ASSESSMENT AND MODELING OF AIR QUALITY IN QUARRY SITES IN ABIA STATE

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CERTIFICATION

This is to certify that this work **"Assessment and modeling of air quality in quarry sites in Abia State."** was carried out by **Arua, Okechukwu Nwankwo** with registration No. **20154944658** in partial fulfilment of the requirements for the award of degree of Master of Engineering (M.Eng.) in Water Resources Engineering in the Department of Civil Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Owerri, Imo State.

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DEDICATION

This work is dedicated to God Almighty.

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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. The study revealed a positive correlation between the observed and predicted pollutants concentration. It also shows the concentration of the pollutants between the model calculation and the actual monitoring are basically consistent. From the results the error of estimate gotten is within the specific range of statistical analysis. Eluama quarry site recorded $120.28ug/m^3$ as the highest predicted concentration in the month of January, 2015 and $54.07ug/m^3$ as the lowest predicted concentration in the month of May, 2015. Eziama quarry site recorded $104.22ug/m^3$ as the highest predicted concentration in the month of March, 2015 and $59.05ug/m^3$ as the lowest predicted concentration in the month of 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 or weather. It is therefore wise to say that the concentrations of the particulates will be severer during the dry season than the rainy seasons. Thus, suppression of dust must be effectively monitored during the dry season. From the predicted pollutants concentration, the two communities will be safe from the adverse effects of the pollutants, as the highest predicted concentration of the pollutants recorded is $120.28ug/m^3$ which is below the permissible limits of NESREA and WHO ($150ug/m^3 and\ 250ug/m^3$). Also Concentrations decrease rapidly on moving away from the source, due to dispersion and dilution, which means there will be more reduction in concentration of the pollutants before it reaches the host communities. 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, Dust, Modeling, Regression, correlation coefficient, Suspended Particulate Matter.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

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. 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.

1.2 Statement of Problem

Quarrying activities in Nigeria has caused significant impact on the environment, the blasting rocks with explosives in order to extract material for processing gives rise to noise pollution, air pollution, damage to biodiversity and habitat destruction which affect the human environment of a particular area (Okafor, 2006).

Dust pollution, cracks in building, noise pollution, reduced photosynthesis by flora, nuisance dust, biodiversity loss and others are usually associated with quarrying. The need for construction materials like sand, gravel or rocks constitutes the basis of the effects of quarrying.

The two communities close to the quarry sites are Eluama and Eziama. Dust pollution and other related problems in this enclave might be due to quarrying activities, exposure to mineral dust can cause a wide range of respiratory problems. The potential health effects of dust are closely related to particle size.

Particulate matter, noise, vibrations and run-offs from the sites are impacting negatively on the health and property of the people living around the cluster sites.

1.3 Objectives of Study

The aim of this study is to assess and model the air quality in quarry sites located in Lokpaukwu, Umunneochi Local Government Area of Abia State.

The specific objectives of this study are:

i. To determine air pollutants at the selected quarry sites.
ii. To develop a model that predicts the concentration of the pollutants.
iii. To calibrate, verify and validate the model.
iv. To compare the air quality parameters with well-known standards.

1.4 Justifications of Study

Concerns have been raised by the people living in the study area about the impacts of dust, run-offs and vibrations from quarrying activities on the health and well-being of the communities. The concerns focused around the impact of dust emissions, blasting vibrations and flooded farmland created by run-off. These have the potential to cause lung diseases (which may include silicosis-scarring of the lung tissue- and other respiratory diseases like catarrh or common cold, cough, whistling chest), destruction of buildings and water- borne or water- related diseases (Gale and Groat, 2001). Their concerns have absolute justification because EPA guidelines require that quarrying activities should not cause a nuisance at a nuisance sensitive place such as a school, child care facility or domestic residence. Since these quarries are very close to the communities identified for the study the possibility that quarrying activities will impact negatively on the inhabitants is high. A very high degree of respiratory morbidity is associated with this industry. Fine rock and mineral dust of many kinds have been shown to be carcinogenic when inhaled (Montgomery et al., 1992). Control of particulate pollution is a matter of both health and aesthetics. Increasing attention is being paid to the impacts of dust on human health, as finer particles can be inhaled and breathed into the lungs and cause harm. It is generally recognized that dust up to 10μm can be inhaled beyond the larynx and dust up to 4μm can be breathed into the lungs.

Potential health impacts are almost exclusively linked to the presence of airborne dusts, in particular respirable particles. Respirable particles, thus, those that are less than 10μm in diameter (also known as PM_{10}), have the potential to cause effects on human health, including effects on the respiratory and cardiovascular systems (Banez, 2010). According to them, inhalation of dusts can cause "pneumoconiosis" which is a term that refers to a group of lung diseases.

Local communities can potentially be affected by dust up to 1 km from the source, although concerns about dust are most likely within 100 meters. Deposited dust gives rise to the greatest number of complaints to quarries from local communities, particularly for contrasting colours that are more noticeable on deposition. Settled particles may show up particularly on clean or polished surfaces such as cars, windows and window ledges, or surfaces that are usually expected to remain free from dust (Cunningham and Saigo, 1992). The impacts from quarrying activities on the health of people are quite significant as blasting vibrations have also resulted in cracks in several buildings posing as a danger to the occupants. Other potential quarrying effects which are of concern to environmentalists include biodiversity loss, land degradation, nuisance effects, reduced plant growth etc.

1.5 Scope of the Study

The study consist of survey of the study area, recording of data and interpretation of data using statistical, graphical and established modeling tools. The survey was carried out in Asphalt Unity Construction Limited located in Eziama and Eluama quarry sites, both in Lokpaukwu, Umunneochi Local Government Area of Abia State. The air pollutants considered in this study are Suspended Particulate Matter,

PM_{10}, $PM_{2.5}$ and $PM_{1.0}$. The study will focus on the assessment and modeling of air quality in Eluama and Eziama quarry sites located in Lokpaukwu, Umunneochi Local Government Area of Abia State.

1.6 Limitations of Study

The limitation of this study was in data collection, as limited field data was available as a result of non-compliance of the facility to Government policy and regulations in carrying out air quality monitoring as at when due.

CHAPTER TWO

LITERATURE REVIEW

2.1 Air Pollution

Air pollution in recent decades has increased massively with increase in industrial, transportation and other anthropogenic activities. Government and other regulatory agencies throughout the world (including India) have taken numerous of efforts in recent decades to reduce air pollution and improve air quality. Despite this, air quality issues such as photochemical smog and visibility degradation etc. are persistent. Estimates are that, worldwide, nearly one billion people in urban environments are continuously being exposed to health hazards from air pollutants (Smit, 2008). Effective air pollution control is extremely challenging to both researcher and administrators around the world, due to heterogeneous and dynamic nature of natural environment. To reduce the impact of air pollution and improve the air quality, constant efforts are required 1) to build extensive inventories of pollutant emissions, 2) to determine the source, substance and dispersion rates of these emissions, 3) to develop computer-based numerical models based on mass conservation flows, 4) to assess the levels of concentration and exposure to air pollution at every location over a particular urban area (Liu, 2007). Thus, in order to form various air pollution control policies and strategies, air pollution modelling plays an important role. Air pollution dispersion models are used to effectively and efficiently plan the management (environment management plan) of air pollution on particular area/ road corridor, along with monitoring of air pollutants. They not only aid in determining the presently influenced area but also help in identifying the future scenarios under different emission/source and meteorological conditions made by these models.

2.2 Requirements of Air Pollution Modeling

Now days air pollution problem is not bound to an area and it becomes global problem (Global warming, ozone depletion etc.). It is very difficult to control air pollution on global scale. To control the air pollution at local or regional scale, air pollution modelling is the most important component in air pollution control policy making. Air pollution modelling required for two major goal 1) increase domain knowledge and 2) Reliable forecasting of pollutant concentration (Karatzas, 2007). Air quality models use mathematical and numerical techniques to simulate the physical and chemical processes that affect air pollutants as they disperse and react in the atmosphere. Based on inputs of meteorological data and source information like emission rates and stack height, these models are designed to characterize primary pollutants that are emitted directly into the atmosphere and, in some cases, secondary pollutants that are formed as a result of complex chemical reactions within the atmosphere. These models are important to our air quality management system because they are widely used by agencies tasked with controlling air pollution to both identify source contributions to air quality problems and assist in the design of effective strategies to reduce harmful air pollutants. Air quality model is one of the most important components of air quality management. Air quality models are used to predict concentration of one or more species in space and time. Modelling provides the ability to assess the current and future air quality in order to enable “informed” policy decisions to be made. This will help the regulatory agencies to assess the extent and type of the air pollution control management strategies (Afshar and Delavar, 2007). Air pollution models are routinely used in environmental impact assessments, risk analysis and emergency planning, and source apportionment studies (Macdonald R, 2003). Air quality model also support in attainment/maintenance of all National Ambient Air Quality Standards (NAAQS).

Thus, air quality modelling play an important role in providing sufficient information for air quality management planning.

2.3 Air Quality Modeling

A mathematical model is an assembly of concepts or phenomena in the form of one or more mathematical equations, which approximate the behavior of a natural system or phenomena. They are usually employed to predict the impacts or concentration of parameters under different types of current or future scenarios, using readily available or measured input data. Mathematical models can be used to determine the environmental impacts of the existing or developing projects which combine the effects of source strength and meteorology to describe the resulting ambient air concentrations. Air pollution modelling, also known as air pollution dispersion modelling, is the mathematical simulation of how air pollutants disperse in the ambient atmosphere. It is performed with computer programs, called dispersion models, that solve the mathematical equations and algorithms which simulate the pollutant dispersion. The dispersion models are used to estimate or to predict the downwind concentration of air pollutants emitted from emission sources such as industrial plants and vehicular traffic. Such models are important to governmental agencies tasked with protecting and managing the ambient air quality. The models also serve to assist in the design of effective control strategies to reduce emissions of harmful air pollutants (Sharma, 2005). A dispersion model is a computer simulation that uses mathematical equations to predict air pollution concentrations based on weather, topography, and emissions data. Any model depends on the following inputs (Fig 1):

- ❖ Emission parameter: Type of source, emission rate, location, height, temperature etc.

❖ Topography: Rural or Urban area, terrain elevation, height and width of any obstruction, receptor location (height, distance from source) etc.

❖ Meteorological Condition: Wind speed and direction, Atmospheric temperature, Atmospheric stability, Cloud cover, solar radiation etc.

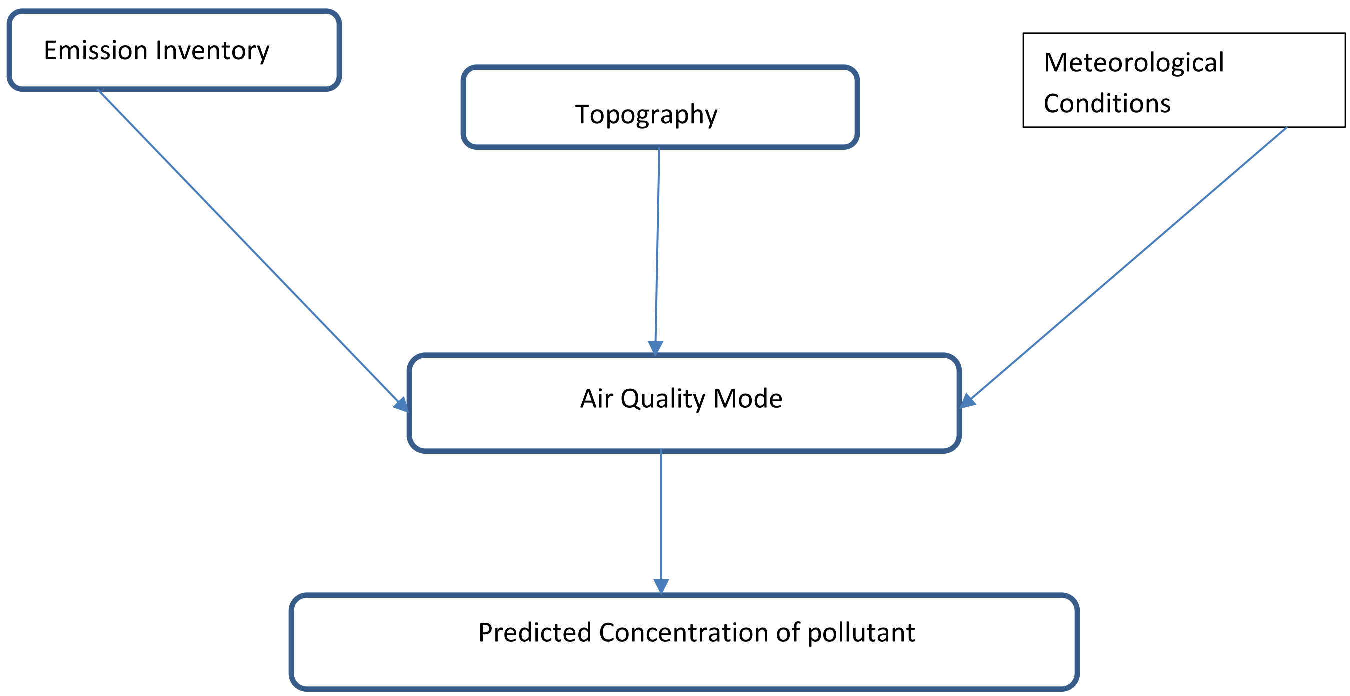


Figure 1: Basic Process of Air Quality Modelling

Air pollution modelling involves four stage approach (Leksmono, 2006):

i. Raw data collection (like emission rate, background concentration, source type, source characteristics etc.)
ii. Assessment of screening model (model for emission rate determination, Meteorological data model etc.)
iii. Running the complex model (prediction of concentration of pollutant)
iv. Analysis/ assessment of model output in order to verify findings.

2.4 Classification

There are several ways of classifying the variety of existing models according to their specific attributes (Sharma, 2004). The most important criteria being:

i. Source – receptor relationship: source – oriented (point, area, line, volume) and receptor – oriented (street canyon, intersection model etc.)
ii. Basic model structure: deterministic or non-deterministic, steady state or time dependent
iii. Frame of reference: Eulerian or Lagrangian
iv. Dimensionality of computational domain: one dimensional, two dimensional, three dimensional or multi dimensional
v. Scale (space and time): microscale (1m, sec-min), mesoscale (5-10 km, hour), small synoptic (100 km, hour-day), large synoptic (100 – 1000 km, days) and planetary (>1000 km, weeks)
vi. Model structure and the approach: used for the closure of the turbulent diffusion equation (closed- form, analytical and numerical, statistical and physical)
vii. The terrain/area: to which they are applicable (rural flat terrain, urban flat terrain, complex terrain, coastal areas)
viii. Level of sophistication: level1 (screening models) and level 2 (refined models)

Whatever may be the classification criteria adopted for classifying the models, the characteristics of the system being studied are:

a. Size (local, regional, national, global)
b. Time horizon (hour, day, month, year)

c. Pollutant of concern (SO_2, NOx, CO, SPM, photochemical oxidant etc.) are equally important.

However, the most important and popular way of classifying air pollution models is based on the model structure and the approach used for the closure of the turbulent diffusion equation which is widely used in urban air pollution modelling also (Sharma et al., 2004). Air pollution model can be classified as:

1. Dispersion Model

2. Statistical Model

3. Physical Model

2.4.1 Dispersion Model

The deterministic mathematical models (DMM) calculate the pollutant concentrations from emission inventory and meteorological variables according to the solutions of various equations that represent the relevant physical processes (Daly and Zannetti, 2007). In other words, differential equation is developed by relating the rate of change of pollutant concentration to average wind and turbulent diffusion which, in turn, is derived from the mass conservation principle. The common Gaussian Model is based on the superposition principle, namely concentration at a receptor, which is the sum of concentrations from all the infinitesimal point sources making up a line/ area source. This mechanism of diffusion from each point source is assumed to be independent of the presence of other point sources. The other assumption considered in DMM is the emission from a point source spreading in the atmosphere in the form of plume, whose concentration profile is generally Gaussian in both horizontal and vertical directions. Deterministic model includes analytical model and numerical model. Both analytical and numerical models are based on mathematical abstraction of fluid dynamics processes (Nagendra and Khare, 2002; Sharma et al., 2004). Example: AERMOD, CALINE 4 etc.

Limitation of deterministic model:

i. Inadequate dispersion parameters
ii. Inadequate treatment of dispersion upwind
iii. Gaussian based plume models perform poorly when wind speeds are less than 1m/s

Gaussian Dispersion Model: Most of the air pollution models are depends on Gaussian Dispersion model. These Gaussian models despite several limitations and assumptions have found favour with the scientific community, as they are very simple and include the solution to the simple Gaussian equation. In addition to their user-friendly nature and simplicity, these models are conceptually appealing as they are consistent with the random nature of the turbulence of the atmosphere. Further the development of Gaussian type dispersion equations/ models has reached a level of sophistication such that they are routinely used as assessment tools by various regulatory agencies (USEPA, 2000).

