GEOENVIRONMENTAL ASSESSMENT OF IMPACTS OF QUARRYING AND QUALITY OF AGGREGATES FROM VARIOUS SOURCES IN PARTS OF SOUTHEASTERN NIGERIA

BY

AGUBOM JOHN-KENNEDY (B.Tech. M.Sc., FUTO)

(20154988618)

A DISSERTATION SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI.

IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS OF THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D.) IN ENVIRONMENTAL GEOLOGY

JULY, 2023

CERTIFICATION

This is to certify that the research "Geoenvironmental Assessment of Impacts of Quarrying and Quality of Aggregates from Various Sources in Parts of Southeastern Nigeria" was carried out by AGUBOM, JOHN-KENNEDY (20154988618) in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy (PhD) in Environmental Geology in the Department of Geology, School of Physical Sciences, Federal University of Technology Owerri, Imo State, Nigeria.

.... **Prof. O. C Okeke** (Principal Supervisor)	16/08/2023 .... Date
.... **Dr. A.A Onunkwo** (Co-Supervisor)	16/8/2023 .... Date
.... **Prof. C.C.Z Akaolisa** (Co-Supervisor)	16/8/23 .... Date
.... **Dr. D. O. Ikoro** (Head of Department)	16/8/2023 .... Date
.... **Prof. (Mrs.) C.E. Ogukwe** (Dean, School of Physical Sciences)	.... Date
.... **Prof. B.O Esonu** (Dean, Post Graduate School)	.... Date
.... **Prof. O. I. Imasuen** (External Examiner)	.... Signature/ Date

DEDICATION

This dissertation is dedicated to the Almighty God for His favours and mercies throughout this period. And to my late parents Dr. & Mrs. Callistus Agubom who could not live to see this day.

ACKNOWLEDGEMENT

I remain grateful to my supervisors- Prof. O.C Okeke, Dr. A.A. Onunkwo and Prof. C.C.Z Akaolisa for their wonderful encouragement, criticisms, concerns, and their fatherly advice to see that this dissertation is fruitful.

I am also grateful to my HOD, Dr. D.O Ikoro and the PG Coordinator, Prof. C.N. Okereke whose sincere commitment made it possible for the actualization of this dream.

I am also very grateful to my brothers, my wife- Mrs Chioma Agubom and children- Uchechukwumewe, Ifunanyachukwu and Munachiomamso for their prayers and support throughout the period of this PhD program.

My special gratitude goes to those who in one way or the other contributed to my success in this program in FUTO; good to mention the Dean, Prof. B.O. Esonu and the Associate Dean, Prof. C.O. Nweke postgraduate school and the entire staff of PG school for their efforts.

TABLE OF CONTENTS

LIST OF TABLE

Tables

LIST OF FIGURES

Figures

ABSTRACT

The increasing demand for sand and crushed aggregates in parts of Southeastern Nigeria has necessitated the assessment of the impacts of aggregate quarrying such as air quality, dust (suspended particulate matter) and noise which constitute serious environmental problems, including health hazards of various types of cancers, silicosis and sometimes premature death amongst quarry workers and residents of immediate community in Lokpaukwu, Amasiri, Ishiagu, Uturu and Afikpo quarry sites, Southeastern Nigeria. Nine (9) sampling points were selected for the study and they include: primary crusher, generator house, secondary crusher, blasting pit, admin block, staff quarters, entrance gate, workshop and weighing bridge.Quarrying of sand in Njaba, Nwaorie and Otamiri rivers respectively has distorted their channel morphology both in depth and width thereby threatening the neighbouring bridges and river banks. However, the physico-mechanical properties of road stone aggregates from some intrusive rock quarries were determined and the results used to evaluate the quality of the aggregates as raodstone. Four aggregate samples were collected from the following intrusive rock quarries: Lokpaukwu (Ezeaku Formation, Diorite); Uturu (Ezeaku Formation, Andesite); Ishiagu (Asu River Group; Diorite); and Afikpo (Ezeaku Formation, Dolerite). The physico-mechanical tests performed on the samples include: Aggregate Crushing Value (ACV); Aggregate Impact Value (AIV); Los Angeles Abrasion Value (LAAV); Water Absorption (WA); and Specific Gravity (SG). Results of the tests (ACV, AIV, LAAV, WA and SG) for aggregate samples from the quarries (Lokpaukwu (Diorite), Uturu (Andesite, Ishiagu (Diorite) and Afikpo (Dolerite)), respectively, are: 15.60%, 13.70%, 26.30%, 0.54% and 2.75; 19.20%, 19.01%, 19.50%, 0.01% and 2.67; 15.50%, 17.40%, 23.50%, 1.2% and 2.75; and 13.80%, 14.40%, 33.70%, 0.50% and 2.81.According to Nigerian Federal Ministry of Works Standards, the values from all the quarries are within the acceptable limits for roadstone aggregates (<30%, < 30%, <40%, <3% and >2.6), respectively. They are therefore recommended to be used as aggregates in road construction. On the other hand sandstones from Elugwu/ Umuchienta (Ameka Formation) are better than Okigwe(Nsukka Formation) sandstones as a result of tests performed on the following parameters(ACV, AIV, LAAV, WA, BD and CCT) for aggregate quality as good for concrete material are: 35.70%, 32.60%, 46.48%, 0.90%, 1.42mg/m^3, 18.90N/mm^{3}and 34.50%, 36.40%, 60.70%, 0.60%, 1.63mg/m^3, 16.65N/mm^3 respectively.

Keywords: Aggregates, Quarry, physico- mechanical, roadstone, concrete

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Our environment is continuously being polluted by human and industrial activities. Recently emphasis has been geared on principal sources of environmental pollution, its health hazards and mitigation of the hazards."Quarrying is a type of surface mining operation where rocks and other construction materials are mined and processed for production of aggregates or building stones"(Okeke,2017). "Metal ores are extracted by mining which involves removal of rock from the ground"(Keeperman, 2000). This involves the removal of rock, gravel and sand from the ground including river beds and beaches.

Quarrying of rock, gravel or sand can cause a numerous on-site and off-site environmental problems throughtransportation of aggregates, excavation, screening, stockpiling, and crushing. The nature and degree of environmental effects caused by quarrying differs according to the type of quarry, the geology of the area ,the scale of operation,the receiving environment, methods used to excavate aggregateand the surrounding land uses. Theenvironmental effects of quarries also differ by their nature (rock and sand) and in continuous use or used irregularly or seasonally,whether they are in short or long term use.

"Crushed stone together with sand and gravel constitute the two main sources of natural aggregates, the vast majority of which are used in the construction industry"(Okeke and Iwuoha, 2005).

"The use of crushed-rock aggregates for engineering construction depends on the strength and durability characteristics of the aggregates" (Okeke and Iwuoha, 2005). "The term crushed stone refers to rock that has been reduced in size after mining to meet consumer specifications"(Okeke, 2017)

"The properties of crushed rock result from the origin and mineralogy of the source rock and its subsequent alteration and weathering. Some important properties of a rock are the type, size, shape, orientation, and proportions of mineral grains; the type of contacts between the mineral grains; the layering of minerals; and the presence and interconnectedness of voids" (Dolar-Mantuani 1983). "The strength of the aggregates refers to the ability of the aggregates to resist compression due to external static or dynamic load" (Prentice, 1984). "In general, they should be hard and tough enough to resist crushing, degradation, and disintegration from any associated activities. About 52% of all construction aggregate is crushed stone, while 48% of the remaining is sand and gravel" (AASHTO, 2001).

Aggregate is an industrial material that is simultaneously low in value, high in bulk, and abundant. It is nearly omnipresent but not always available near major demand centers. The industry is characterized by a large number of operations of variable size.

Most hard rocks are potentially useful for coarse aggregate, butsome specific qualities must be present in the source material because of the variety of specifications and uses. "It may often be taken as a working rule that a rock with a water absorption value of less than about 2 percent will usually produce a good quality aggregate and that rocks with values exceeding about 4 percent may not. Sand and gravel deposits are accumulations of the more durable rock fragments and mineral grains(Dolar- Mantuani, 1983). The principal sources for sand and gravel, from a geological viewpoint, are active or ancient river systems and glaciated terrains.

Deposits that yield sand and/or gravel can be classified as stream deposits, alluvial fans, glacial, and fluvial-glacial deposits. The stream deposits can be subdivided into stream channel deposits, floodplain deposits, and terrace deposits. Glacial and fluvial-glacial deposits 1300 can be identified as outwash deposits, kames and eskers, beach and dune sands, and moraines.

"A considerable number of studies have shown that human activities such as sand mining within river channels have greatly accelerated natural geomorphologic processes with negative consequences which includes modification to channel morphology; ground water table lowering, stream-bank instability; flood flow increase and several other biological impacts"(Kondolf, 1997; 1994).

