasting and from engines, dust from the quarry or the roads that lead to the quarry site, as well as the dust and fumes from the lorry traffic and dust from the blasting process may cause discharge of pollutants to the atmosphere. Dust is one of the most visible, invasive and potentially irritating impact associated with quarrying. Dust concentrations, potential impacts and deposition rates tend to decrease rapidly away from the source (Howard and Cameron, 1998). However, its visibility tends to raise concerns that are not usually directly proportional to its impacts on human health and the environment (Howard and Cameron et al., 1998). Quarries can also be a cause for water table alterations, where the quarries go deep enough to affect ground water aquifers. Formation of dams at quarry sites is also a common feature in abandoned quarry sites (Agevi and Ogero, 1990).

2.2 Quarry Processes

Once the mineral has been extracted and removed from the working area, there will normally be some processing carried out on site. Some materials may need to be crushed to reduce the size of individual pieces to a manageable size. Crushing plants can be noisy, and for hard rock there is sometimes a need to use a pecker on the largest rocks before loading onto the dump truck, or a hydraulic breaker at the crush feed.

Airborne dust is produced by a wide range of processes. These include:

i. Drilling/channeling and wedging

ii. Blasting and cutting of rocks

iii. Crushing and grading (sieving/screening)

iv. Conveyance or transfer

v. Loading and transportation

2.3 Quarry Waste

Quarry wastes are a largely unavoidable by-product of the extraction and processing of rock aggregates .They are defined as wastes because no market currently exists for them, but unlike many other wastes they are generally inert and non- hazardous. Materials that may be classified as quarry wastes include overburden (although this is frequently used in restoration) and inter-burden (material of limited value that occurs above or between layers of economic aggregate material) and processing wastes which are non-marketable, mostly fine-grained material from screening, crushing and other processing activities (Banez, 2010).

Quarry fines can be considered a mixture of coarse, medium and fine sand material, and silt or clay (silt and clay is known collectively as filler). In general terms, the higher the proportion of fine sand, silt and clay, the greater the environmental and social impacts and costs of production, storage and disposal, as the material is difficult to handle and is more prone to mobilization under the action of gravity, wind and water. The filler content has a major impact on technical properties and on potential end use. Disposal areas are a major potential source of dust during operational activities. The impact may extend beyond the closure of operations if steps are not taken to address long-term dust creation and can be exacerbated by the fact that disposal areas are elevated above the original ground level.

2.4 Environmental Issues

The nature of mining processes creates a potential negative impact on the environment both during the mining operations and for years after the mine is closed. This impact has led to most of the world's nations adopting regulations to moderate the negative effects of mining operations (http: //www.answers.com/topic/mining.). Some of the environmental disturbances created by quarrying are caused directly by engineering activities during aggregate extraction and processing. The most obvious engineering impact of quarrying is a change in geomorphology and conversion of land use, with the associated change in visual scene (Gale and Groat, 2001). This major impact may be accompanied by loss of habitat, noise, dust, vibrations, chemical spills, erosion, sedimentation, and dereliction of the mined site. Some of the impacts are short-lived and most are easy to predict and easy to observe. Most engineering impacts can be controlled, mitigated, kept at tolerable levels, and restricted to the immediate vicinity of the aggregate operation by employing responsible operational practices that use available engineering techniques and technology.

Research results, published on 9th May, 1999 in America by the department of the environment, transport and the regions, show that there are significant environmental costs associated with quarrying, including noise, dust, visual intrusion, loss of amenity and damage to biodiversity (http://www.hm-treasury.gov.uk/home.htm.).

2.4.1 Air Pollution

Air pollution resulting from the activities of mining and mining support companies emanates from high airborne particulate matter, black smoke, noise and vibration resulting from blasting (Akabzaa et al., 2000). Large quarry waste tips or quarry fines stockpiles can be a source of airborne dust which can be exacerbated if they are elevated above the original ground level. Dust may also originate from air filtration units or stacks, haulage trucks, conveyors and transfer points (Banez et al., 2010).