2.4.2 Statistical Model

In contrast to deterministic modelling, the statistical models calculate concentrations by statistical methods from meteorological and traffic parameters after an appropriate statistical relationship has been obtained empirically from measured concentrations. Regression, multiple regression and time-series technique are some key methods in statistical modelling. The time-series analysis techniques [Box–Jenkins models] have been widely used to describe the dispersion of Vehicular Exhaust Emissions at traffic intersection and at busy roads. Various studies involving statistical techniques have been used to forecast real-time, Short-term as well as long-term pollutant concentrations and for their trend analysis. This has been done by mostly using long-term (some time short also) emission, meteorology and pollution concentration data. This modelling technique has been employed to find concentrations of primary as well as highly complex secondary pollutants like ozone (Nagendra and Khare et al., 2002; Sharma et al., 2004). Example: Artificial Neural Network (ANN) etc.

Limitation of statistical model:

i. Require long historical data sets and lack of physical interpretation
ii. Regression modelling often underperforms when used to model non-linear systems
iii. Time series modelling requires considerable knowledge in time series statistics i.e. autocorrelation function (ACF) and partial auto correlation function (PACF) to identify an appropriate air quality model
iv. Statistical models are site specific

2.4.3 Physical Model

In physical modelling, a real process is simulated on a smaller scale in the laboratory by a physical experiment, which models the important features of the original processes being studied. Typical experimental devices such as wind tunnels or water tunnels are employed, in which the atmospheric flows, for which boundary layer wind tunnels (wind tunnel modelling) are used. This type of physical modelling carried out in the wind tunnel, in which atmospheric flows have been modelled with air as fluid medium, has also been referred to as fluid modelling by various researchers (Nagendra and Khare et al., 2002; Shama et al., 2004).

Limitation of Physical model:

i. Major limitations of wind tunnel studies are construction and operational cost
ii. Simulation of real time air pollution dispersion is expensive
iii. Real time forecast is not possible

2.5 Selection of Model

A model must include the essential physics of the dispersion process and provide reasonable and reproducible estimates of pollutant concentration (Macdonald R et al., 2003). There are numbers of model available out of which selection of one model is difficult. Model which require minimum numbers of input variable, suitable for type of source and produce good result should be selected. With increase in numbers of input, uncertainty of model output increases. Quality of model is judge by model consistency and model accuracy (EEA, 1996). Batterman (2010) evaluate the sensitivity analysis of CALINE 4 and Mobile 6.2 to determine the input variables which influence the model result most. So that uncertainty can be minimized while identifying the input variables. Prodanova (2008) evaluates that Community Multi-Scale Air Quality (CMAQ) model approach is capable to reproduce the concentration of sulphur dioxide over Baulgeria, Stara Zagora. An understanding of fundamental concept of model and their physical process is also necessary before selection of a model. The background knowledge is required to ensure the most sensible choice are made in all aspects of the data input stages, selection of model options and the interpretation of results (Macdonnald R et al., 2003). Easy availability of model should also be kept in mind while selecting a model.

Accuracy of predicted value of a model depends on (EEA, 1996):

- ❖ Input data accuracy and how the latter affects the accuracy of model results.
- ❖ Uncertainties in model assumptions and parameterizations.

- ❖ Methodologies for judging to what extent model results represent reality.

2.6 Application of Model

- ❖ Regulatory Purposes: Model results are used in issuing emission permits but model accuracy has not been specified in majority of countries.
- ❖ Policy Support: support policy by forecasting the effect.
- ❖ Public Information: by air quality forecasting and possible occurrence of smog episodes.
- ❖ Scientific research; Description of dynamic effects and simulation of complex chemical process involving air pollutants.

2.7 Inadequacy of Air Pollution Modelling

The total uncertainty involved in the air pollution modelling simulation can be considered as the sum of three components: (1) the uncertainty due to the errors in the model physics, (2) the uncertainty due to the input data errors (meteorology and emission-related parameters) and (3) the uncertainty due to stochastic processes (e.g. turbulence) in the atmosphere. It may be possible to reduce the first component of model uncertainty by introducing more physically realistic and computationally efficient algorithms (as done in the new generation of air quality models). It may also be possible to eliminate some of the effects of input data errors once more accurate monitoring instruments are set up at representative locations. However, the stochastic fluctuations are natural characteristics of the atmosphere that cannot be eliminated. Thus, the first two types of uncertainties are reducible uncertainties and the third one due to atmospheric processes is intrinsic uncertainty, which cannot be reduced (Sharma et al., 2004). The experience so far has shown that the values of various input parameters to these models are often adopted from other countries without understanding their applicability in Indian context, resulting in inaccurate and unreliable predictions (Sharma, 2001). Majumdar, (2008) reveals that CALINE 4 with correction factors (0.37) can be applied reasonably well for the prediction of CO in the city of Kolkata. However, in order to make more useful, refinements need to be carried out so as to make it more complete tool for prediction. Every model's accuracy for predicting concentration of pollutant depends on the inputs data. Thus, sensitivity of a model is required to identify the most influential input variables. Sahlodina, (2007) used sensitivity analysis of CALINE 4 model to eliminate the less significant input variable.

The Various Gaussian models are routinely used in India for carrying out air pollution predictions generally require various input parameters pertaining to meteorology, traffic, road geometry, land use pattern, besides receptor locations. Besides the basic Gaussian dispersion approach, each dispersion model differs with respect to the treatment of modified wind and turbulence parameters. Adequacies, limitations, reliability and associated uncertainties of these dispersion models have already been discussed by various researchers. Various Gaussian based dispersion models are extensively used in India without properly calibrating them for Indian climatic and traffic conditions. Moreover, various input parameters used in these models are not accurately known leading to incorrect or sometimes even unreliable predictions. Greatest inaccuracy in modelling exercise in India is due to the improper emission factors. Another source of inaccuracy in these models pertain to non-availability of on-site meteorological data. Most often modellers in India rely on nearest Indian Meteorological Department (IMD) data which does not reflect actual field conditions and adds to inaccurate prediction estimates. Thus, there is a need to upgrade and modernize the facilities so that these IMD stations can better serve in understanding and explaining the dispersion phenomena in urban/city conditions (USEPA, 2000).

2.8 Studies on Air Pollution Modelling

Due to significance of modelling, a number of studies have been carried out to examine the reliability of predicted concentrations from these models. Models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations. These models are reasonably reliable in estimating the magnitude of highest concentrations sometimes occurring within the area (e.g. air pollution episodes). The concentration estimates that occur at a specific time and site are poorly correlated with actually observed concentrations and are less reliable. Ferdous and Ali (2005) uses CALINE 4 model for different stability class and identify the most suitable dispersion coefficient by using CALINE 4 and Gaussian equation for predicting concentration of carbon monoxide in Dhaka city, Bangladesh. Bhati (2009) uses AERMOD model for comparing percentage source of particulate matter from industrial and traffic emission for Delhi city. They found that model under predict the concentration of particulate matter as compared to observed values and also evaluate that traffic emission contributed 66.4% of particulate matter to Delhi total particulate matter. Sathe Y. V. (2012) compares line source model STREET and STREET Box model for a street canyon in Kolhapur city, Maharashtra, India for particulate matter and sulphur dioxide. He found that STREET Box model is output is closer to observed value than STREET model.

Sportisse (2007) found that air quality modelling and simulation suffer from many uncertainties, for instance, many input data are poorly known, numerical algorithms; also induce uncertainties etc. Therefore, not relevant to view outputs of Chemical Transport Models as deterministic values. Even if the models are “validated” (model-to-data comparisons should performed, when possible), one must keep in mind that there are a large amount of degrees of freedom and only a small number of model outputs can be measured.

2.9 Research gap to be filled by this work

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

CHAPTER THREE
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}).

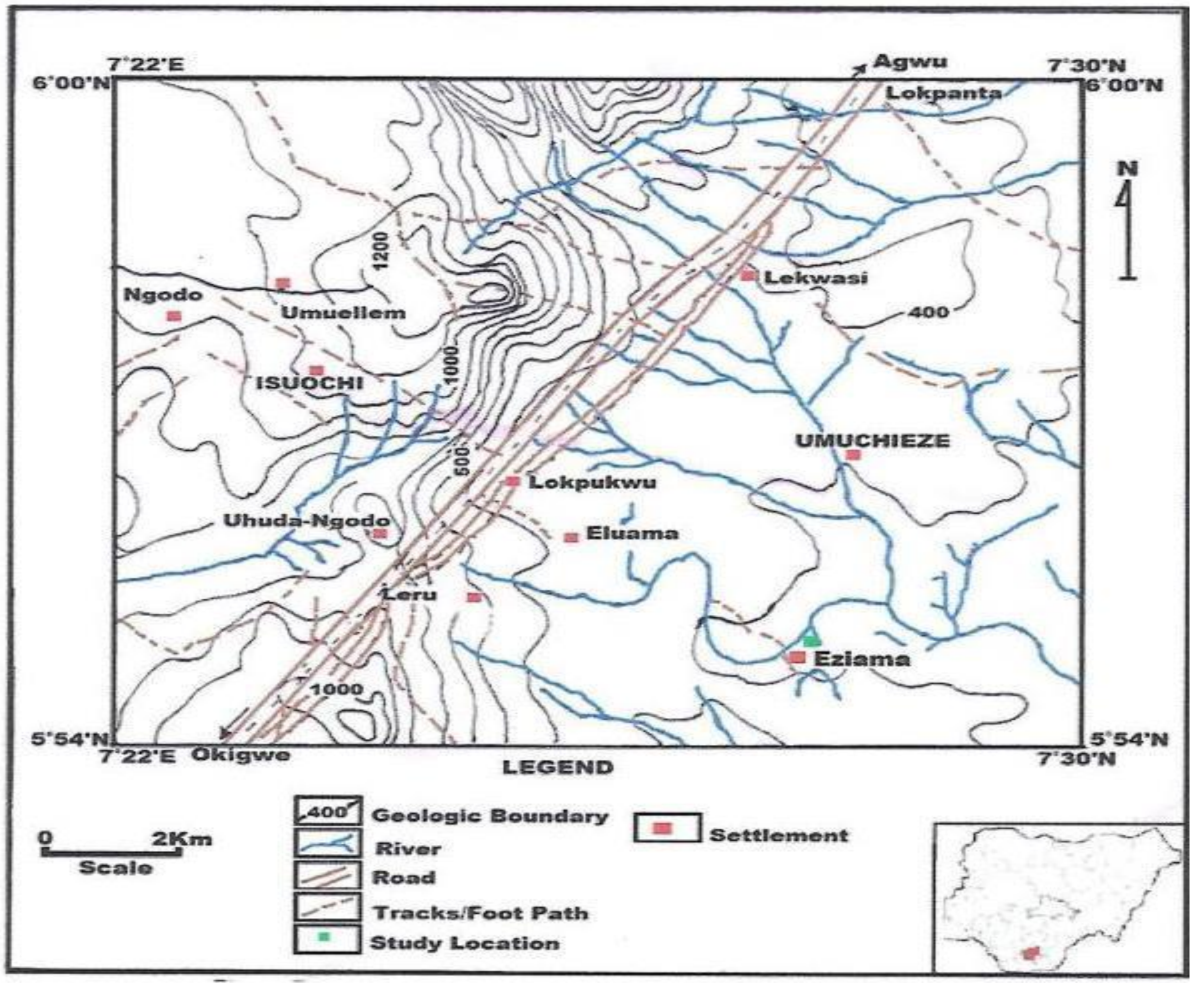


Figure 3.1: Location Map of Eziama quarry site

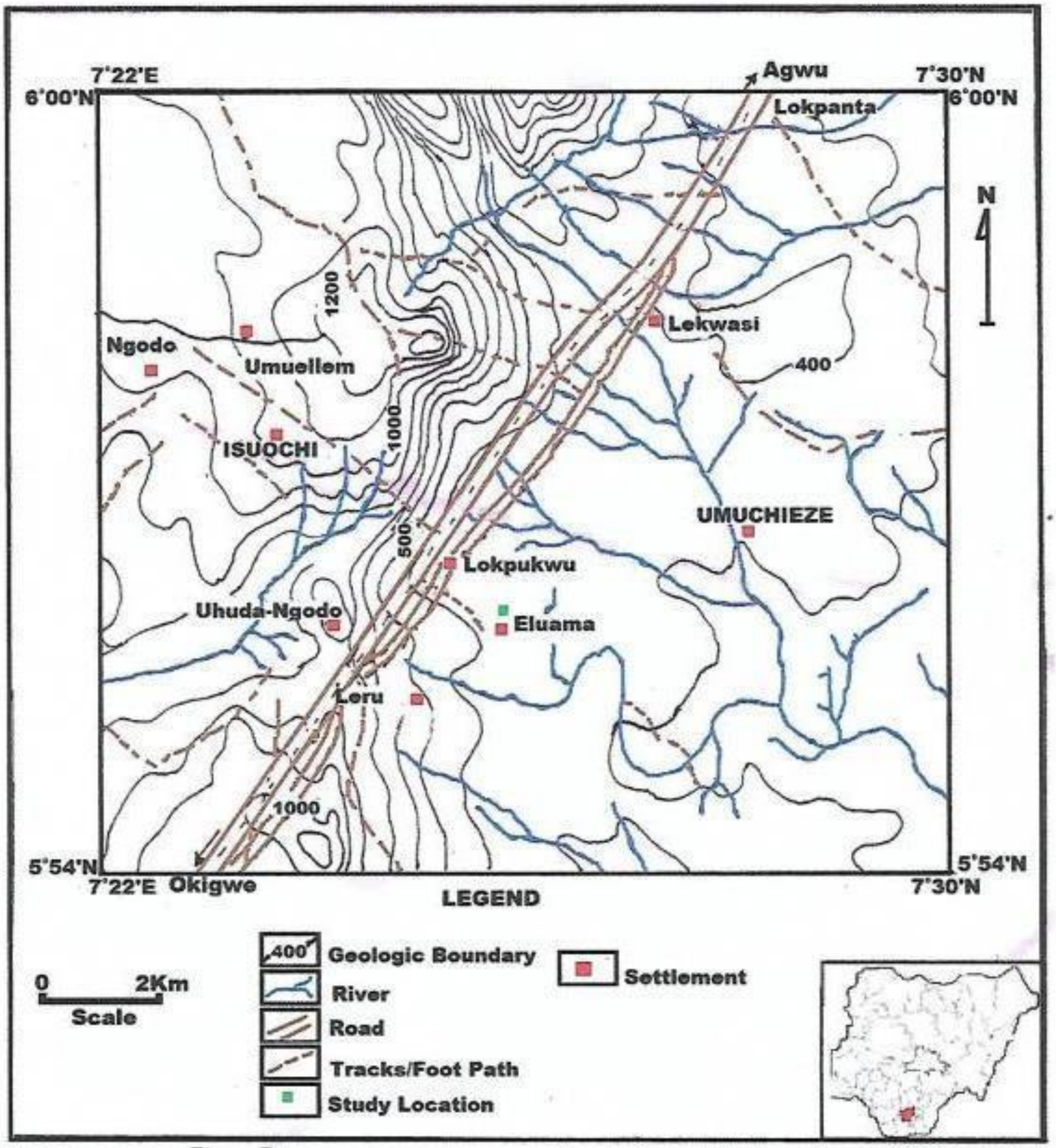


Figure 3.2: Location Map of Eluama quarry site

Plate 3.1: Conveyance of rock particles on conveyor belts at Eluama Quarry Site

Plate 3.2: Conveyance of rock particles on conveyor belts at Eziama Quarry Site

Plate 3.3: Mining pit at Eluama Quarry Site

Plate 3.4: Mining pit at Eziama Quarry Site

Plate 3.5: Routine visit to the Quarry Site for data collection

3.1.3 Parameters of Interest

Particulate Matter (PM) refers to the sum of all solid and liquid particles suspended in air, of which many of them are hazardous. The characteristics of PM rely upon on the source, origin and weather condition of the geographical area. Distinctive sources produce PM with specific characteristics with different emission factor. PM which varies from a few nanometers to tens of micrometer, is a well-known indoor and outdoor air pollutant. PM in ambient air originates from natural sources (wind-born soil and sea spray), anthropogenic sources (combustion of fossil fuels, industry emissions, vehicle and road wear), and atmospheric transformation. Depending on the sources, the size and chemical contents of PM vary largely.

Particles have irregular shapes and their aerodynamic behavior is expressed in terms of the diameter of an idealized sphere. The sampling and description of particles is based on this aerodynamic diameter, which is usually simply referred to as 'particle size'. Particles having the same aerodynamic diameter may have different dimensions and shapes. Some airborne particles are over 10,000 times bigger than others in terms of aerodynamic diameter. Based on size, particulate matter is often divided into two main groups:

- The coarse fraction which contains the larger particles with a size ranging from 2.5 to 10 µm (PM_{10} – $PM_{2.5}$). Coarse particles are produced by mechanical break-up of larger solid particles. The coarse fraction can include dust from roads, agricultural processes, uncovered soil or mining operations, as well as non-combustible materials released when burning fossil fuels.
- The fine fraction contains the smaller ones with a size up to 2.5µm ($PM_{2.5}$). The particles in the fine fraction which are smaller than 0.1µm are called ultrafine particles. Fine particles are largely formed from gases. Ultrafine particles (up to 0.1 µm) are formed by nucleation, which is the initial stage in which gas becomes a particle.