"Sand mining is taking place at a much faster rate than natural replenishments, which in turn has led to severe ecological disorders. Excessive sand mining causes erosion and deposition in riverbeds which leads to alteration in the topography of the riverbeds and affects the ecosystem of the river. Mining activities lead to changes in forms of channels, physical habitats and food webs"(Langer, 2001).

Mining of sand and gravels cause alteration in fluvial characteristics of river channels. One of the effects is modification of groundwater in the channel due to formation of depressions (recharge areas) and change in the pathway of river. Such changesin the pathway of river may increase or decrease groundwater recharge whereby deflection in river paths may lead to drying up of wells while shorter flow paths may increase susceptibility to contamination.

The environmental effects of quarrying primarily include: impact on cultural and historic heritage values,the disturbance of land and vegetation, the discharge of contaminants into air, water,land and the coastal marine area, disturbances or coastal marine areas, dust, vibration, noise, traffic, visual effects.

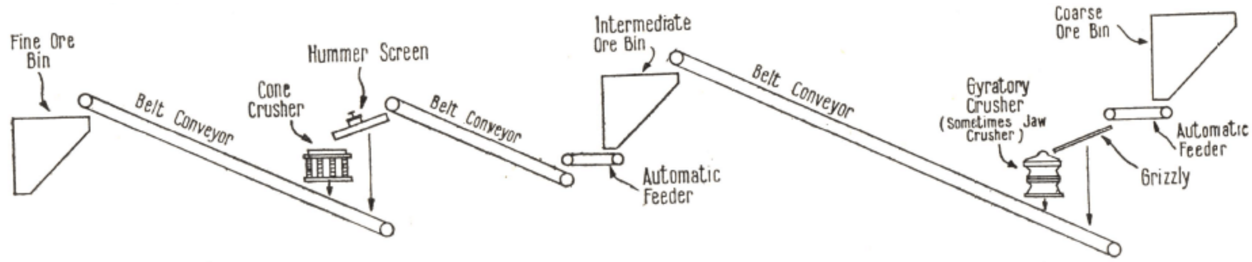


Fig. 1.0 Layout of Crushing Installation (Adapted from Okeke, 2017)

"The fine ore bin can be designed to hold two days' supply of ore, but the coarse ore bin should not hold more than one day's supply on account of the tendency of large lumps to pack under pressure of a heavy column of ore. The intermediate bin with the automatic feeder and belt conveyor following it are occasionally omitted, but the practice is not to be recommended, since the discharge of the primary breaker then passes straight to the vibrating screen and cone crusher, with the result that the unavoidable irregularities of feed in the first stage pass on to the second; moreover, the correct rates of feed for the primary and secondary machines are seldom the same"(Okeke, 2017). Therefore, as a cone crusher can only be run at maximum efficiency if it is given a regular feed at approximately the correct rate, it is best in the interests of efficiency to retain the intermediate bin (Fig.1.0)

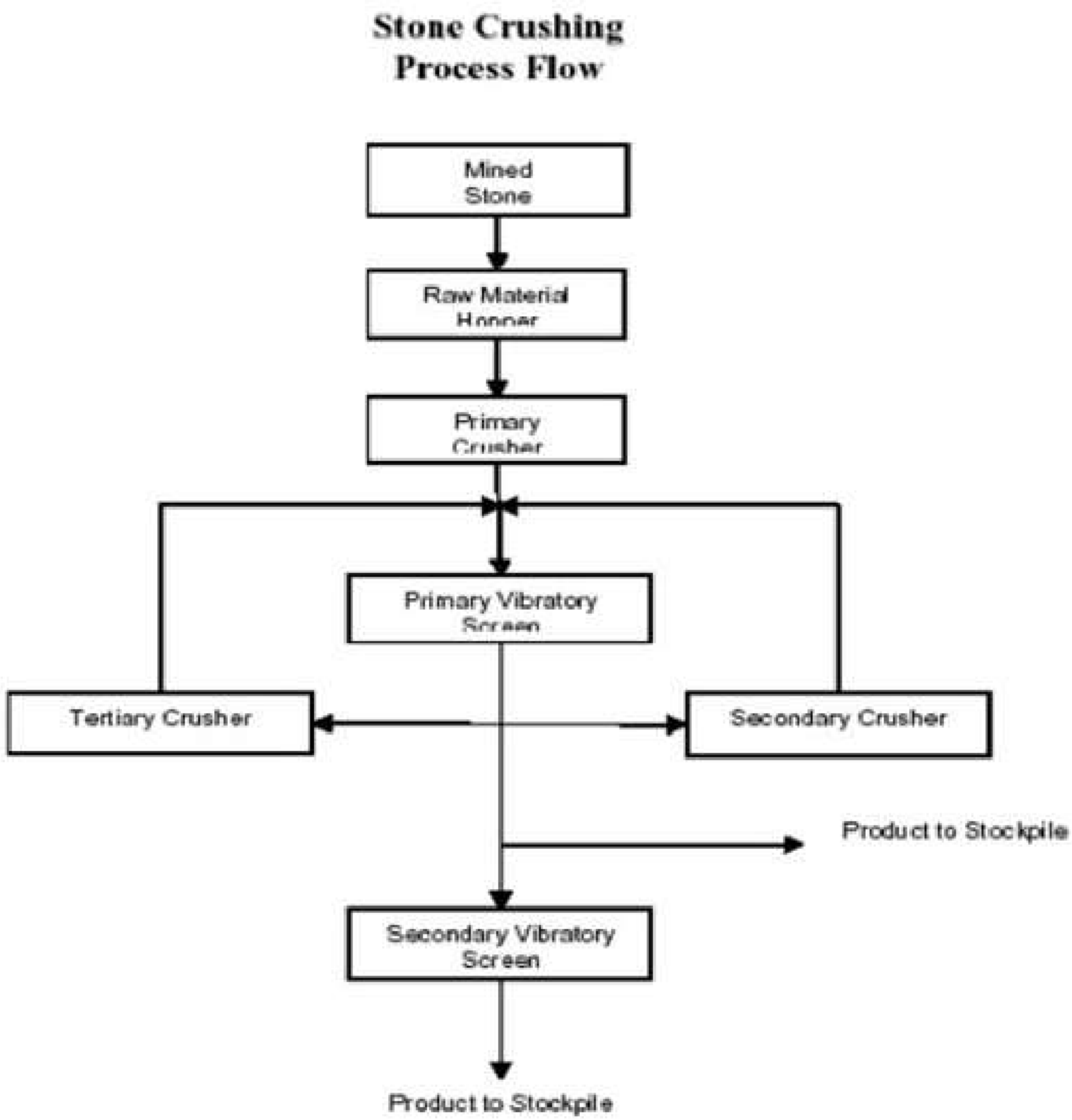


Fig. 1.1: Production process of stone dust (modified from Gregory, 1983)

Primary Crusher: The main purpose of this primary crusher is for the reduction of large fragments of blasted or natural rock down to a size suitable for handling bythe secondary stage crusher and transfer equipment. Feed opening andthe product size ranges for the different models or Gyratory crushers are as follows:

a) Maximum Feed Opening — 1500MM to 750MM (5 ft. to 2½ ft.)
b) Recommended Minimum Product — 162MM (6½ in.)

Fig.1.2 Picture of a primary crusher (adapted from Kamla, 2010)

Things you need to worry about in the selection of a primary crusher are listed below:

i. The ability of the crusher to reduce the size of even the latest rocks it is fed.
ii. All feed to crushers should be smaller than the feed opening of the crusher in at least one dimension, this is to secure the capacities specified.
iii. There is need for the crusher discharge P80 aggregate size needs to remain less than 1/3 of the related conveyor belt width.
iv. A significant crushing ratio that's good enough to impact how many more downstream comminuting units are required by the primary crusher.

v. All crusher, if set at any given discharge opening, will make a product all of which will pass a screen opening of the same dimensions as the given discharge opening.

vi. The main function of a crusher is to provide a smaller uniform aggregate size for each of transport by the conveying system in the in- pit crushing.

vii. Minimum power consumption in part of a good design. In their primary crushers use, comparatively lower energy, to other systems in the coarse duty- which minimum power consumption is built in aggregate.

viii. The horsepower required varies with the size of aggregate being made, the toughness of the rock or ore and the capacity.

ix. The labour requirements of the primary crusher should not be intensified by oversize rock removal or rock-breaker operation and clogging.

x. The wearing parts of the primary crusher need to last as long as operationally-economically possible. Typical numbers are for liner and mantles to have a useful wear-life of almost 2,000,000 tonnes on abrasive taconite and 9,000,000 tonnes on porphyry copper ores.

xi. A good primary crusher design should last up to 30 years which is a landmark for dependability and long service life.

xii. The selection of the primary crusher must consider best-in-breed maintenance services as the whole mine's production goes through 1 or 2 of these machines and make the in-pit crusher a vital piece of equipment.