Dust is defined as particulate matter 1 – 75 µm (micron metre) in diameter and is produced by abrasive forces acting on materials. It is carried by moving air when there is sufficient energy in the airstream and is removed through gravitational settling (sedimentation), washout such as during rainfall or by wetting and through impaction on surfaces. Settled dust can be re-suspended where conditions allow, either by wind blow from bare surfaces or by disturbance such as vehicle movement (http:www.hm-treasury.gov.ule/bud99-prquarrying.htm.)

Agunwamba (2001) defined dust as solid particles dispersed in a gaseous medium as the result of the mechanical disintegration of matter. Dust is one of the most visible, invasive and potentially irritating impacts associated with quarrying, and its visibility often raises concerns that are not directly proportional to its impact on human health and the environment.

Dust particles are dispersed by their suspension and entrainment in airflow. Dispersal is affected by the particle size, shape and density, as well as wind speed and other climatic effects. Smaller dust particles remain airborne for longer periods, dispersing widely and depositing more slowly over a wider area. Large dust particles (greater than 30μm), that make up the greatest proportion of dust emitted from mineral workings will largely deposit within 100m of sources. Intermediate sized particles (10μ - 30μ m) are likely to travel up to 200 – 500m. Smaller particles (less than 10 μm) which make up a small proportion of the dust emitted from most mineral workings or quarries are only deposited slowly. Concentrations decrease rapidly on moving away from the source, due to dispersion and dilution.

PM_{10} is the term given to the fraction of total particles suspended in the air having diameters less than 10μm. The PM_{10} samples will contain all particles less than 2.5μm in diameter ($PM_{2.5}$) as well as particles in the 2.5μm to 10μm fraction. Analysis of the silica content of PM_{10} particles rather than $PM_{2.5}$ particles could lead to a greater crystalline silica mass due to the possible presence of silica particles in the 2.5μm to 10μm size range on the filter. Wind direction is a critical factor in the measurement of the impacts of dust from quarrying operations at monitoring sites.

2.5 Research gap to be filled by this work

Sequel to the complaint from the host community on the air quality in quarry site, I attend to develop a model that will help in determining the concentration of air quality in quarry sites and its environs.

3.0 MATERIALS AND METHODS

3.1 Study Area

The study area is a quarry sites located in Eluama and Eziama communities, which are the two communities surrounding the quarry sites operated by Asphalt Unity Construction Ltd, located in Lokpaukwu, Umunneochi Local Government Area of Abia State, Nigeria. They were established in 2010 and lies between Latitude N05^0 54' 56.574'' and N05^0 55' 11.540'' and Longitude E007^0 26' 116.554'' and E007^0 27' 17.440'', on an elevation of 105.79m & 77.56m above mean sea level (Figure 3.1 and 3.2).

Asphalt Unity Construction Ltd is located in the moist, highland tropical forest zone of Nigeria. The area is dominated by two climate regimes; the wet and dry season. Wet season commences around April and extends to October/November while the dry season is experienced between December and March. However, slight variations in the climatic setting may be observed due to climate change. The mean annual rainfall of the study area is between 2000 and 3000mm while the daily temperature range from 27^0 to 32.5^{0}c. There is usually short dry spill in August during which there are few intense thunderstorms. Relative humidity is highest (75.3% - 85%) in the area in the months of April through October and lowest (55% - 65%) in November through March, which corresponds to the periods in high and low rainfall respectively.

The vegetation cover of the area is characterizes by rain forest. The vegetation cover includes shrubs, palm trees, raffia palms and short trees. Some of the vegetation has been removed by human activities such as farming, burning, construction and mining activities.

The two quarry sites out of ten (10) quarries in Abia State were considered because of availability of air quality data as a result of constant environmental compliance of the two quarry sites for a period of two years.

3.1.1 Data Sources

The ambient air samples generated from the quarry sites formed the primary data while Secondary data sources included stone quarry journals, International Associations publication on quarries, textbooks and articles on the internet. This led to the assessment and modeling of air quality in quarry site.