Table 3.1: Elevation and coordinates of sampling locations with respect to the drilling point (Eziama Quarry Site)

Location	Elevation (m)	Latitude &Longitude
Entrance Gate	104.87	E7^{0}26'16.554'' N5^{0}54'56.574''
Primary Crusher	103.66	E7^{0}26'19.830'' N5^{0}54'55.860''
Secondary Crusher	101.2	E7^{0}26'18.912'' N5^{0}54'58.998''

Generator House	105.79	E7^{0}26’19.704’’ N5^{0}54’01.704’’
Weighing Bridge	99.39	E7^{0}26’16.088’’ N5^{0}54’59.088’’

Table 3.2: Elevation and coordinates of sampling locations with respect to the drilling point (Eluama Quarry Site)

Location	**Elevation (m)**	**Latitude& Longitude**
Generator House	97.56	E7^{0}27’15.599’’ N5^{0}55’10.600’’
Weighing Bridge	97.51	E7^{0}27’14.688’’ N5^{0}55’11.544’’
Primary Crusher	103.66	E7^{0}27’17.106’’ N5^{0}55’09.996’’
Secondary Crusher	101.2	E7^{0}27’11.996’’ N5^{0}55’14.924’’
Entrance (Main Gate)	85.94	E7^{0}27’20.786’’ N5^{0}55’16.788’’

3.2 Methods of Analysis

3.2.1 Statistical Analysis

The data obtained were subjected to statistical modeling.

Statistical Modeling is simply the method of implementing statistical analysis to a dataset, where a statistical model is a mathematical representation of observed data. The statistical model can be expressed as combinations of results depending on consolidated data and population understanding that are deployed to foretell information in a generalized form. Therefore, a statistical model could be an equation or a visual portrayal of the information on the basis of thorough research conducted over the years. In other words, for recognizing relationships between two or more variables, statistical model exist.

3.2.2 Regression Analysis

In this work regression analysis was applied in order to establish relationships via mathematical equations, calibrate such equations in the way of assigning values to associated constants, and adopting such equation (s) for forecasting or predicting.

Regression analysis is one of the most commonly used statistical techniques in social and behavioral sciences as well as in physical sciences which involves identifying and evaluating the relationship between a dependent variable and one or more independent variables, which are also called predictor or explanatory variables. It is particularly useful for assessment and adjusting for confounding. Model of the relationship is hypothesized and estimates of the parameter values are used to develop an estimated regression equation. Various tests are then employed to determine if the model is satisfactory. If the model is deemed satisfactory, the estimated regression equation can be used to predict the value of the dependent variable given values for the independent variables.

3.2.3 Objectives of Regression Analysis

Regression analysis are used to explain variability in dependent variable by means of one or more of independent or control variables and to analyze relationships among variables to answer; the question of how much dependent variable changes with changes in each of the independent's variables, and to forecast or predict the value of dependent variable based on the values of the independent's variables. The primary objective of regression is to develop a relationship between a response variable and explanatory variables for the purposes of prediction, assumes that a functional relationship exists, and alternative approaches (functional regression) are superior.

3.2.4 Multiple Regression Models

Multiple regression model which is an extension of simple linear regression, was used to predict the value of a dependent variable (target or criterion variable) based on the values independent variables (predictor or explanatory variables). Multiple regressions allow us to determine the overall fit (variance explained) of the model and the relative contribution of each of the predictors to the total variance explained.

3.2.5 Correlation Analysis

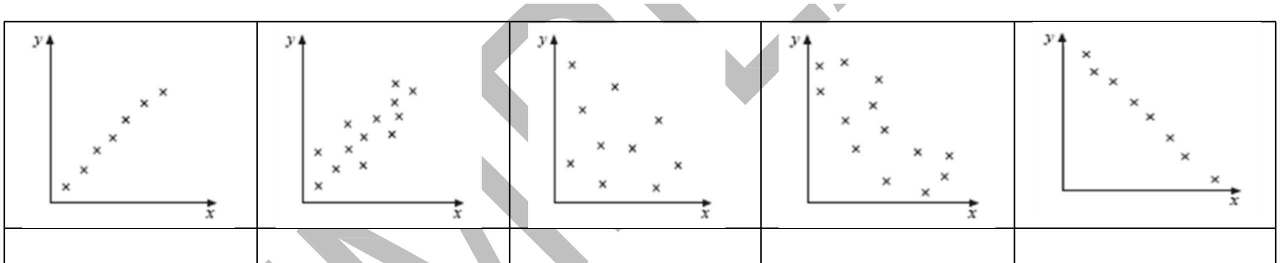
Correlation is a statistical measure that indicates the extent to which two or more variables fluctuate together. A positive correlation indicates the extent to which those variables increase or decrease in parallel; a negative correlation indicates the extent to which one variable increases as the other decreases.

When the fluctuation of one variable reliably predicts a similar fluctuation in another variable, there’s often a tendency to think that means that the change in one causes the change in the other. However, correlation does not imply causation. There may be an unknown factor that influences both variables similarly.

Correlation is a statistical technique that can show whether and how strongly pairs of variables are related. Although this correlation is fairly obvious your data may contain unsuspected correlations. You may also suspect there are correlations, but don't know which are the strongest. An intelligent correlation analysis can lead to a greater understanding of your data.

Correlation is Positive or direct when the values increase together, and

Correlation is Negative when one value decreases as the other increases, and so called inverse or contrary correlation.



a b c d e

If the points plotted were all on a straight line we would have perfect correlation, but it could be positive or negative as shown in the diagrams above,

a. Strong positive correlation between x and y. The points lie close to a straight line with y increasing as x increases.

b. Weak, positive correlation between x and y. The trend shown is that y increases as x increases but the points are not close to a straight line

c. No correlation between x and y; the points are distributed randomly on the graph.

d. Weak, negative correlation between x and y. The trend shown is that y decreases as x increases but the points do not lie close to a straight line

e. Strong, negative correlation. The points lie close to a straight line, with y decreasing as x increases.

Correlation can have a value:

1 is a perfect positive correlation

0 is no correlation (the values don't seem linked at all)

-1 is a perfect negative correlation

The value shows how good the correlation is (not how steep the line is), and if it is positive or negative. Usually, in statistics, there are three types of correlations: Pearson correlation, Kendall rank correlation and Spearman correlation.

3.2.6 Model Calibration

Model Calibration involves estimating the values of various constants and parameters in the model structure. Estimation of the model coefficients and constants was done by solving the model equation for the parameters of interest after supplying observed values of both the dependent and independent variables. The observed values of variables were obtained from field data. Once a satisfactory estimate of the parameters for the model was obtained, the model was checked to assure that they adequately perform the functions for which they are intended.

3.2.7 Comparison of Air Quality Parameters with Well-Known Standards

Generally, air quality in an area should comply with regulatory standards. The Federal Ministry of Environment adopted the WHO standards (Table 3.3) and NESREA standards (A.48) as the national standards for gaseous emissions against which air quality parameters monitored are compared in order to ascertain its "cleanliness"

Table 3.3: Nigerian Ambient Air Quality Standard

Air Pollutants	Emission Limits
Particulates	250 (µg/m^3)
SO_2	0.1 (ppm)
Non-methane Hydrocarbon	160 (µg/m^3)
CO	11-4 (µg/m^3) or 10 (ppm)
NO_X	0.04-0.06 (ppm)
Photochemical Oxidant	0.06 (ppm)

Source: FME 1991

Air Pollutants	Highest Emission
Particulates	120.28 (µg/m^3)
SO_2	0.1 (ppm)
CO	3.0 (ppm)
H_2S	1.0 (ppm)
CH_4	0.1 (ppm)
NH_3	0.1 (ppm)

Source: Field Observation

Table 3.4: Air Quality Classification Based on Total Suspended Particles (TSP) Values

Range of TSP Values (µg/m3)	Class of Air Quality
0 – 75	High Quality
76 – 230	Moderate Quality
231 – 600	Poor Quality

Source: (Jain, et al., 1976)

CHAPTER FOUR

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 Report of Eluama and Eziama Quarry Site

4.1.2 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.

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

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 4.2: Air Quality Data of Eluama Quarry Site (February, 2015)

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	0.01	0.00	0.00	0.10	0.01	3.30	3.00	5.30	28.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	12.70	14.00	36.00	40.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.40	16.00	30.00	32.00
Secondary Crusher	0.10	3.00	0.00	0.10	0.01	20.00	34.00	27.00	34.00
Main Gate	0.10	1.00	0.00	0.10	0.01	24.00	29.00	20.00	35.00
Mean	0.10	1.00	0.00	0.10	0.01	13.88	19.20	23.66	33.80

TPM = 90.54 µg/m^3

Table 4.3: Air Quality Data of Eluama Quarry Site (March, 2015)

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	0.04	0.01	3.00	2.00	50.00	25.00.
Weight Bridge	0.10	0.00	0.00	0.02	0.01	12.00	5.00	30.00	30.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	10.00	9.00	30.00	28.00
Secondary Crusher	0.10	1.00	0.00	0.03	0.01	18.00	30.00	14.00	20.00
Main Gate	0.10	1.00	0.00	0.04	0.01	20.00	33.00	25.00	22.00
Mean	0.10	0.12	0.00	0.02	0.1	12.60	15.80	29.80	25.00

TPM = 83.20 µg/m^3

Table 4.4: Air Quality Data of Eluama Quarry Site (April, 2015)

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	3.00	2.00	60.00	30.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	2.00	5.00	15.00	20.00
Primary Crusher	0.10	0.00	0.00	0.10	0.01	4.00	4.00	20.00	15.00
Secondary Crusher	0.10	0.00	0.00	0.10	0.01	10.00	21.00	10.00	20.00
Main Gate	0.10	0.00	0.00	0.10	0.01	12.00	20.00	20.00	20.00
Mean	0.10	0.00	0.00	0.10	0.01	6.20	6.80	25.00	21.00

TPM = 59.00 µg/m^3

Table 4.5: Air Quality Data of Eluama Quarry Site (May, 2015)

Station	SO_2 ppm	CO ppm	H_2S ppm	CH_4 ppm	NHs ppm	SPM µg/m³	PM10 µg/m³	PM2.5 µg/m³	PM1.0 µg/m³
Generator House	0.10	1.00	0.00	0.10	0.01	2.00	2.00	24.00	13.00
Weight Bridge	0.10	1.00	0.00	0.10	0.01	12.00	10.00	12.00	15.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	4.00	10.00	20.00	17.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	10.00	12.00	18.00	20.00
Main Gate	0.10	1.00	0.00	0.10	0.01	11.00	14.00	20.00	21.00
Mean	0.10	1.00	0.00	0.10	0.01	7.80	9.60	18.80	17.20

TPM = 53.40µg/m³

Table 4.6: Air Quality Data of Eluama Quarry Site (June, 2015)

Station	SO_2 ppm	CO ppm	H_2S ppm	CH_4 ppm	NHs ppm	SPM µg/m³	PM10 µg/m³	PM2.5 µg/m³	PM1.0 µg/m³
Generator House	0.10	1.00	0.00	0.01	0.01	3.00	2.00	25.00	20.00
Weight Bridge	0.10	1.00	0.00	0.01	0.01	10.00	15.00	20.00	26.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	5.00	14.00	15.00	18.00
Secondary Crusher	0.10	1.00	0.00	0.01	0.01	8.00	10.00	10.00	16.00
Main Gate	0.10	1.00	0.00	0.10	0.01	10.00	12.00	20.00	18.00
Mean	0.10	1.00	0.00	0.01	0.01	7.20	10.60	18.00	19.60

TPM = 55.40µg/m

Table 4.7: Air Quality Data of Eluama Quarry Site (July, 2015)

Station	SO_2 ppm	CO ppm	H_2S ppm	CH_4 ppm	NHs ppm	SPM µg/m³	PM10 µg/m³	PM2.5 µg/m³	PM1.0 µg/m³
Generator House	0.10	0.00	0.00	0.10	0.01	3.20	2.00	6.00	30.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	2.00	10.00	20.00	34.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.99	9.00	30.00	30.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	10.00	25.00	20.00	21.00
Main Gate	0.10	1.00	0.00	0.10	0.01	12.00	27.00	24.00	24.00
Mean	0.10	0.12	0.00	0.10	0.01	7.43	14.60	20.00	27.80

TPM = 69.83 µg/m³

Table 4.8: Air Quality Data of Eluama Quarry Site (August, 2015)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM μg/m³**	**PM10 μg/m³**	**PM2.5 μg/m³**	**PM1.0 μg/m³**
Generator House	0.10	0.00	0.00	0.10	0.01	3.30	3.00	4.00	10.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	12.70	14.00	20.00	30.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.40	16.00	30.00	20.00
Secondary Crusher	0.10	3.00	0.00	0.10	0.01	20.00	34.00	20.00	15.00
Main Gate	0.10	1.00	0.00	0.10	0.01	24.00	29.00	10.00	35.00
Mean	0.10	1.00	0.00	0.10	0.01	13.88	19.20	16.80	22.00

TPM = 71.88 μg/m³

Table 4.9: Air Quality Data of Eluama Quarry Site (September, 2015)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM μg/m³**	**PM10 μg/m³**	**PM2.5 μg/m³**	**PM1.0 μg/m³**
Generator House	0.10	0.00	0.00	0.04	0.01	3.00	2.00	20.00	10.00
Weight Bridge	0.10	0.00	0.00	0.02	0.01	12.00	5.00	22.00	21.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	10.00	9.00	20.00	15.00
Secondary Crusher	0.10	1.00	0.00	0.03	0.01	18.00	30.00	14.00	20.00
Main Gate	0.10	1.00	0.00	0.04	0.01	20.00	33.00	25.00	12.00
Mean	0.10	0.60	0.00	0.03	0.01	12.60	15.80	20.20	15.60

TPM = 64.20 μg/m³

Table 4.10: Air Quality Data of Eluama Quarry Site (October, 2015)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM μg/m³**	**PM10 μg/m³**	**PM2.5 μg/m³**	**PM1.0 μg/m³**
Generator House	0.10	0.00	0.00	0.10	0.01	3.20	2.00	6.00	10.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	2.00	8.00	20.00	12.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.00	9.00	24.00	15.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	7.00	21.00	18.00	16.00
Main Gate	0.10	1.00	0.00	0.10	0.01	12.00	27.00	24.00	10.00
Mean	0.10	0.60	0.00	0.10	0.01	6.64	13.40	18.40	12.60

TPM = 51.04 μg/m³

Table 4.11: Air Quality Data of Eluama Quarry Site (November, 2015)

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	3.30	3.00	4.00	10.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	11.00	10.00	15.00	12.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.00	12.00	24.00	10.00
Secondary Crusher	0.10	3.00	0.00	0.10	0.01	20.00	34.00	20.00	11.00
Main Gate	0.10	1.00	0.00	0.10	0.01	20.00	22.00	8.00	25.00
Mean	0.10	1.00	0.00	0.10	0.01	12.60	16.20	13.60	13.60

TPM = 56.00 μg/m^3

Table 4.12: Air Quality Data of Eluama Quarry Site (December, 2015)

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	0.04	0.01	3.00	2.00	15.00	8.00
Weight Bridge	0.10	0.00	0.00	0.02	0.01	8.00	5.00	20.00	18.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	10.00	7.00	15.00	10.00
Secondary Crusher	0.10	1.00	0.00	0.03	0.01	13.00	24.00	14.00	20.00
Main Gate	0.10	1.00	0.00	0.04	0.01	14.00	22.00	20.00	12.00
Mean	0.10	0.60	0.00	0.03	0.01	9.60	12.00	16.80	13.60

TPM = 52.00 μg/m^3

Table 4.13: Air Quality Data of Eluama Quarry Site (January, 2016)

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**
Admin. Block	0.10	0.00	1.00	0.10	0.01	7.00	10.00	18.00	23.00
Weight Bridge	0.10	3.00	0.00	0.10	0.01	5.00	12.00	13.00	38.00
Primary Crusher	0.00	0.00	0.00	0.10	0.01	10.00	8.00	11.00	20.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	4.00	3.00	17.00	21.00
Main Gate	0.10	0.00	0.00	0.10	0.01	1.00	5.00	8.00	24.00
Mean	0.08	0.80	0.20	0.10	0.01	5.40	7.60	13.40	25.20

TPM = 52.60 μg/m^3

Table 4.14: Air Quality Data of Eluama Quarry Site (February, 2016)