Standard (Secondary) Cone Crusher: This is usually applied as a secondary crusher in a multi-stage crushing circuit. The small diameter feed distributor and the wide throat opening at the top of the liners enable the Standard Cone crusher to accommodate the larger feed produced by the

Primary crusher. The HSI crushers break rock by impacting the rock with hammers that are fixed upon the outer edge of a spinning rotor. HSI machines are sold in trailer mounted and crawler mounted configurationsand in stationary. HSI's are used inhard rock and soft materialsand in recycling.In earlier years the practical use of HSI crushers is limited to soft materials and non-abrasive materials, such as limestone, phosphate, gypsum, weathered shales, however improvements in metallurgy have changed the application of these machines(fig.1.3)

Feed opening and product size ranges for the various models of the Standard Cone crusher are as follows:

a) Maximum Feed Opening — 625MM (25 In.)

b) Recommended Product Range — 100MM to 19MM (4 In. to ¾ In.)

Fig.1.3: Picture of a secondary crusher (adapted from Kamla, 2010)

"Environmental degradation accompanies mining operations and remains after they cease, with air pollution, scars on the landscape and threatened surface and underground waters. Quarrying activities dates back to the beginning of the 20^{th} century and are conducted not in isolated areas but near water bodies, farmland and human settlement"(Kakulu,2003).

"However, increase in demand for sand and gravel for construction purposes has placed immense pressure on sand and gravel and rock resources. Therefore, the extraction of these important aggregates is bound to have considerable negative effect on the place where they occur" (Ako, 2014).

Dredges are wet pit operations that remove sand as a slurry directly from the stream channel. The water and coarse aggregate are separated from the sand in a trammel. The separated water is piped to a clarification pond to settle out suspended sediment before it is recycled back into the creek. Organic debris is left in the channel, but coarse material (gravel) and trash have been sent to a landfill. This practice may soon be modified to return the gravel to the channel. The dredges are constrained to operate within a 100 meter segment of channel in which they essentially remove all of the sand down to the bedrock and clay floor of the channel during the excavation.

"Sand dredging operations can produce large quantities of suspended sediment, elevating turbidity levels and creating deposits in streams. There are several physical effects on streams caused by dredging activities: change in channel morphology, locally increased water velocity and scour, head cutting, streambed modification, enhanced fine particle deposits, remobilization of contaminants in the sediment, and increased turbidity" (Brooks,1998). All these effects mentioned shall depend upon the local mining site conditions and dredging methodology.

Additionally, the quality assessment of these aggregates used for road and construction purposes shall be subjected to different test methods for strength and durability of various locations.

1.1.0 Classification of Aggregate Mining Impacts

1.1.1. Engineering impact

Engineering activities during aggregate exploitation and processing lead to environmental problems during mining. The most conspicuous engineering effect being the change in geomorphology, conversion of land use and sudden changes in aesthetic view. The major impact is accompanied by dereliction of the mined site, noise, vibrations, loss of habitat, dust, erosion, chemical spills and sedimentation. Some of the impacts are easy to evaluate and short-lived and easy to notice.(Barksdale,1991) "said that most engineering impacts can be controlled, mitigated, kept at tolerable levels and restricted to the immediate vicinity of the aggregate operation by employing responsible operational practices that use available engineering techniques and technology". Engineering impacts can cause other impacts as sub classified below:

1.1.2. Cascading impacts

"In Karst environments, aggregate mining may alter sensitive parts of a natural system at or near the site thus creating cascading environmental impacts as suggested"by (Langer, 2001). Cascading impacts are triggered by engineering activity which includes the removal of rock, through alteration of the natural system.

1.1.3. Geomorphic impact

"Quarrying has an associated, often dramatic, visual impact. Karst terrain is commonly considered to be of high scenic value, thus compounding the effects of visual impact of quarrying. The principle geomorphic impact of quarrying is the removal of stone, which results in the destruction of habitat including relict and active caves and natural sinkholes. The extent of the geomorphic impact is a function of the size of the quarry, the number of quarries and the location of the quarry, especially with respect to the overall landscape and land forms. The influence of quarry size on environmental impact is obvious: all things being equal, the larger the quarry, the larger the geomorphic impacts. The size of quarries has increased over time, and so has their impact. Great numbers of quarries in a Karst and Region amplifies the geomorphic impact"(Ukpong, 2012). (Adepoju, 2002)" suggested that the disturbance created by numerous smaller quarries is greater than that created by one large quarry and recommend that geomorphic disturbance be minimized by maximizing reserves through deep quarrying".

1.2 Noise

"Noise is an unwanted sound-produced by a source causing vibrations in the medium around it"(Agunwamba, 2001). According to the International Programme on Chemical Safety (WHO,1984)," an adverse effect of noise is defined as change in the morphology and physiology of an organism that results in impairment of functional, capacity, or an impairment of capacity to compensate for additional stress, or increases the susceptibility of an organism to the harmful effects of other environmental influences. Drilling or shotholes, deposition of rock pieces into the jaw crushes by pail-loaders, grinding action of crushers, power generating sets, vehicular motion and rock blasting with explosives are major source of noise within and around the quarry site". (Langer, 2001) "Reported that the impacts of noise and highly dependent on sound source, the topography, land use, ground cover of the surrounding site and climatic conditions. The beat, rhythm, pitch of noise and distance from the noise source affect the impact of noise on the receiver. Exposure to noise pollution arising from industrial machines can induce hearing loss and other pathological changes in the affected worker".

1.2.1. Effect of noise

a) Noise induced hearing impairment worldwide, noise-induced impairment is the most rampart irreversible occupational hazard. (Wills,1995)" reported that in 1995 at the World Health Assembly, it was estimated that there were 120 million persons with disabling hearing difficulties worldwide". "It has been shown that men and women are equally at risk of noise-induced impairments" (Berglund,1974). Another sensory effect that results from exposure is tinnitus (ringing in the ears). Commonly, "tinnitus is referred to as sounds that are emitted by the inner ear itself (physiological tinnitus)"(WHO,1984).

b) Interference with speech communication

"Noise interference with speech communication results in a large number of personal disabilities, handicaps and behavioural changes. Problem with concentration, fatigue, uncertainty and lack of self-confidence; irritation, misunderstandings, decreased working capacity, problems in human relations, and a number of stress reactions have all been identified. Environmental noise may also mask many other acoustical signals important for daily life, such as door bells, telephone signals, alarm clocks, and other warning signals and music. As the sound pressure level of an interfering noise increases, people automatically raise their voice to overcome the masking effect upon speech (increase of vocal effort). This imposes an additional strain on the speaker"(Ukpong,2012).

c) Sleep disturbance

Uninterrupted sleep is known to be a prerequisite for good physiological and mental function of healthy persons, sleep disturbance on the other hand is considered to be a major environmental noise effect. According to William (1996), "from study findings the general conclusion can be drawn to ensure undisturbed sleep, the maximum sound pressure level should not exceed 45db (A). The primary physiological effects that can be induced by noise during sleep include increased blood pressure, increased hear beat, increased finger pulse amplitude, vaso constriction, changes in respiration, cardiac arrhythmia and an increase in body movement".

d) Cardiovascular and physiological effects

"Epidemiological studies involving workers exposed to occupational noise, and general populations (including children) living in noisy areas around airports, industries and noisy streets, indicate that noise may have both permanent and temporary impacts on physiological functions in humans"(William,1996).

e) Mental health effects

FEPA (1991)" defined mental health as the absence of identifiable psychiatric disorders". "According to current norms studies on the diverse effect of environmental noise on mental health cover a variety of symptoms, including anxiety, emotional stress, nervous complaints, nausea, headache, instability, argumentativeness, sexually impotency, change in mood, increase in social conflicts as well as general psychiatric disorders such as neurosis, psychosis and hysteria".

1.3. Dust

(Agunwamba, 2001) "Defined dust as solid particles dispersed in a gaseous medium as the result of the mechanical disintegration of matter". According to Ademola (2008), "dust is one of the most visible, invasive and potentially irritating impacts associated with quarrying, and its visibility often raises concerns that are not directly proportional to its impact on human health and the environment. Dust may occur as fugitive dust from excavation, from haul roads, and from blasting, or from point sources, such as crushing and screening".

1.3.1. Effect of dust

a) Effects of plants

There is significant effect of dust deposits on plant life especially at high dust loading whichincludes:

(1) Reduction of photosynthesis as a result oflight penetration through the leaves.

(2) Plant pet and diseasesincidence increase.

Dust deposits is an avenue for the growth of fungal disease. In addition, it appears that sucking and dust deposits to any great extent do not affect chewing insects, whereas their natural predators are affected.

(3) Reduction of effectiveness of pesticides spray as a result of reduction of penetration.

b) Effect on human beings and health

The dust contaminationwhich is harmful can be seen in various locations where people choose to spend their time, without knowing that they are breathing in dangerous dust particles which may be linked to a barrage of dangerous respiratory illnesses. There may also be minimal health effects like eye irritation when the dust is airborne.If dust predicaments arepermitted to persist for an unreasonable length to time, indirect stress- related health effects could also arise. "For instance, some mineral dusts contain quantities of quartz, which can cause the lung disease known as silicosis when persistent at high concentrations. Exposure of workers to high dust level causes irritation of the respiratory tracts as well as the eyes"(Ukpong, 2012).

c) Soiling and amenity value effect

"This leads to aesthetic degradation caused by both active and abandoned aggregated. The most common areas of concern include the visual soiling of clean surfaces such as cars, window ledges, and household washing. Dust deposits on flowers, fruits and vegetable"(Ukpong,2012).