3.1.2 Data Collection

The air quality was assessed using the digital Growcon mobile Gas Analyzer 2012 Model and PC-GW6AAS-KIT particulate counter. The device is automatically calibrated in the site and records the concentrations of the gases in parts per million (ppm).

The gases and the particulate matters were measured and analyzed by Ahiasco Services Nigeria (Geoscientists and Environmental Consultants), a NESREA accredited environmental consultant.

The ambient air samples were taken in the major activities areas of the quarry site, such as the generator house, the weight bridge, the primary crusher, the secondary crusher, the administration block and the site main gate. Table 3.1 and 3.2 shows the elevation and coordinates of sampling locations with respect to the drilling point. The samples were carried out both in dry and rainy seasons, in the month of January through December of 2015, 2016 and 2019.

The parameters measured in the sampled air were Oxides of Nitrogen (NO_X), oxides of Sulphates (SO_X), Carbon monoxide (CO), Methane (CH_4), Ammonium compounds (NH_S), Suspended Particulates Matter (SPM) and respirable and inhalable particulates ($PM_{1.0}$, $PM_{2.5}$ and PM_{10}).

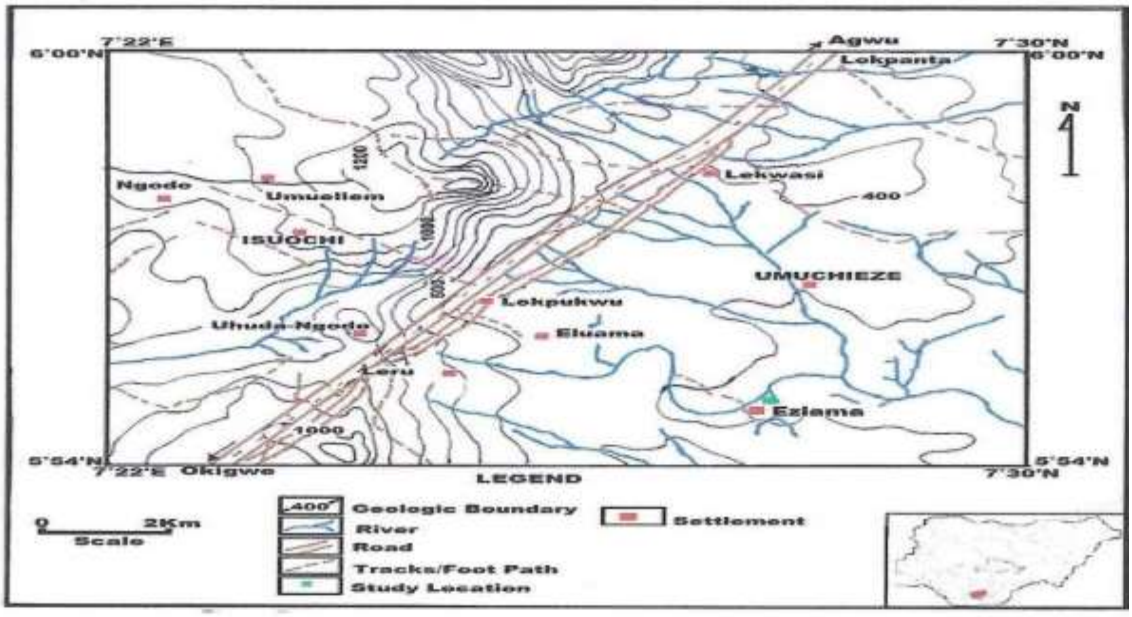

Figure 3.1: Location Map of Eziama quarry site

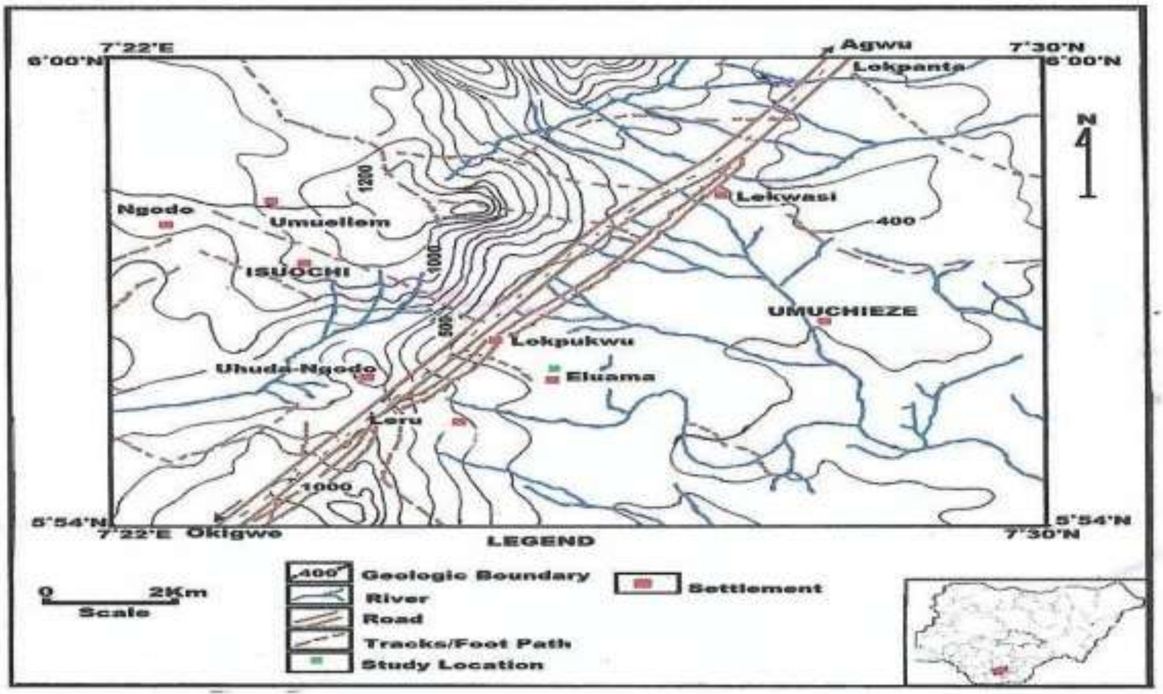

Figure 3.2: Location Map of Eluama quarry site

4.0 Results and Discussion

4.1 Presentation of Results

The results of the several parameters measured are presented in this section. They include analysis of the air quality data from various stations. Table 4.1 through 4.70 shows the results of all the surface environmental parameters investigated through the period of January to December of 2015, 2016 and 2019 respectively.