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**
Admin. Block	0.10	0.10	1.00	0.10	0.01	8.00	8.00	23.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	16.00	10.00	9.00	9.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	7.00	18.00	28.00	21.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	3.00	4.00	22.00	22.00
Main Gate	0.10	0.10	0.00	0.10	0.01	4.00	2.00	16.00	15.00
Mean	0.08	0.10	0.20	0.10	0.01	7.60	8.40	19.60	17.40

TPM = 53.00 µg/m^3

Table 4.15: Air Quality Data of Eluama Quarry Site (March, 2016)

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**
Admin. Block	0.10	0.10	1.00	0.10	0.01	8.00	8.00	25.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	16.00	12.00	10.00	10.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	6.00	9.00	27.00	23.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	3.00	4.00	23.00	21.00
Main Gate	0.10	0.10	0.00	0.10	0.01	3.00	2.00	17.00	17.00
Mean	0.08	0.10	0.20	0.10	0.01	7.20	7.00	20.40	18.20

TPM = 52.80 µg/m^3

Table 4.16: Air Quality Data of Eluama Quarry Site (April, 2016)

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**
Admin. Block	0.10	0.10	1.00	0.10	0.01	7.00	9.00	24.00	18.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	15.00	13.00	9.00	12.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	7.00	8.00	25.00	25.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	4.00	4.00	24.00	23.00
Main Gate	0.10	0.10	0.00	0.10	0.01	5.00	1.00	19.00	16.00
Mean	0.08	0.10	0.20	0.10	0.01	7.60	7.00	20.20	18.80

TPM = 53.60µg/m^3

Table 4.17: Air Quality Data of Eluama Quarry Site (May, 2016)

Station	SO_2 ppm	CO ppm	H_2S ppm	CH_4 ppm	NHs ppm	SPM µg/m³	PM10 µg/m³	PM2.5 µg/m³	PM1.0 µg/m³
Admin. Block	0.10	0.10	1.00	0.10	0.01	6.00	9.00	20.00	15.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	11.00	10.00	9.00	10.00
Primary Crusher	0.10	0.10	0.00	0.10	0.01	5.00	7.00	20.00	21.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	6.00	5.00	21.00	22.00
Main Gate	0.10	0.10	0.00	0.10	0.01	4.00	2.00	18.00	16.00
Mean	0.10	0.10	0.20	0.10	0.01	6.40	6.60	17.60	16.80

TPM = 47.40µg/m³

Table 4.18: Air Quality Data of Eluama Quarry Site (June, 2016)

Station	SO_2 ppm	CO ppm	H_2S ppm	CH_4 ppm	NHs ppm	SPM µg/m³	PM10 µg/m³	PM2.5 µg/m³	PM1.0 µg/m³
Admin. Block	0.10	0.10	1.00	0.10	0.01	7.00	8.00	22.00	18.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	9.00	12.00	10.00	11.00
Primary Crusher	0.10	0.10	0.00	0.10	0.01	7.00	9.00	22.00	23.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	8.00	8.00	19.00	24.00
Main Gate	0.10	0.10	0.00	0.10	0.01	6.00	3.00	15.00	19.00
Mean	0.10	0.10	0.20	0.10	0.01	7.40	8.00	17.60	19.00

TPM = 52.00µg/m³

Table 4.19: Air Quality Data of Eluama Quarry Site (July, 2016)

Station	SO_2 ppm	CO ppm	H_2S ppm	CH_4 ppm	NHs ppm	SPM µg/m³	PM10 µg/m³	PM2.5 µg/m³	PM1.0 µg/m³
Admin. Block	0.10	0.10	1.00	0.10	0.01	6.00	7.00	20.00	19.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	10.00	13.00	11.00	12.00
Primary Crusher	0.10	0.10	0.00	0.10	0.01	8.00	10.00	21.00	22.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	9.00	9.00	20.00	24.00
Main Gate	0.10	0.10	0.00	0.10	0.01	7.00	4.00	17.00	20.00
Mean	0.10	0.10	0.20	0.10	0.01	8.00	8.60	17.80	19.40

TPM = 53.80µg/m³

Table 4.18: Air Quality Data of Eluama Quarry Site (August, 2016)

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**
Admin. Block	0.10	0.10	1.00	0.10	0.01	5.00	5.00	19.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	9.00	12.00	10.00	14.00
Primary Crusher	0.10	0.10	0.00	0.10	0.01	5.00	14.00	25.00	24.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	8.00	8.00	21.00	23.00
Main Gate	0.10	0.10	0.00	0.10	0.01	7.00	5.00	18.00	19.00
Mean	0.10	0.10	0.20	0.10	0.01	6.80	8.80	18.60	20.00

TPM = 54.20µg/m^3

Table 4.19: Air Quality Data of Eluama Quarry Site (September, 2016)

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**
Admin. Block	0.10	0.10	1.00	0.10	0.01	4.00	5.00	18.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	10.00	10.00	9.00	15.00
Primary Crusher	0.10	0.10	0.00	0.10	0.01	8.00	15.00	24.00	23.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	7.00	7.00	20.00	22.00
Main Gate	0.10	0.10	0.00	0.10	0.01	6.00	6.00	17.00	18.00
Mean	0.10	0.10	0.20	0.10	0.01	7.00	8.60	17.60	19.60

TPM = 52.80µg/m^3

Table 4.20: Air Quality Data of Eluama Quarry Site (October, 2016)

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	8.00	4.00	8.00	8.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	6.00	6.00	18.00	12.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	12.00	8.00	17.00	17.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	12.00	18.00	18.00	18.00
Main Gate	0.10	1.00	0.00	0.10	0.01	14.00	23.00	16.00	10.00
Mean	0.10	0.60	0.00	0.10	0.01	10.40	11.80	15.40	13.00

TPM= 50.60 µg/m^3

Table 4.21: Air Quality Data of Eluama Quarry Site (November, 2016)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Generator House	0.10	0.00	0.00	0.10	0.01	3.00	3.00	6.00	8.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	8.00	10.00	15.00	12.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	10.00	10.00	24.00	10.00
Secondary Crusher	0.10	3.00	0.00	0.10	0.01	16.00	30.00	20.00	12.00
Main Gate	0.10	1.00	0.00	0.10	0.01	18.00	20.00	10.00	22.00
Mean	0.10	1.00	0.00	0.10	0.01	11.00	14.60	15.00	12.80

TPM = 53.40 µg/m³

Table 4.22: Air Quality Data of Eluama Quarry Site (December, 2016)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Generator House	0.10	0.00	0.00	0.04	0.01	2.00	4.00	17.00	7.00
Weight Bridge	0.10	0.00	0.00	0.02	0.01	8.00	6.00	18.00	16.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	10.00	10.00	13.00	11.00
Secondary Crusher	0.10	1.00	0.00	0.03	0.01	13.00	20.00	12.00	22.00
Main Gate	0.10	1.00	0.00	0.04	0.01	14.00	22.00	22.00	10.00
Mean	0.10	0.60	0.00	0.03	0.01	9.40	12.40	16.40	13.20

TPM = 51.40 µg/m³

Table 4.23: Air Quality Data of Eluama Quarry Site (January, 2019)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Generator House	0.10	0.00	0.00	0.10	0.01	2.40	2.10	63.00	31.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	3.00	11.20	32.00	32.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	8.80	8.50	37.00	32.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	23.00	39.00	19.50	23.00
Main Gate	0.10	1.00	0.00	0.10	0.01	23.50	42.00	25.00	24.00
Mean	0.10	0.12	0.00	0.10	0.10	12.14	20.56	35.30	28.4

TPM= 96.40 µg/m³

Table 4.24: Air Quality Data of Eluama Quarry Site (February, 2019)

Station	SO_2 ppm	CO ppm	H_2S ppm	CH_4 ppm	NHs ppm	SPM µg/m³	PM10 µg/m³	PM2.5 µg/m³	PM1.0 µg/m³
Generator House	0.01	0.00	0.00	0.10	0.01	4.10	3.50	5.90	29.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	11.90	15.00	38.00	39.50
Primary Crusher	0.10	1.00	0.00	0.10	0.01	10.20	14.50	27.50	32.00
Secondary Crusher	0.10	3.00	0.00	0.10	0.01	21.00	33.70	27.00	36.00
Main Gate	0.10	1.00	0.00	0.10	0.01	23.50	31.00	21.30	34.12
Mean	0.10	1.00	0.00	0.10	0.01	14.14	19.54	23.94	34.12

TPM = 91.74 µg/m³

Table 4.25: Air Quality Data of Eluama Quarry Site (March, 2019)

Station	SO_2 Ppm	CO ppm	H_2S ppm	CH_4 ppm	NHs ppm	SPM µg/m³	PM10 µg/m³	PM2.5 µg/m³	PM1.0 µg/m³
Generator House	0.10	0.00	0.00	0.04	0.01	3.00	5.00	56.00	25.00.
Weight Bridge	0.10	0.00	0.00	0.02	0.01	11.90	6.00	29.20	32.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	12.00	7.70	31.80	27.30
Secondary Crusher	0.10	1.00	0.00	0.03	0.01	17.80	31.00	12.00	20.70
Main Gate	0.10	1.00	0.00	0.04	0.01	22.00	32.00	24.50	22.00
Mean	0.10	0.12	0.00	0.02	0.1	13.34	16.34	30.70	25.40

TPM = 85.78 µg/m³

Table 4.26: Air Quality Data of Eluama Quarry Site (April, 2019)

Station	SO_2 ppm	CO ppm	H_2S ppm	CH_4 ppm	NHs ppm	SPM µg/m³	PM10 µg/m³	PM2.5 µg/m³	PM1.0 µg/m³
Generator House	0.10	0.00	0.00	0.10	0.01	3.00	2.90	60.00	31.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	5.00	5.00	13.00	20.00
Primary Crusher	0.10	0.00	0.00	0.10	0.01	3.50	6.00	22.00	14.80
Secondary Crusher	0.10	0.00	0.00	0.10	0.01	9.60	20.00	9.00	22.00
Main Gate	0.10	0.00	0.00	0.10	0.01	11.00	22.00	21.90	19.00
Mean	0.10	0.00	0.00	0.10	0.01	6.42	11.18	25.18	21.36

TMP = 64.14 µg/m³

Table 4.27: Air Quality Data of Eluama Quarry Site (May, 2019)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM $\mu g/m^3$**	**PM10 $\mu g/m^3$**	**PM2.5 $\mu g/m^3$**	**PM1.0 $\mu g/m^3$**
Generator House	0.10	1.00	0.00	0.10	0.01	10.00	15.00	25.00	15.00
Weight Bridge	0.10	1.00	0.00	0.10	0.01	11.00	12.00	12.00	14.20
Primary Crusher	0.10	1.00	0.00	0.10	0.01	18.70	20.70	25.00	20.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	12.00	12.00	17.30	19.00
Main Gate	0.10	1.00	0.00	0.10	0.01	11.10	13.50	20.10	20.00
Mean	0.10	1.00	0.00	0.10	0.01	12.56	14.64	19.88	17.64

TPM = 64.72$\mu g/m^3$

Table 4.28: Air Quality Data of Eluama Quarry Site (June, 2019)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM $\mu g/m^3$**	**PM10 $\mu g/m^3$**	**PM2.5 $\mu g/m^3$**	**PM1.0 $\mu g/m^3$**
Generator House	0.10	1.00	0.00	0.01	0.01	3.00	4.00	24.00	21.00
Weight Bridge	0.10	1.00	0.00	0.01	0.01	9.90	14.00	21.00	25.80
Primary Crusher	0.10	1.00	0.00	0.01	0.01	5.80	13.70	15.60	18.00
Secondary Crusher	0.10	1.00	0.00	0.01	0.01	6.00	10.00	9.00	17.00
Main Gate	0.10	1.00	0.00	0.10	0.01	12.00	13.10	20.00	16.90
Mean	0.10	1.00	0.00	0.01	0.01	8.78	10.96	17.92	19.74

TPM = 57.40$\mu g/m^3$

Table 4.29: Air Quality Data of Eluama Quarry Site (July, 2019)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM $\mu g/m^3$**	**PM10 $\mu g/m^3$**	**PM2.5 $\mu g/m^3$**	**PM1.0 $\mu g/m^3$**
Generator House	0.10	0.00	0.00	0.10	0.01	3.20	2.00	5.00	3.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	3.00	12.00	11.30	10.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	8.00	8.00	14.00	13.60
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	10.00	24.00	21.00	22.10
Main Gate	0.10	1.00	0.00	0.10	0.01	12.00	23.10	25.00	23.00
Mean	0.10	0.12	0.00	0.10	0.01	7.24	13.82	15.26	14.34

TPM = 50.66 $\mu g/m^3$

Table 4.30: Air Quality Data of Eluama Quarry Site (August, 2019)

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	4.00	4.00	5.00	8.40
Weight Bridge	0.10	0.00	0.00	0.10	0.01	12.00	13.00	19.00	25.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.00	17.40	24.60	21.00
Secondary Crusher	0.10	3.00	0.00	0.10	0.01	19.00	26.80	21.00	14.50
Main Gate	0.10	1.00	0.00	0.10	0.01	20.00	20.00	11.00	25.50
Mean	0.10	1.00	0.00	0.10	0.01	12.80	16.24	16.12	18.28

TPM = 63.44 µg/m^3

Table 4.31: Air Quality Data of Eluama Quarry Site (September, 2019)

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	0.04	0.01	4.00	4.00	19.00	10.00
Weight Bridge	0.10	0.00	0.00	0.02	0.01	11.20	5.00	21.50	20.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	10.50	8.00	21.00	16.00
Secondary Crusher	0.10	1.00	0.00	0.03	0.01	17.00	30.00	15.00	20.00
Main Gate	0.10	1.00	0.00	0.04	0.01	20.00	32.00	25.50	14.00
Mean	0.10	0.60	0.00	0.03	0.01	12.54	15.80	20.40	16.00

TPM = 64.74 µg/m^3

Table 4.32: Air Quality Data of Eluama Quarry Site (October, 2019)

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	4.00	3.10	5.00	9.80
Weight Bridge	0.10	0.00	0.00	0.10	0.01	3.00	8.00	20.00	13.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.00	10.00	24.00	15.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	7.00	22.00	19.10	15.00
Main Gate	0.10	1.00	0.00	0.10	0.01	11.00	26.00	24.00	11.00
Mean	0.10	0.60	0.00	0.10	0.01	6.80	13.82	18.42	12.76

TPM = 51.80 µg/m^3

Table 4.33: Air Quality Data of Eluama Quarry Site (November, 2019)

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	3.50	2.00	4.00	10.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	12.00	11.00	16.00	11.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.80	13.40	23.50	10.80
Secondary Crusher	0.10	3.00	0.00	0.10	0.01	21.00	34.20	22.00	12.06
Main Gate	0.10	1.00	0.00	0.10	0.01	20.00	22.00	6.90	26.00
Mean	0.10	1.00	0.00	0.10	0.01	13.26	16.52	14.48	14.00

TPM = 58.26 µg/m^3

Table 4.34: Air Quality Data of Eluama Quarry Site (December, 2019)

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	0.04	0.01	4.00	2.90	15.20	8.00
Weight Bridge	0.10	0.00	0.00	0.02	0.01	7.90	5.00	20.00	20.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	10.00	8.70	16.00	10.00
Secondary Crusher	0.10	1.00	0.00	0.03	0.01	14.00	25.00	13.00	21.00
Main Gate	0.10	1.00	0.00	0.04	0.01	14.40	22.00	21.00	12.20
Mean	0.10	0.60	0.00	0.03	0.01	10.06	12.72	17.04	14.24

TPM = 52.00 µg/m^3

4.1.3 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.