1.4 Potentially Harmful Materials in Aggregates

"Harmful substances that may be present in aggregates include organic impurities, silt, clay, shale, iron oxide, coal, lignite, and certain lightweight and soft particles. In addition, rocks and minerals such as some cherts, strained quartz" (Buck and Mather, 1984). And certain dolomitic limestones are alkali reactive (see Table 1). Gypsum and anhydrite may cause sulfate attack. Certain aggregateslike some shales, will cause popouts by swelling (simply by absorbing water) or by freezing of absorbed water. Most specifications limit the allowable amounts of these substances. The observed history of an aggregate should be a determining factor in setting the limits for harmful substances. Test methods for detecting harmful substances qualitatively or quantitatively are listed in Table 1. Aggregates that contain compounds known to react chemically with portland cement concretemay be potentially harmful and produce any of the following: (1) significant volume changes of the paste, aggregates, or both; (2) interference with the normal hydration of cement; and (3) otherwise harmful byproducts. Organic impurities may delay setting and hardening of concrete, may reduce strength gain, and in unusual cases may cause deterioration. Organic impurities such as peat, humus, and organic loam may not be as detrimental but should be avoided. Materials finer than the 75-µm (No. 200) sieve especially silt and clay, may be present as loose dust and, may form a coating on the aggregate particles. Even thin coatings of silt or clay on gravel particles can be harmful because they may weaken the bond between the cement paste and aggregate. If certain types of silt or clay are present in excessive amounts, water requirements may increase significantly.

Table 1 Showing harmful effect of materials on aggregates (adapted from Dolar-Mantuani, 1983)

Substances	**Effect on concrete**	**Test designation**
Organic impurities	Affects setting and hardening, may cause deterioration	ASTM C 40 (AASHTO T 21) ASTM C 87 (AASHTO T 71)
Materials finer than the 75-µm (No. 200) sieve	Affects bond, increases water requirement	ASTM C 117 (AASHTO T 11)
Coal, lignite, or other lightweight materials	Affects durability, may cause stains and popouts	ASTM 123 (AASHTO T113
Soft particles	Affects durability	ASTM C 235
Clay lumps and friable particles	Affects workability and durability, may cause popouts	ASTM C 142 (AASHTO T 112)
Chert of less than 2.40 relative density	Affects durability, may cause popouts	ASTM C 123(AASHTO T113) ASTM C 295
Alkali- reactive aggregates	Causes abnormal expansion, map cracking and popouts	ASTM C227 ASTM C289 ASTM C295 ASTM C342 ASTM C586 ASTM C1260 (AASHTO T 303) ASTM C 1293

1.5 Statement of Problems

Aggregate mining operation poses serious environmental problems to both the inhabitants and the workers and physical environment.

No work has been done on the environmental effects of quarrying of aggregates on Njaba, Otamiri and Nworie River in relation to its effect on bridge foundation and also effect of dust / gaseous emissions in Lokpaukwu, Ishiagu and Afikpo quarry sites on humans.

Similar works have been done outside Nigeria on evaluation of air quality in Sudanese gold mining field (Kamal, 2019).

Most research centered on analyzing the quality of aggregates without comparing its quality with the various formations where they occur.

There are increased pavement failures due to poor quality of aggregates for road construction.

Indiscriminate extraction of sand and gravel in these areas threaten river ecosystems.

1.6 Aim of Study

The aim of this study is to assess the environmental impacts of quarrying in parts of southeastern Nigeria and the suitability of aggregates produced in their quarries as concrete and highway pavements materials.

1.7Objectives of the study

This includes:

i) To identify and analyze the quality of aggregates produced at the quarry sites.

ii) To identify, characterize and compare the air quality parameters including Suspended Particulate Matter (SPM) in these quarries with National Environmental Regulations, 2009.

iii) To identify the sources of noise, assess the noise levels and ascertain the impact of the elevated noise levels in the various quarries.

iv) To assess the consequences of sand and gravel mining in terms of accumulation of heavy metals on surface water in the area.

v) To assess, measure and evaluate the width and depth of rivers at extraction point.

1.8 Scope of the Study

The scope of the work involves the identification of the environmental problems associated with quarry and sampling of aggregates derived from the study area.

1.9 Justification of theStudy

Quarrying activity in southeastern Nigeria poses environmental problems. There is need to evaluate the impact of these activities on the environment and suggest mitigation measures.

There is increasing demand for sand, gravel and crushed rock aggregates in the construction industries. There is therefore, need to evaluate the quality of aggregates from existing quarries since the strength and durability of engineering structures constructed with these aggregates depend on the quality of aggregates.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Previous Work

The consequences of quarrying of rock have been studied by various scholars including Langer (2003), Kondolf(2008) and Kondolf (1998) "have shown that in-stream mining of these aggregates can reduce water quality as well as degrade the channel bed and banks. The extraction of sand and gravel from rivers, streams, floodplains and channels conflict with the functionality of river ecosystems. Some of the disturbance is from the mining methods and machineries used. The most common environmental impact is the attraction of land use, most likely from underdeveloped or natural land to excavations in the ground".

Musah (2009) "assessed the sociological and ecological impacts of sand and gravel mining and he noticed that the commercial gravel extraction to supply aggregate to the construction industry had been on the increase in recent years in Ghana. His study revealed loss of farm or grazing lands, formation of pits with water stored in them, enhancement of erosion and loss of vegetation, destruction of landscape, generation of conflicts, loss of biodiversity and dust pollution. Other impacts include abandoned mine pits serving as sources of breeding grounds for the spread of diseases, loss of economically important trees which causes unemployment among women folk, and the pollution of underground water".

Aromolaram (2012) "studied the effects of sand mining activities of rural people on agricultural land in Agraian communities of Ogun State, Nigeria. His work revealed that mining of sand and gravel on agricultural land is one of the alternative livelihood activities of the rural people and is now becoming an environmental issue. He noticed that sand mining is widespread, highly unregulated, uncontrolled and is being carried out at an alarming rate, and having noticeable impacts on the soil structure, vegetation and local wildlife in the rural areas".

Steve Blodgett (2004) "carried out the environmental impacts of aggregate and stone mining. The results of his study showed that the primary environmental impacts from aggregate and stone mining in New Mexico are degraded air quality and associated health effects, resulting from airborne emissions from both the stack and the disturbed areas at these mines".

Ako(2014) "studied the environmental effects of sand and gravel mining on land and soil in Luku, Minna, Niger State, North Central Nigeria which indicated the destruction of landscape, reduction of farm and grazing land , collapsing river banks, deforestation and water pollution, and high concentration of heavy metals".

Vincent (2012) "carried out effects of quarry activities on some selected communities in the lower Manya Krobo district of the Eastern region of Ghana, this study revealed high dust emission during dry and rainy season and recording high values against the acceptable EPA, Ghana limit".

Etusim(2013) "investigated the environmental impact assessment of quarry mining on noise pollution in Uturu community which recorded values of noise level at the generator site, primary crusher site and secondary and tertiary crusher sites of 95.5dB, 96.8dB and 94.7Db respectively above the FEPA limit of 90Db".

Mgbemena(2017)" investigated the status of heavy metals pollution in the sediments of New calabar River in River State where Geo-accumulation index(Igeo), contamination factor (CF), degree of contamination (Cdeg), and pollution load index(PLI) were used to ascertain the degree of heavy metals pollution which showed moderate pollution of the sediment samples by lead (Pb) and cadmium (Cd)".

Magdi and Hassan (2019) "carried out a study on scour failure at bridge foundation in Khartoum, Sudan which revealed high scouring rate of water lead to washout of the soil from the embankment of the abutment and the foundation piles; and also foundation design mistakes, poor construction, inadequate abutment protection and lack of maintenance".

Nwimo, Ohaegbulem, Aghamelu, and Nonyelum(2021) "conducted preliminary investigation on the quality of Amasiri sandstone in Southeastern Nigeria as construction material which revealed the predominance of quartz, relatively low WA, moderately low to high SG and reasonable ACV and FI are indications that the sandstone would be marginally suitable as road construction aggregates".

2.2 Study Area Description

2.2.1 Location

The study area is located between Longitudes $6^0 50'$E and $8^0 15'$E and Latitudes $6^0 20'$N and $5^0 20'$N (Fig. 2.0). The study area includes the following towns in southeastern Nigeria: Lokpaukwu, Ishiagu, Uturu, Amasiri,Okigwe, Ihitte-Uboma (Elugwu/Umuchienta), Okwudor(Njaba river), FUTO (Otamiri) and Owerri (Nwaorie).