4.1.1 Air Quality Data of Eluama Quarry Site

From the results of the ambient air quality of Eluama quarry site, the values of the Mean Total Particulate Matter (TPM) were below NESREA and WHO permissible limit and the wind speed (Appendix A.1 to A.47) within the facility is moderately high and this enhances the dispersion of gases and fugitive dust while the wind direction indicates the direction of dispersal of the gaseous emissions.

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m^3**	**PM10 µg/m^3**	**PM2.5 µg/m^3**	**PM1.0 µg/m^3**
Generator House	0.10	0.00	0.00	0.10	0.01	3.20	2.00	60.00	30.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	2.00	10.00	35.00	34.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.99	9.00	36.00	30.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	20.00	41.00	20.00	21.00
Main Gate	0.10	1.00	0.00	0.10	0.01	22.00	40.00	24.00	24.00
Mean	0.10	0.12	0.00	0.10	0.10	11.43	20.40	35.00	27.80

TPM= 94.63 µg/m^3

Table 4.1: Air Quality Data of Eluama Quarry Site (January, 2015)

4.1.2 Air Quality Data of Eziama Quarry

From the results of the ambient air quality of Eziama quarry site, the values of the Mean Total Particulate Matter (TPM) were below NESREA and WHO permissible limit and the wind speed (Appendix A.1 to A.47) within the facility is moderately high and this enhances the dispersion of gases and fugitive dust while the wind direction indicates the direction of dispersal of the gaseous emissions.