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

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs $\mu g/m^3$**	**SPM $\mu g/m^3$**	**PM10 $\mu g/m^3$**	**PM2.5 $\mu g/m^3$**	**PM1.0 $\mu g/m^3$**
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 $\mu g/m^3$

Table 4.36: Air Quality Data of Eziama Quarry Site (February, 2015)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM $\mu g/m^3$**	**PM10 $\mu g/m^3$**	**PM2.5 $\mu g/m^3$**	**PM1.0 $\mu g/m^3$**
Admin. Block	0.10	0.10	1.00	0.10	0.01	10.00	10.00	24.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	16.00	12.00	12.00	32.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	10.00	10.00	30.00	24.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	3.00	4.00	24.00	26.00
Main Gate	0.10	0.10	0.00	0.10	0.01	3.00	2.00	18.00	16.00
Mean	0.08	0.10	0.20	0.10	0.01	8.40	7.60	21.20	23.60

TPM = 60.80 $\mu g/m^3$

Table 4.37: Air Quality Data of Eziama Quarry Site (March, 2015)

Station	**SO_2 (ppm)**	**CO (ppm)**	**H_2S (ppm)**	**CH_4 (ppm)**	**NHs (ppm)**	**SPM $\mu g/m^3$**	**PM10 $\mu g/m^3$**	**PM2.5 $\mu g/m^3$**	**PM1.0 $\mu g/m^3$**
Admin. Block	0.07	1.00	0.00	0.10	0.01	24.00	32.00	20.00	14.00
Weight Bridge	0.08	1.00	0.00	0.10	0.01	22.00	16.00	22.00	30.00
Primary Crusher	0.04	1.00	0.00	0.10	0.01	10.30	15.00	34.00	31.00
Secondary Crusher	0.05	1.00	0.00	0.10	0.01	20.00	33.00	21.00	42.00
Main Gate	0.09	1.00	0.00	0.10	0.01	4.00	18.00	30.00	21.00
Mean	0.07	1.00	0.00	0.10	0.01	16.60	22.80	25.40	27.60

TPM = 92.40 $\mu g/m^3$

Table 4.38: Air Quality Data of Eziama Quarry Site (April, 2015)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin. Block	0.10	0.00	0.00	0.10	0.01	6.00	10.00	16.00	32.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	7.20	13.00	13.00	44.00
Primary Crusher	0.10	0.00	0.00	0.10	0.01	12.0	11.00	14.00	22.00
Secondary Crusher	0.10	0.00	0.00	0.10	0.01	4.00	4.00	19.00	22.00
Main Gate	0.10	0.00	0.00	0.10	0.01	2.00	2.00	8.00	27.00
Mean	0.10	0.00	0.00	0.10	0.01	6.20	8.00	14.00	29.40

TPM = 57.60 µg/m³

Table 4.39: Air Quality Data of Eziama Quarry Site (May, 2015)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin. Block	0.10	0.10	0.00	0.10	0.01	7.00	9.00	23.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	16.00	12.00	12.00	30.00
Primary Crusher	0.10	0.10	0.00	0.10	0.01	8.00	10.00	28.00	23.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	3.00	4.00	24.00	26.00
Main Gate	0.10	0.10	0.00	0.10	0.01	3.00	2.00	20.00	16.00
Mean	0.10	0.10	0.00	0.10	0.01	7.40	7.40	16.60	23.00

TPM = 54.40 µg/m³

Table 4.40: Air Quality Data of Eziama Quarry Site (June, 2015)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin. Block	0.07	1.00	0.00	0.10	0.01	20.00	12.00	20.00	14.00
Weight Bridge	0.08	1.00	0.00	0.10	0.01	20.00	16.00	20.00	15.00
Primary Crusher	0.04	1.00	0.00	0.10	0.01	10.00	15.00	30.00	20.00
Secondary Crusher	0.05	1.00	0.00	0.10	0.01	10.00	13.00	21.00	22.00
Main Gate	0.09	1.00	0.00	0.10	0.01	2.00	14.00	25.00	11.00
Mean	0.07	1.00	0.00	0.10	0.01	12.40	14.00	23.20	16.00

TPM = 65.60 µg/m³

Table 4.41: Air Quality Data of Eziama Quarry Site (July, 2015)

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	6.00	30.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	2.00	10.00	20.00	34.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.99	9.00	30.00	30.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	10.00	25.00	20.00	21.00
Main Gate	0.10	1.00	0.00	0.10	0.01	12.00	27.00	24.00	24.00
Mean	0.10	0.60	0.00	0.10	0.01	7.43	14.60	15.20	27.80

TPM = 65.03 µg/m^3

Table 4.42: Air Quality Data of Eziama Quarry Site (August, 2015)

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	3.30	3.00	4.00	10.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	12.70	14.00	20.00	30.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.40	16.00	30.00	20.00
Secondary Crusher	0.10	3.00	0.00	0.10	0.01	20.00	34.00	20.00	15.00
Main Gate	0.10	1.00	0.00	0.10	0.01	24.00	29.00	10.00	35.00
Mean	0.10	1.00	0.00	0.10	0.01	13.88	19.20	16.80	15.00

TPM = 64.88 µg/m^3

Table 4.43: Air Quality Data of Eziama Quarry Site (September, 2015)

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	0.04	0.01	3.00	2.00	20.00	10.00
Weight Bridge	0.10	0.00	0.00	0.02	0.01	12.00	5.00	22.00	21.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	10.00	9.00	20.00	15.00
Secondary Crusher	0.10	1.00	0.00	0.03	0.01	18.00	30.00	14.00	20.00
Main Gate	0.10	1.00	0.00	0.04	0.01	2.00	33.00	25.00	12.00
Mean	0.10	1.00	0.00	0.02	0.01	12.60	15.80	20.20	15.60

TPM = 64.20 µg/m^3

Table 4.44: Air Quality Data of Eziama Quarry Site (October, 2015**)**

Station	SO_2 ppm	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
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	12.00	13.00	13.00	20.00
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	0.00	3.00	7.00	27.00
Mean	0.10	0.80	0.00	0.10	0.01	5.94	8.40	14.00	29.40

TPM = 58.14 µg/m³

Table 4.45: Air Quality Data of Eziama Quarry Site (November, 2015)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1. 0 µg/m³**
Admin Block	0.10	0.10	1.00	0.10	0.01	10.00	9.00	24.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	16.00	12.00	11.00	10.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	8.00	10.00	28.00	23.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	3.00	4.00	23.00	22.00
Main Gate	0.10	0.10	0.00	0.10	0.01	3.00	2.00	18.00	16.00
Mean	0.08	0.10	0.20	0.10	0.01	7.00	7.60	20.80	18.20

TPM = 54.40 µg/m³

Table 4.46: Air Quality Data of Eziama Quarry Site (December, 2015)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin Block	0.07	1.00	0.00	0.10	0.01	24.00	12.00	20.00	6.00
Weight Bridge	0.08	1.00	0.00	0.10	0.01	10.00	16.00	13.00	12.00
Primary Crusher	0.04	1.00	0.00	0.10	0.01	10.00	8.00	12.00	11.00
Secondary Crusher	0.05	1.00	0.00	0.10	0.01	12.00	33.00	21.00	15.00
Main Gate	0.09	1.00	0.00	0.10	0.01	4.00	10.00	15.00	10.00
Mean	0.07	1.00	0.00	0.10	0.01	12.00	15.80	16.20	10.80

TPM = 54.80 µg/m³

Table 4.47: Air Quality Data of Eziama Quarry Site (January, 2016)

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**
Admin Block	0.10	0.00	1.00	0.10	0.01	7.50	10.00	18.00	24.00
Weight Bridge	0.10	3.00	0.00	0.10	0.01	6.20	13.00	14.00	40.00
Primary Crusher	0.00	0.00	0.00	0.10	0.01	11.00	11.00	12.00	20.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	5.00	3.00	18.00	22.00
Main Gate	0.10	0.00	0.00	0.10	0.01	0.00	5.00	8.00	25.00
Mean	0.08	0.80	0.20	0.10	0.01	5.94	8.40	14.00	26.20

TPM = 54.54 µg/m^3

Table 4.48: Air Quality Data of Eziama Quarry Site (February, 2016)

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**
Admin Block	0.10	0.10	1.00	0.10	0.01	9.00	8.00	24.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	16.00	11.00	10.00	9.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	8.00	19.00	27.00	22.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	3.00	4.00	23.00	22.00
Main Gate	0.10	0.10	0.00	0.10	0.01	3.00	2.00	17.00	15.00
Mean	0.08	0.10	0.20	0.10	0.01	7.80	8.80	20.20	17.60

TPM = 54.40 µg/m^3

Table 4.49: Air Quality Data of Eziama Quarry Site (March, 2016)

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**
Admin Block	0.10	0.10	1.00	0.10	0.01	9.00	8.00	25.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	16.00	12.00	10.00	10.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	7.00	9.00	27.00	23.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	3.00	4.00	23.00	21.00
Main Gate	0.10	0.10	0.00	0.10	0.01	3.00	2.00	17.00	17.00
Mean	0.08	0.10	0.20	0.10	0.01	7.60	7.00	20.40	18.20

TPM = 53.20µg/m^3

Table 4.50: Air Quality Data of Eziama Quarry Site (April, 2016)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin Block	0.10	0.10	1.00	0.10	0.01	8.00	7.00	24.00	19.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	15.00	10.00	11.00	11.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	8.00	10.00	27.00	22.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	2.00	4.00	22.00	20.00
Main Gate	0.10	0.10	0.00	0.10	0.01	4.00	3.00	16.00	17.00
Mean	0.08	0.10	0.20	0.10	0.01	7.40	6.80	20.00	17.80

TPM = 52.00 µg/m³

Table 4.51: Air Quality Data of Eziama Quarry Site (May, 2016)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm)**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 (µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin Block	0.10	0.10	1.00	0.10	0.01	8.00	8.00	24.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	15.00	9.00	11.00	12.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	9.00	10.00	26.00	24.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	4.00	3.00	20.00	20.00
Main Gate	0.10	0.10	0.00	0.10	0.01	4.00	4.00	17.00	17.00
Mean	0.08	0.10	0.20	0.10	0.01	8.00	6.80	19.60	18.60

TPM = 53.00µg/m³

Table 4.52: Air Quality Data of Eziama Quarry Site (June, 2016)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin Block	0.10	0.10	1.00	0.10	0.01	7.00	8.00	23.00	21.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	14.00	10.00	9.00	10.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	8.00	11.00	25.00	23.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	4.00	4.00	19.00	20.00
Main Gate	0.10	0.10	0.00	0.10	0.01	4.00	5.00	18.00	17.00
Mean	0.08	0.10	0.20	0.10	0.01	7.40	7.60	18.80	18.20

TPM = 52.00µg/m³

Table 4.53: Air Quality Data of Eziama Quarry Site (July, 2016)

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**
Admin Block	0.10	0.10	1.00	0.10	0.01	6.00	7.00	22.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	13.00	11.00	10.00	10.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	8.00	10.00	23.00	20.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	5.00	4.00	20.00	21.00
Main Gate	0.10	0.10	0.00	0.10	0.01	4.00	5.00	17.00	18.00
Mean	0.08	0.10	0.20	0.10	0.01	7.20	7.40	18.40	17.80

TPM = 50.80µg/m^3

Table 4.54: Air Quality Data of Eziama Quarry Site (August, 2016)

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**
Admin Block	0.10	0.10	1.00	0.10	0.01	7.00	8.00	20.00	21.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	14.00	12.00	8.00	11.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	9.00	14.00	25.00	21.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	6.00	5.00	18.00	19.00
Main Gate	0.10	0.10	0.00	0.10	0.01	5.00	6.00	18.00	18.00
Mean	0.08	0.10	0.20	0.10	0.01	8.00	9.00	17.80	18.00

TPM = 52.80µg/m^3

Table 4.55: Air Quality Data of Eziama Quarry Site (September, 2016)

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**
Admin Block	0.10	0.10	1.00	0.10	0.01	5.00	7.00	22.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	12.00	10.00	8.00	10.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	8.00	13.00	24.00	20.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	5.00	5.00	17.00	20.00
Main Gate	0.10	0.10	0.00	0.10	0.01	6.00	7.00	19.00	20.00
Mean	0.08	0.10	0.20	0.10	0.01	8.00	9.00	17.80	18.00

TPM = 51.60µg/m^3

Table 4.56: Air Quality Data of Eziama Quarry Site (October, 2016)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin Block	0.10	0.00	0.50	0.00	0.00	8.00	4.00	8.00	8.00
Weight Bridge	0.10	3.00	0.00	00.0	0.00	6.00	6.00	18.00	10.00
Primary Crusher	0.00	0.00	0.00	0.00	0.00	2.00	8.00	17.00	17.00
Secondary Crusher	0.10	1.00	0.00	0.00	0.00	12.00	18.00	18.00	18.00
Main Gate	0.10	0.00	0.00	0.00	0.00	14.00	23.00	16.00	10.00
Mean	0.08	0.80	0.10	0.00	0.00	8.40	11.80	15.40	12.60

TPM = 48.20µg/m³

Table 4.57: Air Quality Data of Eziama Quarry Site (November, 2016)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin Block	0.10	0.05	1.00	0.00	0.01	7.00	4.00	7.00	9.00
Weight Bridge	0.10	0.05	0.00	0.00	0.01	6.00	5.00	18.00	8.00
Primary Crusher	0.00	0.05	0.00	0.00	0.01	3.00	9.00	16.00	17.00
Secondary Crusher	0.10	0.05	0.00	0.00	0.01	11.00	16.00	19.00	19.00
Main Gate	0.10	0.05	0.00	0.00	0.01	13.00	22.00	16.00	10.00
Mean	0.08	0.05	0.20	0.00	0.01	8.00	11.20	15.20	12.60

TPM = 47.00 µg/m³

Table 4.58: Air Quality Data of Eziama Quarry Site (December, 2016**)**

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin Block	0.07	0.05	0.00	0.00	0.00	6.00	3.00	9.00	8.00
Weight Bridge	0.08	0.05	0.00	0.00	0.00	8.00	4.00	16.00	8.00
Primary Crusher	0.04	0.05	0.00	0.00	0.00	4.00	9.00	15.00	16.00
Secondary Crusher	0.05	0.05	0.00	0.00	0.00	13.00	15.00	20.00	18.00
Main Gate	0.09	0.05	0.00	0.00	0.00	14.00	21.00	14.00	11.00
Mean	0.07	0.05	0.00	0.00	0.00	9.00	10.40	14.80	12.20

TPM = 46.40µg/m

Table 4.59: Air Quality Data of Eziama Quarry Site (January, 2019)

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	8.50	9.00	15.50	31.80
Weight Bridge	0.10	3.00	0.00	0.10	0.01	7.00	12.00	14.00	45.30
Primary Crusher	0.00	0.00	0.00	0.10	0.01	14.00	12.50	13.00	21.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	3.00	3.00	20.50	24.00
Main Gate	0.10	0.00	0.00	0.10	0.01	2.40	3.00	9.00	29.00
Mean	0.10	0.80	0.20	0.10	0.01	6.50	9.5	14.40	30.22

TPM = 60.62 µg/m^3

Table 4.60: Air Quality Data of Eziama Quarry Site (February, 2019)

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**
Admin. Block	0.10	0.10	1.00	0.10	0.01	10.00	7.00	23.50	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	16.00	12.50	12.00	32.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	10.00	10.00	29.70	25.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	3.00	4.00	25.00	25.80
Main Gate	0.10	0.10	0.00	0.10	0.01	3.00	3.00	18.00	17.00
Mean	0.08	0.10	0.20	0.10	0.01	8.40	7.30	21.64	23.96

TPM = 61.30 µg/m^3

Table 4.61: Air Quality Data of Eziama Quarry Site (March, 2019)

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**
Admin. Block	0.07	1.00	0.00	0.10	0.01	23.00	32.00	20.10	15.00
Weight Bridge	0.08	1.00	0.00	0.10	0.01	23.00	16.00	22.00	30.00
Primary Crusher	0.04	1.00	0.00	0.10	0.01	9.50	16.00	33.00	31.50
Secondary Crusher	0.05	1.00	0.00	0.10	0.01	20.00	33.50	21.80	41.00
Main Gate	0.09	1.00	0.00	0.10	0.01	4.30	17.00	30.90	21.70
Mean	0.07	1.00	0.00	0.10	0.01	15.96	22.90	25.56	27.84

TPM = 92.26 µg/m^3

Table 4.62: Air Quality Data of Eziama Quarry Site (April, 2019)

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**
Admin. Block	0.10	0.00	0.00	0.10	0.01	6.00	10.00	16.00	30.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	8.60	13.50	13.00	45.00
Primary Crusher	0.10	0.00	0.00	0.10	0.01	13.0	10.00	14.00	21.00
Secondary Crusher	0.10	0.00	0.00	0.10	0.01	4.00	4.00	18.00	22.00
Main Gate	0.10	0.00	0.00	0.10	0.01	3.00	2.50	7.70	28.10
Mean	0.10	0.00	0.00	0.10	0.01	6.92	8.00	13.74	29.22

TPM = 57.88 μg/m^3

Table 4.63: Air Quality Data of Eziama Quarry Site (May, 2019)

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**
Admin. Block	0.10	0.10	0.00	0.10	0.01	7.00	10.00	24.00	21.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	17.80	12.50	12.90	30.90
Primary Crusher	0.10	0.10	0.00	0.10	0.01	8.00	10.00	28.80	24.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	4.00	4.00	24.40	25.90
Main Gate	0.10	0.10	0.00	0.10	0.01	2.50	2.00	20.00	16.00
Mean	0.10	0.10	0.00	0.10	0.01	7.86	7.70	22.02	23.56

TPM = 61.14μg/m^3

Table 4.64: Air Quality Data of Eziama Quarry Site (June, 2019)

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**
Admin. Block	0.07	1.00	0.00	0.10	0.01	19.90	13.00	14.00	15.00
Weight Bridge	0.08	1.00	0.00	0.10	0.01	19.00	16.00	16.50	10.00
Primary Crusher	0.04	1.00	0.00	0.10	0.01	10.00	14.00	16.00	18.90
Secondary Crusher	0.05	1.00	0.00	0.10	0.01	11.00	13.00	18.40	15.00
Main Gate	0.09	1.00	0.00	0.10	0.01	2.90	14.50	18.00	11.90
Mean	0.07	1.00	0.00	0.10	0.01	12.56	14.10	16.58	14.16