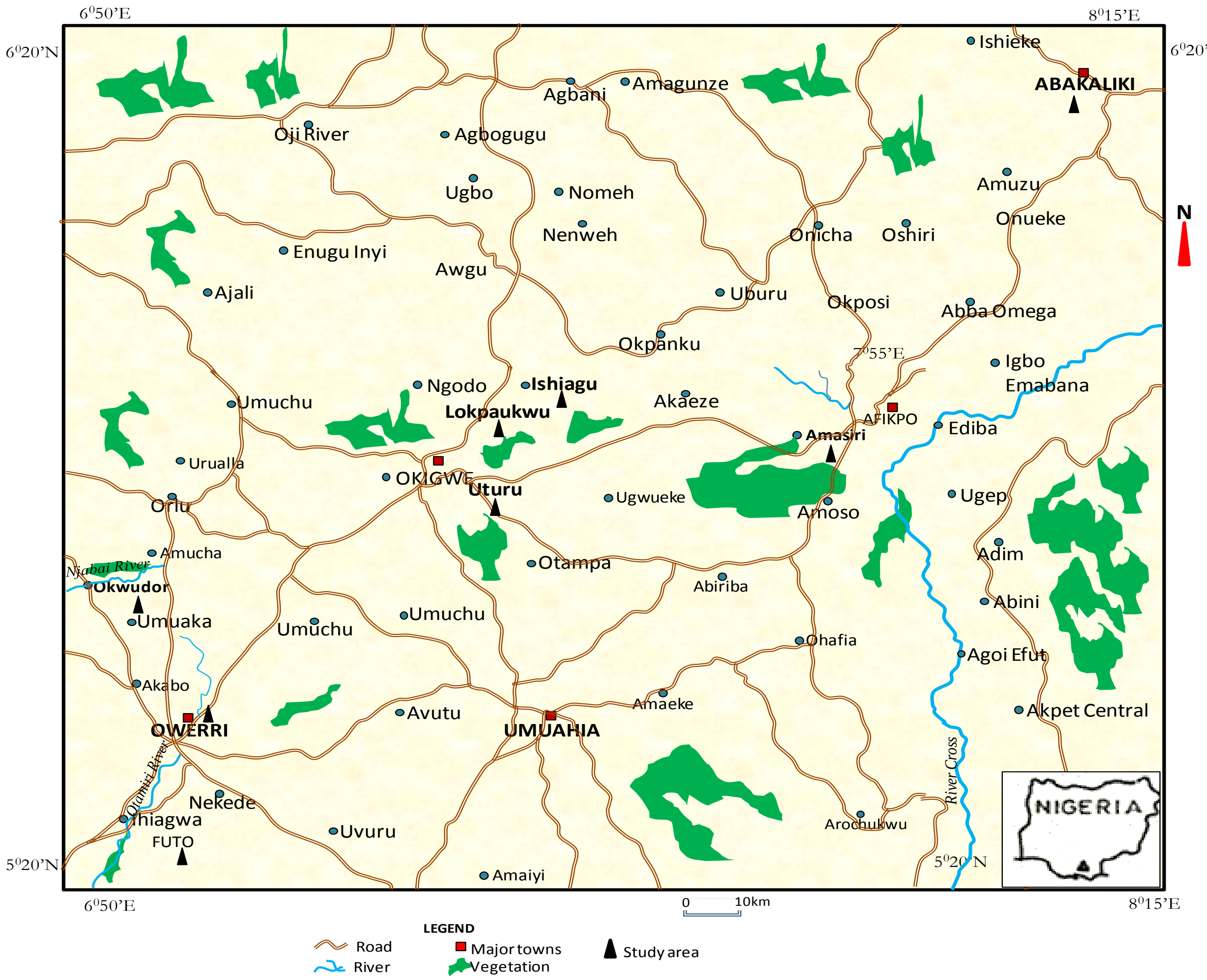


Fig.2.0: Location map of the study area

2.2.2 Drainage

The study area is drained by the Njaba River, Otamiri River, Nworie River, River cross and Aku River respectively.

2.2.3 Climate

There are two seasons in a year in this area, namely: the rainy season and the dry season. The rainy season begins in March and ends in October with a break in August usually referred to as the little dry season. The dry season which lasts for four months begins in November. Heavy thunderstorm is the characteristics of the onset of the rainy season. The hottest months are January to March where the mean temperature is above 27^{o} C. it has an annual rainfall of about 200mm and a high humidity (60-70%pa).The relative humidity is usually high throughout the year reaching a maximum during the raining season when values above 90% are recorded.

2.2.4 General Geology

"Sedimentation in the Lower Benue Trough commenced with the marine Neocomian – Albian Asu River Group, although some pyroclastics of Aptian – Early Albian age have been scantly reported "(Uzuakpunwa, 1975 and Ojoh,1992) (Fig. 2.1).

"The Asu River Group sediments in the Lower Benue Trough comprises predominantly of shales with localized sandstones, siltstones and limestones "(Olade,1975) "as well as extrusive and intrusive material of the Abakaliki Formation in the Abakaliki area and the Mfamosing Limestone in the Calabar Flank" (Peters,1982). In addition, (Akande,2011) described the "Asu River Group as consisting of arkosic sandstones, volcaniclastics, marine shales, siltstones and limestone which overly the Pre-Cambrian to Lower Paleozoic crystalline basement rocks". "The arkosic sediments were derived principally from the extensive weathering of the basement rocks which were invaded by alkaline basaltic rocks prior to the initial rapid marine flooding of the Middle Albian times. The Asu River Group is interpreted as sediments of the first transgressive cycle into the Lower Benue Trough" (Reyment, 1965).

The marine Cenomanian – Turonian Nkalagu Formation (black shales, limestones and siltsones) and the interfingering regressive sandstones of the Agala and Agbani Formations (Cross River Group) rest on the Asu River Group. Although sequence of sandstone, limestones and shales with calcareous sandstones of Odukpani Formation were deposited unconformably on the Basement rocks in the Calabar Flank during the Late Albian. The Santonian was a period of non-deposition, folding and faulting. This was followed by uplift and erosion of the sediments.

The intensive Middle–Santonian deformation and magmatism in the Benue Trough displaced the major depositional axis westward which led to the formation of the Anambra Basin. Post deformational sedimentation in the Lower Benue Trough, therefore, constitutes the Anambra Basin. Sedimentation in the Anambra Basin thus commenced with the Early Campanian – Early Maastrichtian of the Enugu and Nkporo Formations (lateral equivalents) which consist of a sequence of bluish to dark grey shale and mudstone locally with sandy shales, thin sandstones and shelly limestone beds. The shaly facies grade laterally to sandstones of the Owelli and Afikpo Formations in the Anambra Basin. The Enugu and Nkporo Formations are essentially marine sediments of the third transgressive cycle. These, in most parts of the Anambra Basin is overlain by the Lower Maastrichtian sandstones, shales, siltstones and mudstones and the interbedded coal seams of the deltaic Mamu Formation. The deltaic facies grade laterally into the overlying marginal marine sandstones of the Ajali and Nsukka Formations.

The marine shales of the Imo and Nsukka Formations were deposited in the Paleocene. The Nsukka Formation and the Imo Shale mark the onset of another transgression in the Anambra Basin during the Paleocene. Imo and Nsukka Formations are overlain by the tidal Nanka Sandstone of Eocene age. The Eocene Nanka Sands mark the return to regressive conditions. Nanka Formation is overlain by sandstones, shales and lignite beds of the Oligocene / Miocene Ogwashi – Asaba Formation. These Tertiary units constitute the proto- Niger Delta Eocene to Recent sequences in the subsurface. Down dip, towards the Niger Delta, the Akata Shale and the Agbada Formation constitute the Paleocene equivalents of the Anambra Basin.

Geological Survey of Nigeria Agency has played an active role in the exploration for mineral deposits in Nigeria. The Lower Benue Trough like other Sedimentary Basins in Nigeria is found to be endowed with mineral resources. The mineral resources so far reported in the Trough by the Geological Survey of Nigeria Agency are discussed below.

Coal:

"Anambra Basin in the Lower Benue Trough is a major coal producing basin in Nigeria where intensive exploration and exploitation activities have been on since 1916 owing to the discovery of commercial coal in Udi near Enugu in 1909 by the Mineral Survey of Sothern Nigeria" (Fatoye, 2013). "Coal was discovered in the Mamu Formation (formerly called the 'Lower Coal Measures') of the Anambra Sedimentary Basin of south-eastern Nigeria" (Simpson, 1954).

"Occurrence of coals in the Nsukka Formation (formerly called the 'Upper Coal Measures'), located 4 miles north of Okaba town was later reported"(De-Swardt,1963) . Mineable coal deposits in Lower Benue Trough occur at Enugu, Orukpa, Okobo, Okaba, Odokpono and Ogboyaga.