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs µg/m^3**	**SPM µg/m^3**	**PM10 µg/m^3**	**PM2.5 µg/m^3**	**PM1.0 µg/m^3**
Admin. Block	0.10	0.00	1.00	0.10	0.01	6.50	10.00	16.00	32.00
Weight Bridge	0.10	3.00	0.00	0.10	0.01	7.20	13.00	14.00	46.00
Primary Crusher	0.00	0.00	0.00	0.10	0.01	12.40	12.00	14.00	21.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	4.00	3.00	20.00	22.00
Main Gate	0.10	0.00	0.00	0.10	0.01	2.40	2.00	8.00	28.00
Mean	0.10	0.80	0.20	0.10	0.01	6.50	8.00	14.40	29.80

TPM = 58.70 µg/m^3

Table 4.35: Air Quality Data of Eziama Quarry Site (January, 2015)

4.1.3 Model Derivation

4.1.4 Model Equation, using the Multiple Linear Regression Equation

The multiple linear regression equation is as follows:

$$Y = b_0 + b_1x_1 + b_2x_2 + .. + b_px_p \qquad 4.1$$

Where

Y is the predicted or expected value of the dependent variable, x_1 through x_p are p distinct independent or predictor variables, b_0 is the value of Y when all of the independent variables (x_1 through x_p) are equal to zero, and b_1 through b_p are the estimated regression coefficients. Each regression coefficient represents the change in Y relative to a one unit change in the respective independent variable. In the multiple regression situation, b_1, for example, is the change in Y relative to a one unit change in x_1, holding all other independent variables constant.

Therefore, using the above multiple linear regression equation, the Concentration of Pollutants (C) in the air;

$$C = a + bx + c\alpha + d\beta + e\emptyset \qquad 4.2$$

$x = SPM \quad Suspended\ Particulate\ Matter$ (**μg/m3**)

$\alpha = PM_{10}$ Coarse or Respirable Particulate (**μg/m**^{3})

$\beta = PM_{2.5}$ Fine or Inhalable Particulate (**μg/m**^{3})

$\emptyset = PM_{1.0}$ Fine or Inhalable Particulate (**μg/m**^{3})

Using multiple regression analysis, the model will be calibrated, verified and validated using the limited data obtained from the field.

Applying Statistical Performance Measure for Analysis of Results

For Coefficient of Correlation (R)

$$\boldsymbol{R} = \frac{\sum_{i=1}^{n}(C_i^o - C_i^{-o})(C^{-p})}{\sqrt{\sum_{i=1}^{n}(C_i^o - C_i^{-o})^2}\sqrt{\sum_{i=1}^{n}(C_i^o - C_i^{-p})^2}} \qquad 4.3$$

For Mean Absolute Percentage Error (MAPE);

$$\boldsymbol{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left[\frac{C_i^p - C_i^o}{C_i^o}\right] * 100 \qquad 4.4$$

For Root Mean Square Error (RMSE);

$$\boldsymbol{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(C_i^o - C_i^p)^2}{n}} \qquad 4.5$$

$Where, \quad n = number\ of\ data\ points, \quad C_i^o\ and\ C_i^p\ are\ observed\ and\ predicted\ concentration\ of\ pollutants$ $while\ C_i^{-o}\ and\ C_i^{-p}\ are\ their\ mean\ values\ respectively$

4.1.6 Model Calibration

$$\sum C = an + b\sum x + c\sum \alpha + d\sum \beta + e\sum \emptyset \qquad 4.6$$

$$\sum Cx = a\sum x + b\sum x^2 + c\sum \alpha x + d\sum \beta x + e\sum \emptyset x \qquad 4.7$$

$$\sum C\alpha = a\sum \alpha + b\sum \alpha x + c\sum \alpha^2 + d\sum \beta\alpha + e\sum \emptyset\alpha \qquad 4.8$$

$$\sum C\beta = a\sum \beta + b\sum \beta x + c\sum \beta\alpha + d\sum \beta^2 + e\sum \emptyset\beta \qquad 4.9$$

$$\sum C\emptyset = a\sum \emptyset + b\sum \emptyset x + c\sum \emptyset\alpha + d\sum \emptyset\beta + e\sum \emptyset^2 \qquad 4.10$$