TPM = 57.40 μg/m^3

Table 4.65: Air Quality Data of Eziama Quarry Site (July, 2019)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM $\mu g/m^3$**	**PM10 $\mu g/m^3$**	**PM2.5 $\mu g/m^3$**	**PM1.0 $\mu g/m^3$**
Generator House	0.10	0.00	0.00	0.10	0.01	3.20	2.00	5.00	5.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	2.60	11.00	21.00	24.50
Primary Crusher	0.10	1.00	0.00	0.10	0.01	8.19	9.00	15.00	25.00
Secondary Crusher	0.10	1.00	0.00	0.10	0.01	10.00	20.00	20.00	21.00
Main Gate	0.10	1.00	0.00	0.10	0.01	12.60	20.0	20.00	23.00
Mean	0.10	0.60	0.00	0.10	0.01	7.32	14.30	16.2	19.7

TPM = 57.52 $\mu g/m^3$

Table 4.66: Air Quality Data of Eziama Quarry Site (August, 2019)

Station	**SO_2 ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM $\mu g/m^3$**	**PM10 $\mu g/m^3$**	**PM2.5 $\mu g/m^3$**	**PM1.0 $\mu g/m^3$**
Generator House	0.10	0.00	0.00	0.10	0.01	3.00	3.00	4.00	5.00
Weight Bridge	0.10	0.00	0.00	0.10	0.01	12.00	14.00	17.00	20.00
Primary Crusher	0.10	1.00	0.00	0.10	0.01	9.40	16.00	21.00	17.00
Secondary Crusher	0.10	3.00	0.00	0.10	0.01	20.00	32.00	15.00	12.00
Main Gate	0.10	1.00	0.00	0.10	0.01	22.00	27.00	10.00	15.70
Mean	0.10	1.00	0.00	0.10	0.01	13.28	18.40	13.40	13.94

TPM = 59.02 $\mu g/m^3$

Table 4.67: Air Quality Data of Eziama Quarry Site (September, 2019)

Station	SO_2 **ppm**	**CO ppm**	**H_2S ppm**	**CH_4 ppm**	**NHs ppm**	**SPM $\mu g/m^3$**	**PM10 $\mu g/m^3$**	**PM2.5 $\mu g/m^3$**	**PM1.0 $\mu g/m^3$**
Generator House	0.10	0.00	0.00	0.04	0.01	5.00	3.00	20.00	10.00
Weight Bridge	0.10	0.00	0.00	0.02	0.01	13.50	5.00	22.00	20.00
Primary Crusher	0.10	1.00	0.00	0.01	0.01	13.00	10.00	20.00	16.70
Secondary Crusher	0.10	1.00	0.00	0.03	0.01	18.00	30.00	14.00	20.00
Main Gate	0.10	1.00	0.00	0.04	0.01	10.00	32.00	25.20	12.00
Mean	0.10	1.00	0.00	0.02	0.01	11.90	16.00	20.24	15.70

TPM = 63.88 $\mu g/m^3$

Table 4.68: Air Quality Data of Eziama Quarry Site (October, 2019**)**

Station	SO_2 **ppm**	**CO ppm**	H_2S **ppm**	CH_4 **ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
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	12.00	13.00	13.00	20.00
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	15.00	16.70	15.90	27.00
Mean	0.10	0.80	0.00	0.10	0.01	8.94	11.14	15.78	29.40

TPM = 65.26 µg/m³

Table 4.69: Air Quality Data of Eziama Quarry Site (November, 2019)

Station	SO_2 **ppm**	**CO ppm**	H_2S **ppm**	CH_4 **ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1. 0 µg/m³**
Admin Block	0.10	0.10	1.00	0.10	0.01	10.00	9.00	24.00	20.00
Weight Bridge	0.10	0.10	0.00	0.10	0.01	16.00	12.00	11.00	10.00
Primary Crusher	0.00	0.10	0.00	0.10	0.01	8.00	10.00	27.70	24.00
Secondary Crusher	0.10	0.10	0.00	0.10	0.01	10.00	15.00	23.00	22.00
Main Gate	0.10	0.10	0.00	0.10	0.01	18.00	18.90	18.00	16.00
Mean	0.08	0.10	0.20	0.10	0.01	12.40	12.98	20.74	18.40

TPM = 64.52 µg/m³

Table 4.70: Air Quality Data of Eziama Quarry Site (December, 2019)

Station	SO_2 **ppm**	**CO ppm**	H_2S **ppm**	CH_4 **ppm**	**NHs ppm**	**SPM µg/m³**	**PM10 µg/m³**	**PM2.5 µg/m³**	**PM1.0 µg/m³**
Admin Block	0.07	1.00	0.00	0.10	0.01	23.80	12.00	20.00	15.80
Weight Bridge	0.08	1.00	0.00	0.10	0.01	10.00	16.00	13.00	14.80
Primary Crusher	0.04	1.00	0.00	0.10	0.01	17.00	15.00	19.30	18.80
Secondary Crusher	0.05	1.00	0.00	0.10	0.01	12.00	35.00	21.00	15.30
Main Gate	0.09	1.00	0.00	0.10	0.01	22.00	18.00	15.00	26.00
Mean	0.07	1.00	0.00	0.10	0.01	16.96	19.20	17.66	18.14

TPM = 71.96 µg/m³

4.1.4 MODEL DERIVATION

The multiple linear regression equation is as follows:

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

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;

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

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

$\alpha = PM_{10}$ Coarse or Respirable Particulate (**μg/m³**)

$\beta = PM_{2.5}$ Fine or Inhalable Particulate (**μg/m³**)

$\emptyset = PM_{1.0}$ Fine or Inhalable Particulate (**μg/m³**)

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)

$$\boldsymbol{R} = \frac{\sum_{i=1}^{n}\left(C_i^0 - C_i^{-0}\right)\left(C^{-p}\right)}{\sqrt{\sum_{i=1}^{n}\left(C_i^0 - C_i^{-0}\right)^2}\sqrt{\sum_{i=1}^{n}\left(C_i^0 - C_i^{-p}\right)^2}} \qquad 4.3$$

For Mean Absolute Percentage Error (MAPE);

$$\boldsymbol{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left[\frac{C_i^p - C_i^0}{C_i^0}\right] * 100 \qquad 4.4$$

For Root Mean Square Error (RMSE);

$$\boldsymbol{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}\left(C_i^0 - C_i^p\right)^2}{n}} \qquad 4.5$$

$Where, \quad n = number\ of\ data\ points,$

C_i^0 and C_i^p $are\ observed\ and\ predicted\ concentration\ of\ pollutants$

$while$ C_i^{-0} and C_i^{-p} $are\ their\ mean\ values\ respectively$

4.1.5 Model Calibration

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

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

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

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

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

Table 4.71: Model Calibration Using Eluama 2016 Dataset

Months	$\boldsymbol{x}\ (\boldsymbol{ug/m^3})$	$\alpha\ (\boldsymbol{ug/m^3})$	$\boldsymbol{\beta}\ (\boldsymbol{ug/m^3})$	$\emptyset\ (\boldsymbol{ug/m^3})$	$\complement\ (\boldsymbol{ug/m^3})$
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

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

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

$\sum \complement x = 3135.26 \qquad \sum \alpha^2 = 1065.4$

$\sum \alpha = 109.4 \qquad \sum \complement\alpha = 4354.65 \qquad n = 12$

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

$\sum \complement\beta = 8209.01 \qquad \sum \emptyset^2 = 3933.32$

$\sum \emptyset = 213.4 \qquad \sum \complement\emptyset = 8316.30$

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

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

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

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

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

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

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

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

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

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

Thus, the Model Equation is derived as;

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

4.1.6 Model Verification

The model was verified by using a different set of data (Eluama 2015 Data). This is shown as follows;

Table 4.72: Model Verification Using Eluama 2015 Dataset

Months	$x\ (ug/m^3)$	$\alpha\ (ug/m^3)$	$\beta\ (ug/m^3)$	$\emptyset\ (ug/m^3)$	$C\ (ug/m^3)$ Observed	$C\ (\boldsymbol{ug/m^3})$ **Predicted**
Jan.	22	41	60	34	94.63	120.28
Feb.	24	34	36	40	90.54	105.28
March	20	33	50	30	83.20	101.90
April	12	21	60	30	59.00	85.58
May	12	14	24	21	53.40	54.07
June	10	15	25	26	55.40	56.44
July	12	27	30	34	69.83	78.90
August	24	34	30	35	71.88	99.41
Sept.	20	33	25	21	64.20	83.95
Oct.	12	27	24	16	51.04	65.88
Nov.	20	34	24	25	56.00	86.75
Dec.	14	24	20	20	52.00	64.66

Note: the optimum values of the particulate matter were used for verification of the model. This is done in order to accommodate the worst case scenario.

4.1.7 Model Validation

The validation of the model was done using data from Eziama Quarry Site for the years 2015, 2016 2019 and Eluama 2019.

Table 4.73: Model Validation Using Eziama 2015 Dataset

Months	$x\ (ug/m^3)$	$\alpha\ (ug/m^3)$	$\beta\ (ug/m^3)$	$\emptyset\ (ug/m^3)$	$C\ (ug/m^3)$ Observed	$C\ (\boldsymbol{ug/m^3})$ **Predicted**
Jan.	12.40	13.00	20.00	46.00	58.70	65.02
Feb.	16.00	12.00	30.00	32.00	60.80	65.04
March	24.00	33.00	34.00	42.00	92.40	104.22
April	12.00	13.00	19.00	44.00	57.60	63.00
May	16.00	12.00	28.00	30.00	54.40	62.90

June	20.00	16.00	30.00	22.00	65.60	68.06
July	16.00	12.00	28.00	23.00	54.40	59.05
August	24.00	34.00	30.00	35.00	64.88	99.41
Sept.	20.00	33.00	25.00	21.00	64.20	83.95
Oct.	12.00	13.00	20.00	46.00	58.14	64.62
Nov.	12.00	27.00	30.00	34.00	65.03	78.90
Dec.	24.00	33.00	21.00	15.00	54.80	82.61

Table 4.74: Model Validation Using Eziama 2016 Dataset

Months	$x\ (ug/m^3)$	$\alpha\ (ug/m^3)$	$\beta\ (ug/m^3)$	$\emptyset\ (ug/m^3)$	C (ug/m^3) Observed	**C (ug/m^3) Predicted**
Jan.	11.00	13.00	18.00	40.00	54.54	59.27
Feb.	16.00	19.00	27.00	22.00	54.40	65.82
March	16.00	12.00	27.00	23.00	53.20	58.53
April	15.00	10.00	27.00	22.00	52.00	54.73
May	15.00	10.00	26.00	24.00	53.00	55.31
June	14.00	11.00	25.00	23.00	52.00	54.35
July	13.00	11.00	23.00	21.00	50.80	51.20
August	14.00	14.00	25.00	21.00	52.80	56.61
Sept.	12.00	13.00	24.00	20.00	51.60	52.40
Oct.	14.00	23.00	18.00	18.00	48.20	61.40
Nov.	13.00	22.00	19.00	19.00	47.00	60.34
Dec.	14.00	21.00	20.00	18.00	46.40	60.20

Table 4.75: Model Validation Using Eziama 2019 Dataset

Months	$x\ (ug/m^3)$	$\alpha\ (ug/m^3)$	$\beta\ (ug/m^3)$	$\emptyset\ (ug/m^3)$	C (ug/m^3) Observed	**C (ug/m^3) Predicted**
Jan.	14.00	12.50	20.50	45.30	60.62	65.96
Feb.	16..00	12.50	29.70	32.00	61.30	65.40
March	23.00	32.00	33.00	41.00	92.26	101.02
April	13.00	13.50	18.00	45.00	57.88	64.60
May	17.80	12.50	28.80	30.90	61.14	66.20

June	19.90	16.00	18.40	18.90	57.40	60.23
July	12.60	20.00	21.00	25.00	57.52	62.04
August	22.00	32.00	17.00	20.00	59.02	80.14
Sept.	18.00	32.00	25.20	20.00	63.88	80.36
Oct.	15.00	16.70	20.00	46.00	65.29	71.79
Nov.	18.00	18.90	27.70	24.00	64.52	69.19
Dec.	23.80	35.00	21.00	26.00	71.96	90.70

Table 4.76: Model Validation Using Eluama 2019 Dataset

Months	$x\ (ug/m^3)$	$\alpha\ (ug/m^3)$	$\beta\ (ug/m^3)$	$\emptyset\ (ug/m^3)$	$C\ (ug/m^3)$ Observed	$\mathbf{C\ (ug/m^3)}$ **Predicted**
Jan.	23.50	42.00	63.00	32.00	96.40	99.64
Feb.	23.50	33.70	38.00	39.50	91.74	105.21
March	22.00	32.00	56.00	32.00	85.78	107.02
April	11.00	22.00	60.00	31.00	64.14	86.24
May	18.70	20.70	25.00	25.00	64.74	71.06
June	12.00	14.00	24.00	25.80	57.40	56.67
July	12.00	24.00	25.00	23.00	50.66	66.85
August	20.00	26.80	24.60	25.50	63.44	79.24
Sept.	20.00	32.00	25.50	20.00	64.74	82.54
Oct.	11.00	26.00	24.00	15.00	51.80	63.20
Nov.	21.00	3.20	23.50	26.00	58.26	88.27
Dec.	14.00	25.00	21.00	21.00	52.00	66.85

Applying statistical measures of performance using equations 4.3 through 4.5, the verification model using Eluama 2015 data set gave a coefficient of correlation *(R)* of 0.81 with a mean absolute percentage error (MAPE) of 4.94% and a Root Mean Square Error (RMSE) of 8.21%, while that of the model validation using Eziama dataset gave the following results below.

Table 4.77: Values of *R*, MAPE and RMSE for Eziama Data set

Year	***R***	**MAPE (%)**	**RMSE (%)**
2015	0.88	3.72	6.02
2016	0.92	2.56	3.05

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 detected, but 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 $\mu g/m^3$ 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 $\mu g/m^3$ and 250 $\mu g/m^3$.

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 the results of predicted concentration of pollutants, the highest predicted concentration of pollutants occurred during the dry season while the lowest predicted concentration of pollutants occurred during the rainy season, and were all below the permissible limit of WHO and NESREA.

4.2.3 Model Calibration

Calibration involves estimating the values of various constants and parameters in the model structure. Estimation of the model coefficients and constants was done by solving the model equation for the parameters of interest after supplying observed values of both the dependent and independent variables. The observed values of variables were obtained from field data. From equation 4.1 the values of the various constants and parameters were derived through model calibration, using Eluama 2016 dataset, which was thereafter used in deriving the model equation.

4.2.4 Model Verification and Validation

Once a satisfactory estimate of the parameters for the model was obtained, the model was checked to assure that they adequately perform the functions for which they are intended.

Model verification and validation are the primary processes for quantifying and building credibility in numerical models.

Verification is the process of determining that a model implementation accurately represents the developer's conceptual description of the model and its solution.

Validation is the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model.

Both verification and validation are processes that accumulate evidence of a model's correctness or accuracy for a specific scenario; thus, model verification & validation cannot prove that a model is correct and accurate for all possible scenarios, but, rather, it can provide evidence that the model is sufficiently accurate for its intended use.

Verification is concerned with identifying and removing errors in the model by comparing numerical solutions to analytical or highly accurate benchmark solutions. Validation, on the other hand, is concerned with quantifying the accuracy of the model by comparing numerical solutions to experimental data.

The model was checked with the Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE) which is frequently used measure of differences between values predicted by model and the value observed. The RMSE serves to aggregate the magnitudes of the error in predictions for various data points into a single measure of predictive power. RMSE is a measure of accuracy to compare forecasting errors of different models for a particular dataset (Hyndman, 2006). RMSE is always a non-negative and a value of 0 (almost never achieved in practice) would indicate a perfect fit to the data. In general, the lower the value for RMSE and MAPE the better the model is able to forecast values.

The Eluama dataset of 2015 has RMSE and MAPE values of 8.21 and 4.94 while that of Eziama 2015 and 2016 dataset have RMSE and MAPE of 6.02, 3.72 and 3.05, 2.56 respectively. However, the error of estimate gotten is within the specific range of statistical analysis.

The model verification using Eluama 2015 dataset gave a Coefficient of Correlation *(R)* of 0.81 while that of model validation using Eziama 2015 and 2016 dataset gave Coefficient of Correlation *(R)* of 0.88 and 0.92 respectively, which show 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.