"The coal deposits in the Lower Benue Trough are of medium quality, non-coking and sub-bituminous. These put together suggest that they do not possess some coking qualities suitable for coke making blends. However, the coals are suitable for electric power generation and as domestic fuel. They are also rich in resinous and waxy materials and are therefore suitable raw material for the chemical industry and also for use in the manufacture of plastics,

when fractionally distilled" (Fatoye, 2013). The coals are also good producer of gas fuel, and are suitable for complete gasification using the oxygen enriched steam blast process. They can also be processed to produce automotive fuel.

Lead – Zinc:

"Deposits of zinc and lead minerals in the form of their ores of sphalerite and galena respectively often associated with barytes mineralization in the Cretaceous sediments of the Lower Benue Trough. The general geology of Lower Benue Trough in Abakaliki area is made up of thick sequences (500m) of slightly deformed Cretaceous sedimentary rocks made up of essentially of Albian shales, subordinate siltstones of the Asu River Group. There is also the presence of volcanic and pyroclastic materials forming elongated conical hills in the cores of the anticlinal structures.The Abakaliki lead–zinc is believed to be of hydrothermal origin emplaced at a low temperature of about 140^{o}C and it is made up of primarily four lodes namely;Ishiagu, Enyigba, Ameri and Ameki in the Lower Benue Trough located in Ebonyi State"(Farrington,1952).

Enyigba Lode:

The Enyigba lode which appears to be the largest mineralized body in the Lower Benue Trough section is up to 2km in length and has a width of approximately 30km. It occurs as an open vein fillings of a series of steeply dipping N – S near vertical fault which cuts regional fold (Abakaliki anticlinorium). The lode also extends southwards into Ameri lode.

Ameri Lode:

The Ameri lode which is located south of the Enyigba lode trends almost N – S which flanks the southeastern limb of the Abakaliki anticlinorium. It is also a vein/fracture infilling which appears to be a continuous extension of Enyigba.

Ameki Lode:

The Ameki lode is to the southeast of the above two lodes and is bounded in the north and south by siltstone. The fracture/vein infilling displaces the siltstone border and the Abakaliki anticlinorium. In the Abakaliki area, in particular, lead-zinc mineralization was found associated with calcareous shales and shaly limestones. The Abakaliki field is still Nigeria's most important lead-zinc deposit. Lead is used in the manufacture of cable coverings, pigments, storage batteries, solder, sheet lead and pipes, shot, and bearing metals. Uses of zinc include galvanizing steelplate, the manufacture of brass and other alloys, rubber vulcanizing, and the production of pigments and certain medicines and chemicals.

Barytes:

Barytes occurs as vein infilling materials associated with lead–zinc lodes and veins in the both Pre-Cambrian Basement and Cretaceous Sedimentary rocks of the Lower Benue Trough. Recently the Nigerian Geological Survey Agency embarked on the evaluation of newly reported deposit in Cross River State. Barytes veins in Cross River State are hosted in both hard and soft rocks. This study divided the mineralized areas into: North comprising of Obubra, Ikom and Yala LGA and the South consisting of Biase and Yakkur LGA. Barytes are hosted more by sedimentary rocks in the north while in the south only 2 out of 18 locations are in sedimentary rocks.The importance of barytes in the oil, paint and paper industries is well known. At the present time, Nigeria imports a considerable quantity of this mineral for use in its oil-operations. Barytes is the chief constituent of lithopone paint and it is also extensively used as an inert volume and weight filler in drilling mud, rubber, glass, paper, etc. and in the chemical industry.

Limestone:

"The Sedimentary limestone of Cretaceous and Tertiary ages is associated with shale, siltstone, and fine-grained sandstone in Lower Benue Trough. They are often hard, gray and shelly. In all occurrences the deposition of limestone is related to the transgressive and regressive cycles in the Trough. The shallow water sediments of the Albian around Mfamosing, contain the largest and the purest deposit in Nigeria. It is about 50 metres thick, at the quarry site.

The first Middle Albian transgression ended about the Cenomanian, marking its shorelines with the deposition of the limestones of the Odukpani Formation, at the Calabar Flank, in the southeast. The Calabar Flank is the main carbonate province in Nigeria, with well-developed tropical karsts and caves" (Reijers, 1998).

"The Mfamosing limestone has over 96 percent calcite ($CaCO_3$). Reserves in this area exceed 30 million tonnes. The Calabar Cement Company (CALCEMCO) was using the limestone for cement alone. It was also used by the Delta Steel plant at Aladja as a fluxing agent and for making hydrated lime. Over 174 million tonnes of limestone exist in Nkalagu area in Ebonyi State and occur within the Turonian – Eze-Aku Formation. There are six major limestone beds varying in thickness from 3 – 10 metres each. The Nigerian Cement Company (NIGERCEM) was the sole worker of this deposit for cement manufacture. Apart from cement manufacturing, limestone is used as cut stone for building, as crushed stone, or aggregate, for general building purposes, roadbeds and railway lines. Finely crushed limestone is also used as filler in industrial products such as asphalt, rubber, paint, plastic, and fertilizers. When heated, the calcium carbonate in limestone decomposes to lime, or calcium oxide, and is important as a flux in smelting copper and lead ores and in making iron and steel. Lime is a key ingredient in the manufacture of cement and concrete. It also used in the production of asbestos, glass and ceramics"(Farrington, 1952).

Clay:

Clay is found almost everywhere in Lower Benue Trough, though not always in sufficient quantity or of suitable quality for modern industrial purposes. Excellent clays that could be put to a variety of uses are found around Awka and Owerri. Fire-clay is found in the Late Campanian – Late Maastrichtian Lower Coal Measures of Anambra Basin at Enugu. "Clay is one of the earliest mineral substances utilized by man. It played an extremely important part in ancient civilizations, records of which were preserved in brick buildings, in monuments and in pottery, and as inscriptions upon clay tablets. Clay is still an indispensable raw material today. The present uses of clay and clay products are too numerous to list completely. In domestic life, clay is used extensively in pottery, earthenware, china, cooking ware, vases, plumbing fixtures, tiles, porcelain wares and ornaments. In building, it is used for building bricks, vitrified and enameled bricks, tiles for floors, roofs, walls and drains, sewer pipes and as an ingredient of cement. In the electrical industry, it is used for conduits, sockets, insulators and switches. It is used on a large scale in making refractory ware, such as fire bricks, furnace linings, chemical stone ware, crucibles, retorts and saggars"(Peters,1978).

Glass Sands:

Large deposits of glass sands occur in the Maastrichtian False-bedded Sandstones along the escarpment near Enugu in Anambra Basin. Glass sand deposits are also found in many localities; and some of these have been investigated and found to occur in sufficiently large quantities and good quality to support bottle-making industries. Glass sands are also being exploited in Port Harcourt and Ughelli for the manufacture of sheet glass.

Gypsum:

In the Lower Benue Trough, gypsum has been found as scattered crystals in Cretaceous and Tertiary clays and shales in Anambra and Imo States. No workable deposits have yet been found. Gypsum is a minor but essential ingredient of cement, in which its function is to control the setting time. Gypsum is important also as a fertilizer and for making plaster and plaster-board.

Phosphate:

Phosphate is closely associated with gypsum and limestone in Lower Benue Trough. It is found in Cretaceous shales and clay in Imo State. The Geological Survey of Nigeria Agency is currently attending to evaluate the quantity of the mineral in the area. Phosphate is used for fertilizer manufacturing. Detergents, metal treatment, water treatment, pulp and paper, glass and ceramics, textiles, plastics, rubber, pharmaceuticals and cosmetics, petroleum production, toothpaste, paints, fuels, cells are end-user industries of phosphate rock. Phosphates are also used in flame retard/fire extinguisher production, food and beverage industries, dentistry, etc. It is also important to metabolism in both plants and animals.

Fluorspar:

Fluorspar occurs in small quantities in the lead-zinc lodes in the Albian shales, siltstones and limestones of Asu River Group in Ishiagwu and Ogoja, but the deposits are generally too small to be of value. Fluorspar or Fluorite is a mineral composed of calcium fluoride (CaF_2), the principal fluorine-bearing mineral. The main use of fluorite has been for the production of hydrofluoric acid, an essential raw material in the manufacture of synthetic cryolite and aluminum fluoride for the aluminum industry, and in many other applications in the chemical industry. It is also employed as a standard flux used in the making of steel, in the smelting of lead ores, in ceramic industry and in the production of enamel and opal glass, andperfect crystals are used for the manufacture of a pochromatic lenses.

Ironstone:

"Lateritic ironstone, consisting of loose angular fragments with some clayey sand, was discovered in 1952 on the high country west of Enugu. Large reserves are present, but only certain stretches of unfarmed land close to the Enugu Colliery have been investigated. Prospecting undertaken by the Geological Survey of Nigeria Agency has indicated nearly 50.8 million tonnes of ironstone in a bed from 1.5m to 9.1m thick, overlain by clayey soil ranging up to 15.2m in thickness. By screening out the sandy matrix, material with an average iron content of 43 percent can be obtained. The deposit, although of low grade, is favourably situated close to the colleries, and limestone is available a few kilometers to the east. However, because the Enugu coal does not yield coke, the conventional blast furnace cannot be used to reduce the ore to the metallic state. Ironstone is a source of iron (Fe), it is used as a component in some ceramics and also as a building material"(Farrington, 1952).