Months	$x\ (ug/m^3)$	$\alpha\ (ug/m^3)$	$\beta\ (ug/m^3)$	$\emptyset\ (ug/m^3)$	$C\ (ug/m^3)$
Jan.	5.4	7.6	13.4	25.2	52.6
Feb.	7.6	8.4	19.6	17.4	53.0
March	7.2	7.0	20.4	18.2	52.8
April	7.6	7.0	20.2	18.8	53.6
May	6.4	6.6	17.6	16.8	47.4
June	7.4	8.0	17.6	19.0	52.0
July	8.0	8.6	17.8	19.4	53.8
August	6.8	8.8	18.6	20.0	54.2
Sept.	7.0	8.6	17.6	19.6	52.8
Oct.	10.4	11.8	15.4	13.0	50.6
Nov.	11.0	14.6	15.0	12.8	53.4
Dec.	9.4	12.4	16.4	13.2	51.4

Table 4.71: Model Calibration Using Eluama 2016 Dataset

From the data of Eluama Quarry Site 2016 above, the model was calibrated. The following results were obtained;

$\sum x^2 = 769, \ \sum x = 94.2 \quad \sum C = 470.91$

$\sum Cx = 3135.26$ $\sum \alpha^2 = 1065.4$

$\sum \alpha = 109.4$ $\sum C\alpha = 4354.65$ $n = 12$

$\sum \beta^2 = 3711.12$ $\sum \beta = 209.6$

$\sum C\beta = 8209.01$ $\sum \emptyset^2 = 3933.32$

$\sum \emptyset = 213.4$ $\sum C\emptyset = 8316.30$

$\sum \alpha x = 898.64$ $\sum \beta x = 1636$

$\sum \emptyset x = 1618.84$ $\sum \beta\alpha = 1879.84$

$\sum \emptyset\alpha = 1874.92$ $\sum \emptyset\beta = 3730.8$

Substituting these results in the simultaneous equations 1 to 5 above, the values of the model constants were determined as shown below

$$12a + 94.2b + 109.4C + 209.6d + 213.4e = 470.91 \quad 4.11$$

$$94.2a + 769b + 898.64C + 1636d + 1618.84e = 3135.26 \quad 4.12$$

$$109.4a + 898.64b + 1065.4C + 1879.84d + 1874.92e = 4354.65 \quad 4.13$$

$$209.6a + 1636b + 1879.84C + 3711.12d + 3730.8e = 8209.01 \quad 4.14$$

$$213.4a + 1618.84b + 1874.92C + 3730.8d + 3933.32e = 8316.30 \quad 4.15$$

$\boldsymbol{a = 2.24}$, $\boldsymbol{b = 1.01}$, $\boldsymbol{c = 1.12}$, $\boldsymbol{d = 0.52}$, $\boldsymbol{e = 0.55}$

Thus, the Model Equation is derived as;

$$[C = \mathbf{2.24 + 1.01}x + \mathbf{1.12}\alpha + \mathbf{0.52}\boldsymbol{\beta} + \mathbf{0.55}\emptyset] \quad \mathbf{4.16}$$

4.2 Discussion of Results

4.2.1 Determination of air pollutants at the selected quarry sites

From the ambient air samples taken in the major activity areas of the quarry sites, from January to December of 2015, 2016 and 2019 as recorded in tables 4.1 through 4.70, the major air pollutants at the quarry sites were suspended particulate matter, PM_{10}, $PM_{2.5}$, and $PM_{1.0}$. Gases like CO, SO_2, NH_S, H_2S and CH_4 were below limit. From the air quality data, 96.40 ug/m^3 was recorded as the highest total particulate matter (TPM) value at Eluama quarry site in January 2019 while 92.40 μg/m^3 was recorded as highest TPM value at Eziama quarry site in March, 2015. From the field observed data, the highest concentration of the Total Particulate Matter in the two quarry sites were below NESREA (A.48) and WHO (Table 3.3) standards of 150 μg/m^3 and 250 μg/m^3.