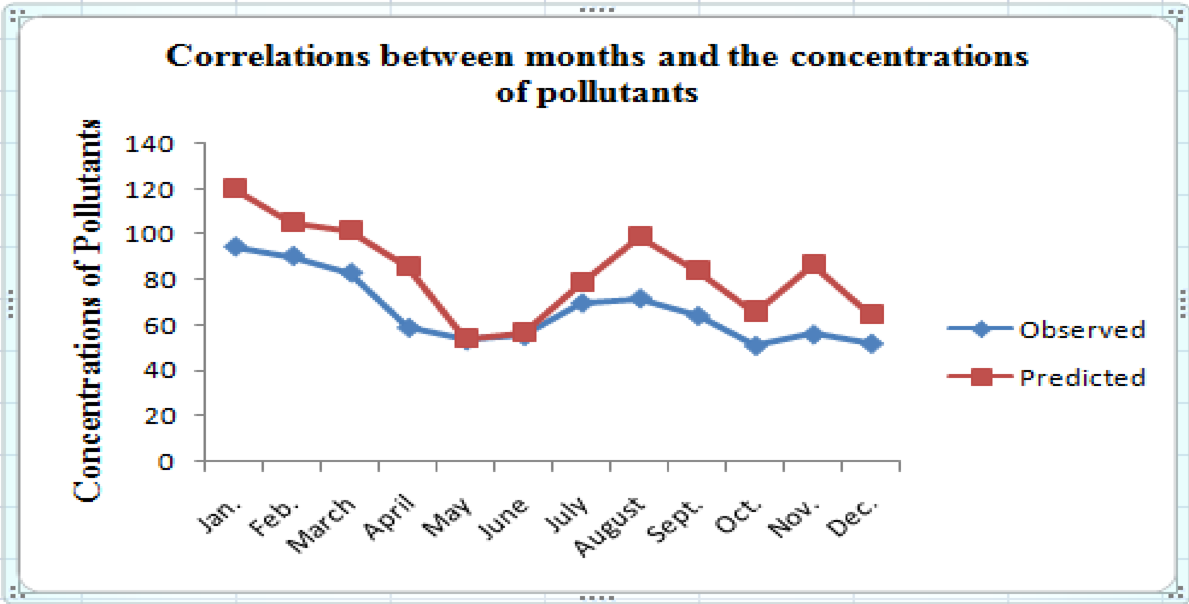


Figure 4.1: Graphical representation of model verification of observed and predicted concentration of pollutants of Eluama 2015 Dataset

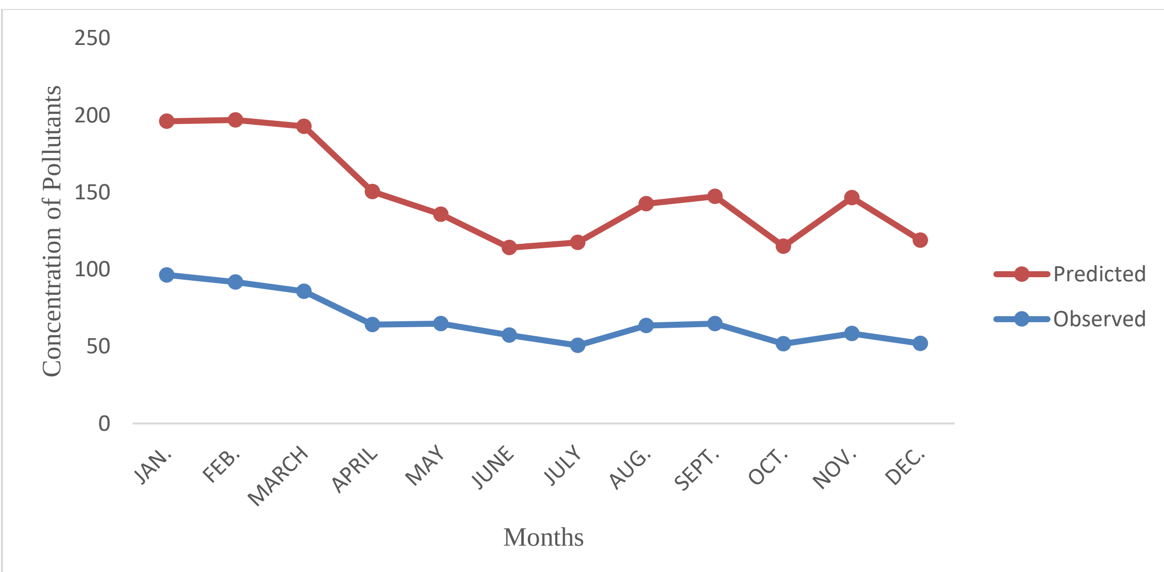


Figure 4.2: Graphical representation of model validation of observed and predicted concentration of pollutants of Eluama 2019 Dataset

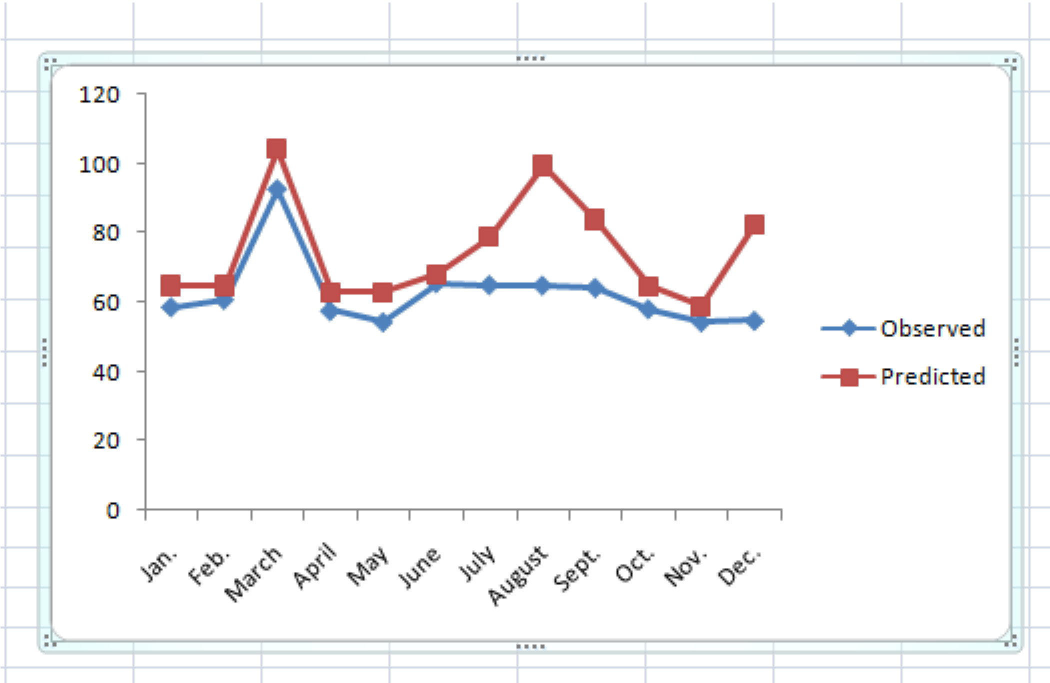


Figure 4 3: Graphical representation of model validation of observed and predicted concentration of pollutants of Eziama 2015 Dataset

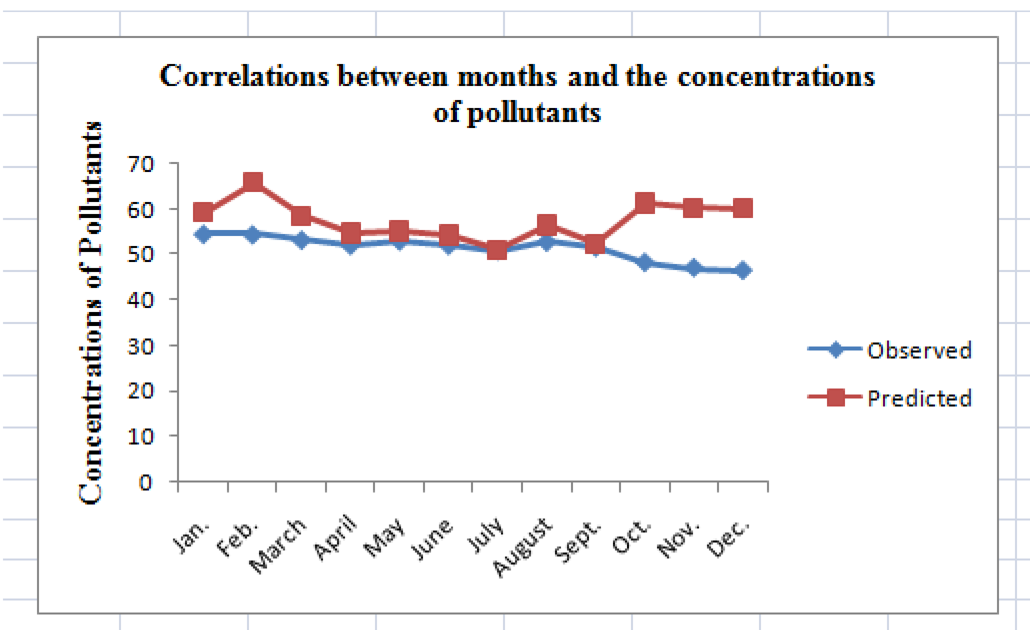


Figure 4.4: Graphical representation of model validation of observed and predicted concentration of pollutants of Eziama 2016 Dataset

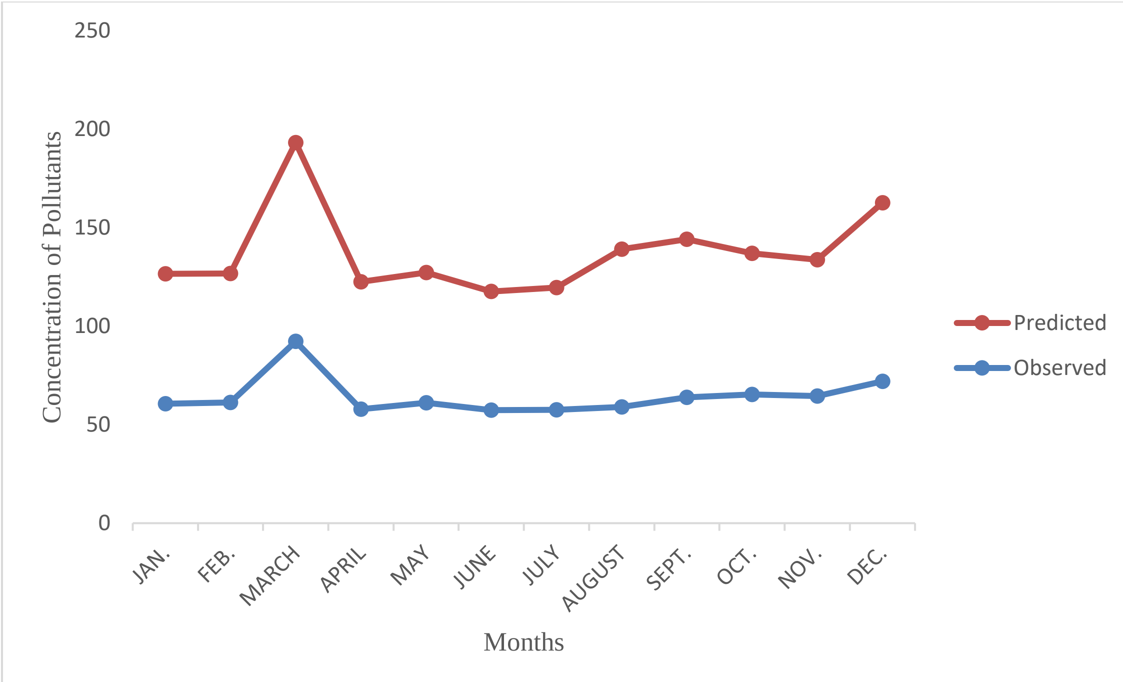


Figure 4.5: Graphical representation of model validation of observed and predicted concentration of pollutants of Eziama 2019 Dataset

From the graphs, the concentration move gradually upward as dry season approaches and decline gradually during rainy season. It shows that the level of concentration of the particulates in air is highest during the dry season and lowest during the rainy season or weather.

4.2.5 Comparison of the air quality parameters with well-known standards.

Generally, air quality in an area should comply with regulatory standards. The Federal Ministry of Environment adopted the WHO standards (Table 3.3) and NESREA standards (A.48) as the national standards for gaseous emissions against which air quality parameters monitored are compared in order to ascertain its "cleanliness". From the results gotten, both the observed and predicted values of particulates are below NESREA and WHO permissible limit, thus from air quality classification on Table 3.53, the air quality in both Eluama and Eziama as a result of the quarry activity is of Moderate Quality.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 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/)

5.2 Recommendations

The recommendations provided below will enhance quarrying activity in Eluama and Eziama Community. These are as follows;

i. For sustainable quarry activities, quarry site should be located in the interior area surrounded by adequate vegetation which would act as sinks and block for various emissions emanating from the quarry. Inhabitant of the area where a quarry is to be sited should be relocated to prevent the impact of the emissions generated by the quarry industries on them.

ii. Environmental regulations and laws must be enforced by government agencies, local communities and non-governmental organizations or pressure groups for the protection and preservation of the environment. The monitoring agencies should be equipped with the necessary logistics for effective enforcement.

iii. Haul trucks from the quarry sites should not be allowed to use the unpaved road which passes through the communities and their buckets must be covered. These trucks generate a lot of fugitive dust which disturb the inhabitants.

iv. Quarrying companies must be urged to take positive steps to suppress dust at the emission points. A lot of dust is emitted by crushing, screening and the other processes thus, a water browser or tanker should be acquired and used to spray water on surfaces of roads, stockpiles and others at least once a day especially during dry and sunny days. Other systems like pipes could also be developed to suppress dust at the blasting and processing sites and also along roads. Dust suppression measures must, therefore, be effectively implemented during the dry season.

v. The potential effects of blasting must be reduced by the companies. The use of alarm to alert inhabitants of blasting should be adhered to. It is a requirement by EPA guidelines that notice must be given to communities living close to the quarries prior to blasting. Blasting vibration is not only causing damage to buildings but also impacting negatively on other life activities.

5.3 Contributions to Knowledge

The aim of the study is to assess and model the air quality in selected quarry sites in Abia State. The expected contributions to knowledge from this study are:

i. The results obtained from this study will provide reliable model in predicting or determining the air quality in quarry sites and its environment.

ii. The study will provide a frame work to make decisions on effective and efficient ways to implement the National Ambient Air Quality Standards and improve air quality in quarry communities.

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APPENDIX

Climate/Meteorology of Eluama and Eziama Quarry Sites

A.1: Climate/Meteorology Data of Eluama Quarry Site (January, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.40	54.40	2.60	NE
Weight Bridge	32.00	55.00	3.80	NE
Primary Crusher	35.00	54.20	2.90 3.40	NE
Secondary Crusher	33.50	54.80	5.00	NE
Main Gate	32.50	58.20	4.00	NE
Mean	33.26	55.32	4.34	

A.2: Climate/Meteorology Data of Eluama Quarry Site (February, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	55.00	2.50	NE
Weight Bridge	32.40	55.80	2.80	NE
Primary Crusher	34.00	56.00	2.30	NE
Secondary Crusher	33.60	54.80	3.50	NE
Main Gate	32.00	58.00	4.00	NE
Mean	33.20	55.92	3.02	

A.3: Climate/Meteorology Data of Eluama Quarry Site (March, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.20	54.20	2.50	NE
Weight Bridge	31.80	54.50	2.20	NE
Primary Crusher	35.00	55.50	1.50	NE
Secondary Crusher	33.50	55.00	3.80	NE
Main Gate	32.40	58.00	5.00	NE
Mean	33.38	55.44	3.00	

A.4: Climate/Meteorology Data of Eluama Quarry Site (April, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	31.00	57.00	2.50	NE
Weight Bridge	30.00	58.00	3.40	NE
Primary Crusher	33.50	56.00	2.90 3.00	NE
Secondary Crusher	33.00	55.80	5.00	NE
Main Gate	31.00	58.00	4.00	NE
Mean	31.70	56.96	3.60	

A.5: Climate/Meteorology Data of Eluama Quarry Site (May, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	30.00	58.00	2.60	NE
Weight Bridge	32.00	56.00	3.00	NE
Primary Crusher	32.00	56.60	2.40	NE
Secondary Crusher	30.00	57.00	3.60	NE

Main Gate	30.00	58.00	4.00	NE
Mean	30.80	57.12	3.12	

A.6: Climate/Meteorology Data of Eluama Quarry Site (June, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	30.00	59.00	2.60	NE
Weight Bridge	30.50	58.50	2.40	NE
Primary Crusher	31.00	56.00	1.80	NE
Secondary Crusher	30.50	57.00	3.60	NE
Main Gate	30.00	55.00	5.00	NE
Mean	30.40	57.10	3.68	

A.7: Climate/Meteorology Data of Eluama Quarry Site (July, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	31.00	57.00	2.60	NE
Weight Bridge	30.80	59.00	2.50	NE
Primary Crusher	31.00	58.00	2.80	NE
Secondary Crusher	32.00	56.50	3.60	NE
Main Gate	30.00	57.50	5.00	NE
Mean	30.90	57.70	3.30	