Salt/Brine:

The folded Cretaceous rocks of the Lower Benue Trough give rise to many dilute brine springs that are the centres of village salt industries. Such springs are known to occur mainly in Abakaliki. Attempts in the past to prove the quality and quantity of the brine at depth by drilling were unsuccessful. In 1966, the Geological Survey of Nigeria analysed samples of water which it obtained during the dewatering of a 76.2m deep mie shaft at Ameri by the Nigerian Lead-Zinc Mining Company. The water was shown to have a relatively high salinity, with the highest obtained percentage of dissolved solids being 7.98 percent of the total dissolved solids in the brine was found to be composed of common salt (NaCl). No buried rock salt has been discovered in the Trough and even elsewhere in the country by the Geological Survey of Nigeria Agency. Salt is the most familiar of all minerals and has played an important role from the beginning of man. It is used for a great variety of purposes in the chemical, metallurgical and ceramic industries, and in agriculture, medicine, and the household. Salt is so widespread in its uses that the materials made from it or requiring its use in their manufacture are continually met in everyday life. Some of its uses are the manufacture of industrial chemicals like soda, sodium bicarbonate, caustic soda, chlorine, and certain acids; the smelting and refining of ores and metals, the making of soap and dyes, the tanning of leather, the preservation of foods, the making of explosives, and the bleaching of cotton and paper.

Uranium:

"The Lower Benue Trough which occupies most of the eastern part of the country is filled with Cretaceous to Quaternary sediments. Most of these sediments are marine and consequently of no potential for uranium mineralization. However, uranium anomalies which may be indicative of uranium mineralization have been located by airborne spectrometric survey in some of the continental sediments, notably in the Ajali Sandstone. The anomalies in the formation occur along a belt stretching from Okigwe in the south to Angba about 150 km away in the north. Uranium is used for the production of nuclear weapons and as a potential source of industrial power"(Farrington, 1952).

Sulphur:

Native sulphur is the chief commercial source of sulphur, but pyrites and anhydrites are also mined for their sulphur content. Pyrites and marcasite, sulphides of iron, occur in the lead-zinc ores of Abakaliki and it is possible that they could be concentrated at the same time as the lead-zinc ores. Sulphur is used in chemical and fertilizer, insecticide, paper, paint, explosive, dye, rubber, oil-refining, textile, sugar, and many other industries.

Cassiterite:

Small amounts of cassiterite, ore of tin have been found in the Oban Hills Older Granite massif of Cross River State in the Lower Benue Trough. "Tin is a widely sought metal and is used in hundreds of industrial processes throughout the world. In the form of tinplate, it is used as a protective coating for copper vessels, various metals used in the manufacture of tin cans, and similar articles. Tin is important in the production of the common alloys bronze (tin and copper), solder (tin and lead), and type metal (tin, lead, and antimony). It is also used as an alloy with titanium in the aerospace industry and as an ingredient in some insecticides. Stannic sulphide, known also as mosaic gold, is used in powdered form for bronzing articles made of plaster of paris or wood. Its compounds are used in dyeing and fire-proofing"(Reijers and Nwajide, 1998).

Mica:

Small deposits of mica are known in the Oban Hills of Cross River State. Muscovite, also called white mica or common mica is used as insulating material in the manufacture of electrical apparatus, particularly vacuum tubes. Scrap mica, obtained as waste material in the manufacture of sheet mica, is used as a lubricant when mixed with oils and as a fireproofing material.

Silver:

Small amounts of silver are as well present in the lead-zinc ores of galena and sphalerite respectively in Abakaliki lead-zinc field and this could probably be recovered as a by-product if the ore is mined on a sufficiently large scale. The use of silver in jewelry, tableware, and as coinage is well known. The metal is usually alloyed with small amounts of other metals to make it harder and more durable. Silver is used to coat smooth glass surfaces for mirrors by vaporization of the metal or by precipitation from a solution. Silver is also widely used in the circuitry of electrical and electronic components. Colloidal silver, dilute solutions of silver nitrate ($AgNO_3$), and some insoluble compounds, such as potassium, are used in medicine as antiseptics and bactericides. Argyrol, a silver-protein compound, is a local antiseptic for the eyes, ears, nose, and throat. The silver-halide salts—silver bromide, silver chloride, and silver iodide—which darken on exposure to light, are used in emulsions for photographic plates, film, and paper. The salts are soluble in sodium thiosulphate, which is the compound used in the photographic fixing process.

Table 2: Lithostratigraphic Succession of Lower Benue Trough (modified from Peters, 1982)

Geologic Age	Geologic Formation	Lithologic Description
Pleistocene-Holocene	Alluvium and Quaternary deposits	Unconsolidated Freshwater sands and gravels with silt and clay admixtures
	Beach Ridges	Fine grained grayish white sands
Oligocene-Pliocene	Coastal Plain sands	Course to medium grained unconsolidated sands, with gravels ferruginous sandstones and clays.
Oligocene-Pliocene	Ogwashi - Asaba Formation	Gritty clays and pebbly sandstones with lignite layer
Eocene	Bende – Ameke Formation	Sandstone and shale sequence with boulder and shalely limestone.
Paleocene	Imo shale Group	Grey Calcareous shales and siltstones with bands of sandstone and ironstone.
Maastrichtian	Nsukka Formation	Alternating sequence of shales and sandstones with coal seams (the coal measures)
	Ajali Formation	
	Mamu Formation	
Campano – Maastrichtian	Nkporo Formation	Dark grey shales and soft mudstones with occasional thin beds of sandstones and limestones
Coniacian	Awgu – Ndeaboh Shale Group	Shales with thin limestone bands and lenticular sand bodies.
	New Netim Marl Formation	Thick Marl unit with intercalations of thin bands of dark shales

Turonian	Amaseri Sandstone Formation	Formation highly bio-turbated fine to medium grained calcareous sandstones with fossilferous shales at the base.
	Ezillo Formation	Dark grey shales with fine sandstone and siltstone intercalations.
	Ezeaku Formation	Alternating shales, siltstones and limestones with lateral facies changes to sandstones
Cenomanian	Ekenkpon Shale	Thick black highly fissile shales with intercalations of marls, calcareous mudstones and shell beds.
Albian	Asu River Group	Poorly bedded sandy shales with fine to medium grained sandstones lenses.
	Mamfe Formation	Cross bedded coarse to medium grained immature sandstones with basal conglomerates and arkoses.
	Mfamosing Formation	Massive bedded grey chalky limestones with fossils
Aptian – Neocomian	Awi Sandstone Formation	Fluvio – deltaic clastics consisting of grits, sandstones mudstones and shales.