From the results gotten, it was observed that rainy weather condition reduces the amount of dust emitted while sunny, windy and dry weather promote dust emission and impact. The wind speed within the facility is moderately high and this enhances the dispersion of gases and fugitives dust while the wind direction indicates the direction of dispersal of the gaseous emissions (A.1 to A.47).

The data obtained confirms the statement that dry weather promotes dust emission, thus there should be adequate suppression of dust in the quarry site during dry season.

4.2.2 Development of model that predicts the concentration of the pollutants

The model equation was derived from the available field data of Eluama and Eziama quarry site. The model equation was derived as $[C = \mathbf{2.24 + 1.01}\boldsymbol{x} + \mathbf{1.12}\boldsymbol{\alpha} + \mathbf{0.52}\boldsymbol{\beta} + \mathbf{0.55}\emptyset]$

However, from the derived model equation, the concentrations of the pollutants were predicted, by substituting the values of the variables into the model equation. Tables 4.72, 4.73, 4.74, 4.75 and 4.76 shows the results of the predicted pollutants concentrations. The model equation enables us to predict the outcome variable with greater precision.

From Table 4.72, Eluama quarry site recorded $120.28ug/m^2$ as the highest predicted concentration in the month of January, 2015 and $54.07ug/m^2$ as the lowest predicted concentration in the month of May, 2015.

From Table 4.73, Eziama quarry site recorded $104.22ug/m^2$ as the highest predicted concentration in the month of March, 2015 and $59.05ug/m^2$ as the lowest predicted concentration in the month of November, 2015.

From Table 4.74, Eziama quarry site recorded $65.82ug/m^2$ as the highest predicted concentration in the month of February, 2016 and $51.20ug/m^2$ as the lowest predicted concentration in the month of July, 2016.

From Table 4.75, Eziama quarry site recorded $101.02ug/m^2$ as the highest predicted concentration in the month of May, 2019 and $62.04ug/m^2$ as the lowest predicted concentration in the month of July, 2019.

From Table 4.76, Eluama quarry site recorded $107.02ug/m^2$ as the highest predicted concentration in the month of May, 2019 and $56.67ug/m^2$ as the lowest predicted concentration in the month of June, 2019.

From the results, it also shows that the level of predicted concentration of the pollutants in air will be highest during the dry season and lowest during the rainy season or weather, and were all below the permissible limit of WHO and NESREA.

5.0 Conclusion

Quarry activities released air pollutants into the environment. Findings from this research revealed that the major air pollutants at the two quarry sites were suspended particulate matter, PM_{10}, $PM_{2.5}$, and $PM_{1.0}$, and little concentrations of gases like CO, SO_2, NH_s, H_2S and CH_4.

A model was developed from the available field data, which was used to predict the concentration of the pollutants in the quarry sites. From the model equation derived, the ambient air quality in any location within the quarry area can be calculated.

The model was calibrated, verified and validated. From the model calibration, the values of various constants and parameters in the model structure were gotten, which helped in derivation of the model equation. From statistical performance measure for analysis of results, the error of estimate gotten is within the specific range of statistical analysis, and there is a positive correlation between the observed and predicted pollutants concentration. It also revealed that the concentration of the pollutants between the model calculation and the actual monitoring are basically consistent. Overall, the model performance is satisfactory and this would provide reliable model in predicting or determining the air quality in Quarry Sites and its vicinity.

The air quality was compared with NESREA and WHO standards. The values of the observed and predicted particulate matters were below NESREA and WHO permissible limits, thus the air quality in that vicinity is of Moderate Quality.

From the study, there will not be health impact in terms of respiratory disease cause by the particulate matter to the host communities, since the study revealed that the air quality is of Moderate Quality and is far below the permissible limit of NESREA and WHO. In the United State of America, exposure to very fine particulate matter is considered safe by the US Environmental Protection Agency's national ambient air quality standards so long as a person breathes in an average of 12microngrams per cubic meter of air ($\mu g/m^2$) or less per day over the duration of a year (https://qz.com/1166010/air-pollution-even-at-level/)

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The author declare that there is no conflict of interest.

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