A.7: Climate/Meteorology Data of Eluama Quarry Site (August, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	55.70	2.50	NE
Weight Bridge	32.80	55.00	3.00	NE
Primary Crusher	34.00	56.00	2.40	NE

Secondary Crusher	33.00	56.00	2.50	NE
Main Gate	32.30	58.20	4.00	NE
Mean	33.20	56.18	2.88	

A.8: Climate/Meteorology Data of Eluama Quarry Site (September, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	54.40	2.50	NE
Weight Bridge	33.00	54.00	2.20	NE
Primary Crusher	35.00	55.50	1.50	NE
Secondary Crusher	33.50	55.60	3.80	NE
Main Gate	32.00	58.70	5.00	NE
Mean	33.50	55.64	3.00	

A.9: Climate/Meteorology Data of Eluama Quarry Site (October, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	35.00	55.00	2.60	NE
Weight Bridge	34.00	56.00	3.60	NE
Primary Crusher	35.00	54.20	2.80 3.60	NE
Secondary Crusher	33.00	53.00	5.00	NE
Main Gate	32.00	58.40	4.00	NE
Mean	33.40	55.32	4.40	

A.10: Climate/Meteorology Data of Eluama Quarry Site (November, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	55.00	2.50	NE
Weight Bridge	33.00	54.00	3.00	NE
Primary Crusher	34.00	56.00	2.00	NE
Secondary Crusher	35.00	54.00	3.00	NE
Main Gate	32.30	53.00	4.00	NE
Mean	33.66	54.40	2.90	

A.11: Climate/Meteorology Data of Eluama Quarry Site (December, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	54.00	3.20	NE
Weight Bridge	35.00	52.00	3.00	NE
Primary Crusher	35.00	55.00	1.50	NE
Secondary Crusher	33.50	55.00	3.40	NE
Main Gate	33.00	53.00	4.00	NE
Mean	34.10	53.80	3.02	

A.12: Climate/Meteorology Data of Eluama Quarry Site (January, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.50	51.00	3.00	NE
Weight Bridge	34.00	50.00	3.50	SW
Primary Crusher	34.00	52.00	4.00	NW
Secondary Crusher	33.50	52.10	2.50	SE

Main Gate	36.00	51.00	3.00	SE
Mean	34.40	51.22	3.20	

A.13: Climate/Meteorology Data of Eluama Quarry Site (February, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.50	52.00	3.00	NE
Weight Bridge	35.00	52.20	3.20	SW
Primary Crusher	33.80	51.00	3.00	NW
Secondary Crusher	35.00	52.00	2.80	SE
Main Gate	34.50	52.00	2.40	SE
Mean	34.56	51.84	2.88	

A.14: Climate/Meteorology Data of Eluama Quarry Site (March, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	35.00	52.00	3.00	NE
Weight Bridge	35.00	51.00	3.40	SW
Primary Crusher	34.00	51.00	3.00	NW
Secondary Crusher	34.50	52.00	2.80	SE
Main Gate	35.00	53.00	3.20	SE
Mean	34.70	51.80	3.08	

A.15: Climate/Meteorology Data of Eluama Quarry Site (April, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	53.00	3.30	NE
Weight Bridge	35.00	51.00	3.20	SW

Primary Crusher	33.00	54.00	3.00	NW
Secondary Crusher	34.50	52.00	2.70	SE
Main Gate	32.00	55.00	3.20	SE
Mean	33.70	53.00	3.08	

A.16: Climate/Meteorology Data of Eluama Quarry Site (May, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	55.00	3.00	NE
Weight Bridge	33.00	54.80	3.40	SW
Primary Crusher	33.00	56.00	3.00	NW
Secondary Crusher	34.50	54.00	2.80	SE
Main Gate	33.00	55.50	3.20	SE
Mean	33.50	55.06	3.08	

A.17: Climate/Meteorology Data of Eluama Quarry Site (June, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	30.50	56.00	3.00	NE
Weight Bridge	31.00	56.50	3.40	SW
Primary Crusher	30.00	55.00	3.00	NW
Secondary Crusher	31.50	55.50	3.10	SE
Main Gate	32.00	56.00	3.20	SE
Mean	31.00	55.80	3.14	

A.18: Climate/Meteorology Data of Eluama Quarry Site (July, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	32.00	55.40	2.60	NE
Weight Bridge	31.80	55.50	2.50	SW
Primary Crusher	30.30	56.00	2.80	NW
Secondary Crusher	30.00	57.00	3.60	SE
Main Gate	31.00	56.00	5.00	SE
Mean	31.02	55.98	3.30	

A.19: Climate/Meteorology Data of Eluama Quarry Site (August, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	31.00	55.70	2.70	NE
Weight Bridge	30.80	55.00	3.00	NE
Primary Crusher	31.00	56.00	2.50	NE
Secondary Crusher	30.00	56.00	2.40	NE
Main Gate	31.30	57.20	4.00	NE
Mean	30.82	55.98	2.92	

A.20: Climate/Meteorology Data of Eluama Quarry Site (September, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.00	55.50	2.50	NE
Weight Bridge	32.00	55.00	3.00	NE
Primary Crusher	33.00	56.00	2.50	NE
Secondary Crusher	31.00	55.00	3.00	NE
Main Gate	32.00	55.20	3.50	NE

Mean	32.20	55.34	2.90	

A.21: Climate/Meteorology Data of Eluama Quarry Site (October, 2016)

Station	Amble Temp. (°c)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.00	55.00	3.80	NE
Weight Bridge	31.00	55.00	4.60	NE
Primary Crusher	32.00	53.00	4.80	NE
Secondary Crusher	31.00	54.00	6.00	NE
Main Gate	30.00	59.30	6.00	NE
Mean	31.40	55.26	5.04	

A.22: Climate/Meteorology Data of Eluama Quarry Site (November, 2016)

Station	Amble Temp. (°c)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.00	55.00	3.50	NE
Weight Bridge	31.00	54.00	3.00	NE
Primary Crusher	33.00	56.00	3.00	NE
Secondary Crusher	33.00	54.00	3.00	NE
Main Gate	31.00	53.00	5.00	NE
Mean	32.20	54.40	3.50	

A.23: Climate/Meteorology Data of Eluama Quarry Site (December, 2016)

Station	Amble Temp. (°c)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	32.00	55.00	3.20	NE
Weight Bridge	33.00	53.00	3.00	NE

Primary Crusher	34.00	56.00	1.50	NE
Secondary Crusher	31.50	55.00	3.40	NE
Main Gate	31.00	54.00	4.00	NE
Mean	32.30	52.00	3.02	

A.24: Climate/Meteorology Data of Eziama Quarry Site (January, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.00	54.60	1.20	NE
Weight Bridge	34.60	52.00	1.80	SW
Primary Crusher	31.60	54.50	2.20	NW
Secondary Crusher	32.90	52.10	1.60	SE
Main Gate	31.00	56.40	1.40	SE
Mean	32.62	53.92	1.64	

A.25: Climate/Meteorology Data of Eziama Quarry Site (February, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	52.60	1.40	NE
Weight Bridge	35.20	53.00	2.20	SW
Primary Crusher	34.00	53.40	2.20	NW
Secondary Crusher	33.40	54.00	1.80	SE
Main Gate	34.00	54.00	1.40	SE
Mean	34.12	53.40	1.80	

A.26: Climate/Meteorology Data of Eziama Quarry Site (March, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	32.80	53.00	1.40	NE
Weight Bridge	32.20	54.00	3.00	SW
Primary Crusher	32.60	54.80	1.00	NW
Secondary Crusher	32.40	54.60	1.50	SE
Main Gate	32.00	54.00	2.20	SE
Mean	32.40	54.68	2.00	

A.27: Climate/Meteorology Data of Eziama Quarry Site (April, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.40	54.80	1.80	NE
Weight Bridge	34.60	56.50	2.10	SW
Primary Crusher	31.80	55.00	2.40	NW
Secondary Crusher	33.00	52.40	2.00	SE
Main Gate	32.00	56.90	1.60	SE
Mean	33.00	55.10	5.20	

A.28: Climate/Meteorology Data of Eziama Quarry Site (May, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	32.60	56.50	2.40	NE
Weight Bridge	32.40	55.00	2.00	SW
Primary Crusher	31.00	54.60	2.40	NW
Secondary Crusher	33.50	56.50	1.80	SE
Main Gate	31.00	58.50	2.00	SE

Mean	32.10	56.22	2.10	

A.29: Climate/Meteorology Data of Eziama Quarry Site (June, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	31.00	57.40	1.60	NE
Weight Bridge	33.40	58.00	3.400	SW
Primary Crusher	32.00	55.80	2.00	NW
Secondary Crusher	32.60	56.60	1.80	SE
Main Gate	33.50	56.00	2.40	SE
Mean	32.50	56.76	2.24	

A.30: Climate/Meteorology Data of Eziama Quarry Site (July, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	31.60	58.00	1.80	NE
Weight Bridge	30.00	56.00	1.80	SW
Primary Crusher	32.00	55.50	2.60	NW
Secondary Crusher	31.00	57.10	2.00	SE
Main Gate	31.00	56.40	1.80	SE
Mean	31.12	56.60	2.00	

A.31: Climate/Meteorology Data of Eziama Quarry Site (August, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	52.00	1.60	NE
Weight Bridge	35.20	53.70	2.24	SW

Primary Crusher	31.50	53.60	2.20	NW
Secondary Crusher	34.00	54.00	2.80	SE
Main Gate	32.60	58.40	1.60	SE
Mean	33.46	54.34	2.08	

A.32: Climate/Meteorology Data of Eziama Quarry Site (September, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.80	55.00	1.80	NE
Weight Bridge	33.20	59.00	3.00	SW
Primary Crusher	32.00	55.80	2.40	NW
Secondary Crusher	35.60	54.60	2.30	SE
Main Gate	33.40	55.60	2.80	SE
Mean	33.60	56.00	2.46	

A.33: Climate/Meteorology Data of Eziama Quarry Site (October, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	54.00	2.40	NE
Weight Bridge	34.00	52.00	2.60	SW
Primary Crusher	33.00	54.00	2.30	NW
Secondary Crusher	32.00	52.10	2.00	SE
Main Gate	33.00	54.40	2.00	SE
Mean	33.20	53.30	2.40	

A.34: Climate/Meteorology Data of Eziama Quarry Site (November, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	52.00	1.60	NE
Weight Bridge	35.00	52.00	2.60	SW
Primary Crusher	32.00	53.00	2.40	NW
Secondary Crusher	34.00	54.00	2.80	SE
Main Gate	32.00	54.00	2.10	SE
Mean	33.40	53.00	2.30	

A.35: Climate/Meteorology Data of Eziama Quarry Site (December, 2015)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.00	55.00	2.20	NE
Weight Bridge	33.20	54.00	3.00	SW
Primary Crusher	32.40	53.00	2.00	NW
Secondary Crusher	35.00	53.00	2.40	SE
Main Gate	33.00	52.50	2.80	SE
Mean	33.48	53.50	2.80	

A.36: Climate/Meteorology Data of Eziama Quarry Site (January, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.30	53.00	3.00	NE
Weight Bridge	34.00	52.00	3.00	SW
Primary Crusher	32.00	52.00	4.00	NW
Secondary Crusher	32.50	52.10	2.00	SE
Main Gate	33.00	51.40	3.00	SE

Mean	32.96	52.10	3.00	

A.37: Climate/Meteorology Data of Eziama Quarry Site (February, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.50	52.00	2.00	NE
Weight Bridge	35.00	53.00	2.80	SW
Primary Crusher	33.00	53.00	3.00	NW
Secondary Crusher	34.00	53.00	2.80	SE
Main Gate	34.00	52.00	2.00	SE
Mean	34.10	52.60	2.52	

A.38: Climate/Meteorology Data of Eziama Quarry Site (March, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.50	52.00	1.80	NE
Weight Bridge	35.00	53.00	2.80	SW
Primary Crusher	33.00	54.00	3.00	NW
Secondary Crusher	34.00	52.00	2.80	SE
Main Gate	35.00	53.00	2.00	SE
Mean	34.30	52.80	2.48	

A.39: Climate/Meteorology Data of Eziama Quarry Site (April, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	32.00	54.00	2.00	NE
Weight Bridge	34.00	53.00	2.80	SW
Primary Crusher	33.00	54.00	3.00	NW

Secondary Crusher	34.00	53.00	2.80	SE
Main Gate	33.00	54.00	2.00	SE
Mean	33.20	53.60	2.52	

A.40: Climate/Meteorology Data of Eziama Quarry Site (May, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	31.00	55.50	2.20	NE
Weight Bridge	33.50	53.00	2.80	SW
Primary Crusher	32.00	55.00	3.50	NW
Secondary Crusher	33.00	53.00	2.80	SE
Main Gate	31.00	56.00	2.50	SE
Mean	32.10	54.50	2.75	

A.41: Climate/Meteorology Data of Eziama Quarry Site (June, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	31.00	55.50	2.20	NE
Weight Bridge	32.50	55.00	2.80	SW
Primary Crusher	32.00	55.00	3.50	NW
Secondary Crusher	32.00	54.00	2.80	SE
Main Gate	31.00	56.00	2.50	SE
Mean	31.70	55.10	2.75	

A.42: Climate/Meteorology Data of Eziama Quarry Site (July, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.

Generator House	32.00	55.50	2.50	NE
Weight Bridge	32.00	56.00	2.80	SW
Primary Crusher	32.00	55.00	3.50	NW
Secondary Crusher	32.50	56.00	2.80	SE
Main Gate	31.00	56.00	3.00	SE
Mean	32.10	55.70	2.92	

A.43: Climate/Meteorology Data of Eziama Quarry Site (August, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.50	53.00	1.80	NE
Weight Bridge	35.00	53.70	2.50	SW
Primary Crusher	31.50	53.50	2.20	NW
Secondary Crusher	34.00	54.00	2.80	SE
Main Gate	32.50	58.50	1.60	SE
Mean	33.30	54.54	2.18	

A.44: Climate/Meteorology Data of Eziama Quarry Site (September, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	33.50	55.00	1.80	NE
Weight Bridge	33.00	59.00	3.00	SW
Primary Crusher	32.00	55.80	3.00	NW
Secondary Crusher	32.50	55.60	2.50	SE
Main Gate	31.20	56.00	2.80	SE
Mean	32.44	56.28	2.62	

A.45: Climate/Meteorology Data of Eziama Quarry Site (October, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	52.00	2.40	NE
Weight Bridge	34.00	52.00	2.60	SW
Primary Crusher	32.00	54.00	2.30	NW
Secondary Crusher	33.00	52.10	2.00	SE
Main Gate	34.00	52.40	2.00	SE
Mean	33.80	52.50	2.20	

A.46: Climate/Meteorology Data of Eziama Quarry Site (November, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	34.00	52.00	1.60	NE
Weight Bridge	35.00	52.50	2.60	SW
Primary Crusher	35.50	53.70	2.40	NW
Secondary Crusher	34.00	53.00	2.80	SE
Main Gate	34.00	53.00	2.00	SE
Mean	34.50	52.84	2.28	

A.47: Climate/Meteorology Data of Eziama Quarry Site (December, 2016)

Station	Amble Temp. (ºc)	Rel. Hum. (%)	Wind speed (m/s)	Wind Dir.
Generator House	35.00	51.00	2.20	NE
Weight Bridge	35.00	55.00	3.00	SW
Primary Crusher	35.50	52.00	4.60	NW
Secondary Crusher	34.40	53.00	2.40	SE

Main Gate	34.00	53.00	2.80	SE
Mean	34.78	52.80	3.00	

A.48: Ambient Air Quality Standards of NESREA

SCHEDULE XIII

AMBIENT AIR QUALITY STANDARDS

[*Regulations* 29, 30 *and* 33]

S/N	*Pollutant*	*Time Weighted Average*	*Concentration in Ambient Air*
1.	Sulphur dioxide (SO_2)	Annual	80 µg/m³
		24 hours	120 µg/m³
		1 hour	350 µg/m³
2.	Nitrogen dioxide (NO_2)	Annual	80 µg/m³
		24 hours	120 µg/m³
		1 hour	200 µg/m³
3.	Carbon monoxide (CO)	8 hours	5.0 mg/m³
		1 hour	10 mg/m³
4.	Particulate Matter (PM10)	Annual	60 µg/m³
		24 hours	150 µg/m³
5.	Ozone (O_3)	8 hours	100 µg/m³
		1 hour	180 µg/m³
6.	Lead (Pb)	Annual	1.0 µg/m³
		24 hours	1.4 µg/m³
7.	Arsenic (As)	Annual	6,000 µg/m³
8.	Nickel (Ni)	Annual	20,000 µg/m³
9.	Cadmium (Cd)	Annual	5,000 µg/m³
10.	Ammonia (NH_3)	Annual	0.2 mg/m³
		24 hours	0.6 mg/m³