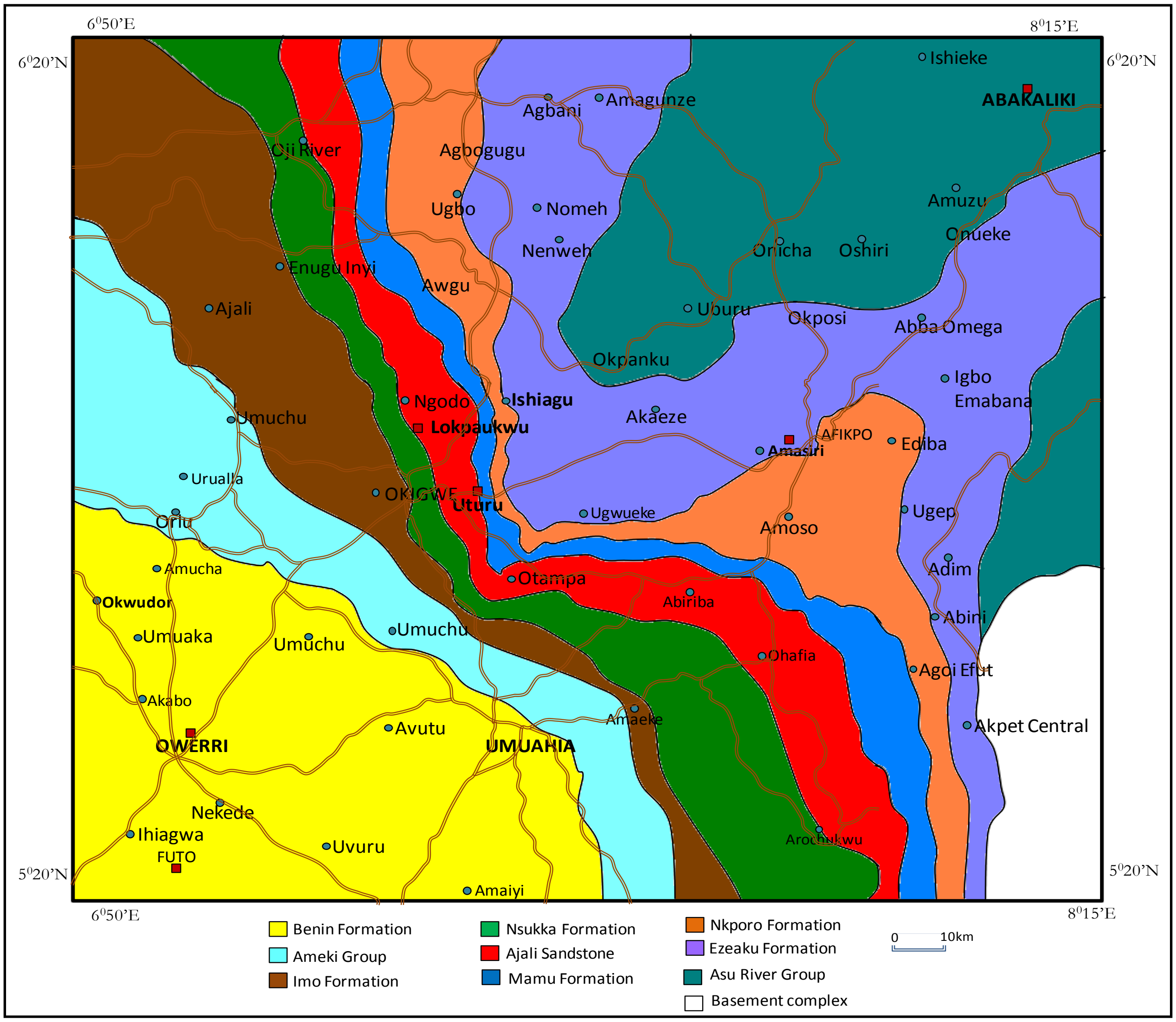


Fig.2.1: Geologic Map of the Study Area (adapted from NGSA, 2004)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1Field Studies and Samples Collection

The field work and laboratory study were carried out in order to get the desired result.

First, the reconnaissance survey of the area was done and, the mine/ quarry sites were located in which the aggregate and surface water samples were collected and, the depth of active mine site of river channel in comparison with the upstream and downstream of active mining areas, dust and noise were also measured.However, the environmental aspect identified in the fieldwas captured through the use of a digital camera.

3.1.1 Collection of Aggregate Samples

About 10kg of crushed rock aggregates - andesite, diorite and dolerite from different point locations were collected from Lokpaukwu quarry site, Uturu, Ishiagu quarry site and Afikpo quarry site respectively as shown in fig.1.0. And also, sandstone samples were collected from Okigwe and Ihitte-Uboma (Elugwu/ Umuchienta) for analysis. The samples were bagged in polythene bags, labeled and taken to Ministry of works Laboratory, Owerri and Civil Engineering Laboratory of Federal Polytechnic Nekede Owerri, Imo State for various test. The tests were carried out to test the following parameters including aggregate crushing value, aggregate impact value, Los Angeles abrasion value, water absorption, bulk density, concrete compression test and specific gravity(BS 812, 1975 and AASHTO T96-92, 2001) and in accordance to the Nigerian Federal Ministry of Works and Housing (1997).

3.1.2 Collection of Surface Water Sample

The surface water samples were collected from the various rivers where active sand and gravel quarrying is taking place. Six water samples were collected for analysis from the upstream and downstream of Njaba, Nworie and Otamiri rivers. The containers were washed thoroughly and rinsed with the same sample before collection to avoid analytical error. The samples were adequately labeled at the time of collection.

3.1.3 Measurement of Noise Level

The noise level data was measured at the predetermined sample points using sound level meter/ dosimeter (TES sound level meter model TES 1350a in table 3). Eight (8) measurements were taken for noise level at the following locations including blasting pit, primary crusher, secondary crusher, generator house, aggregate dump, admin block, staff quarters and the entrance gate and compared with the Federal Ministry of Environment limits and NESREA limits. Sound level meter is an instrument for measuring the intensity of noise. This includes music and other sounds. It consists of a microphone for picking up the sound and converting it into an electric signal, an amplifier, a filter bank and detector/ readout and other electric systems so that the desired characteristics can be measured.

3.1.4 Measurement of Dust

The equipment used is the haz-dust TM particulate monitor (Table 3) with exchangeable filtersconnected to with the following instrument: weighing balance, air pump and containers with filters. The following pollutants were also analyzed SO_2, CO, H_2S, HCN, NH_3, Cl_2, NO_2 and was compared with the Federal Ministry of Environment limits.

Table 3 : Methods used in determining the Gaseous Emissions

Parameters	Equipment	Range	Alarm levels
Sulphur dioxide (So_2)	SO_2 Gas monitor Gasman model 19648H	0-10ppm	2.0 ppm
Carbon Monoxide (CO)	CO Gas monitor Gasman model 19648H	0-50ppm	50ppm
Volatile Organic Carbon (VOC)	A multi RAE plus	0-200ppm	
Nitrogen dioxide (NO_2)	NO_2 Gas monitor Gasman model 19648H	0-10ppm	3.0 ppm
Hydrogen Sulphide H_2S	H_2S Gas monitor Gasman model 19648H	0-5ppm	10ppm
Ammonia (NH_3)	NH_3 Gas monitor Gasman model 19648H	0-50ppm	25ppm
Chloride (Cl_2)	Cl_2 Gas monitor Gasman model 19648H	0-5ppm	0.5ppm
Hydrogen Cyanide (HCN)	HCN Gas monitor Gasman model 19773	0-25ppm	5.0ppm
Suspended Particulate Matter (SPM)	Haz-Dust TM particulate monitor	0.1-200	+1.0
Radiation	Radiation alert monitor 4 se international USA	0.5-5MR/hr	

3.1.5 Measurement of Active Mine Site of River Channel

The river channels measured included the Njaba river channel, the Nworie river channel and the Otamiri river channel where sand mining is taking place.The area upstream of the mining site is taken to be undisturbedlocation and thus considered as reference site. The mining site isregarded as an area of potential active sand mining. The downstream area isregarded as the downstream of the active mining site, but without mining activity.In each of the three sitessample points were selectedfor morphometric assessment.Width of the three river channels weredetermined with the help of metal tape through one end of theriverchannels to the other horizontally on transect at 6-m intervals. The depth of the three rivers channels weredetermined from the lowest point in the flood plain to the top of the bank with the use of a steel metal tape.

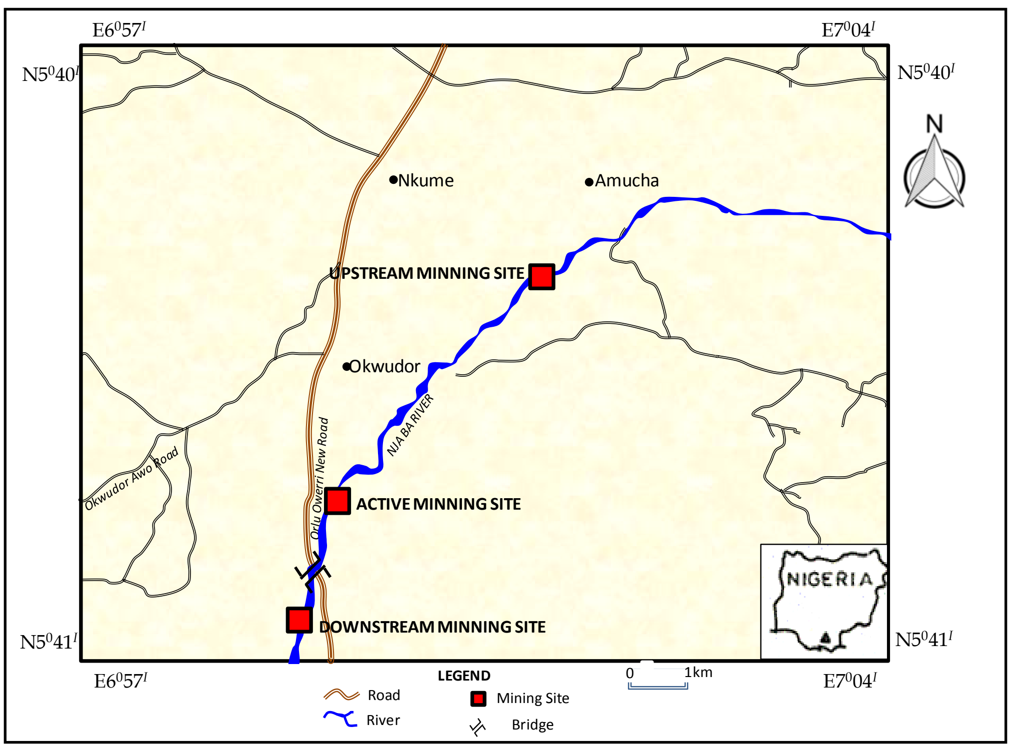


Fig. 3.0: Map showing Njaba river mining site

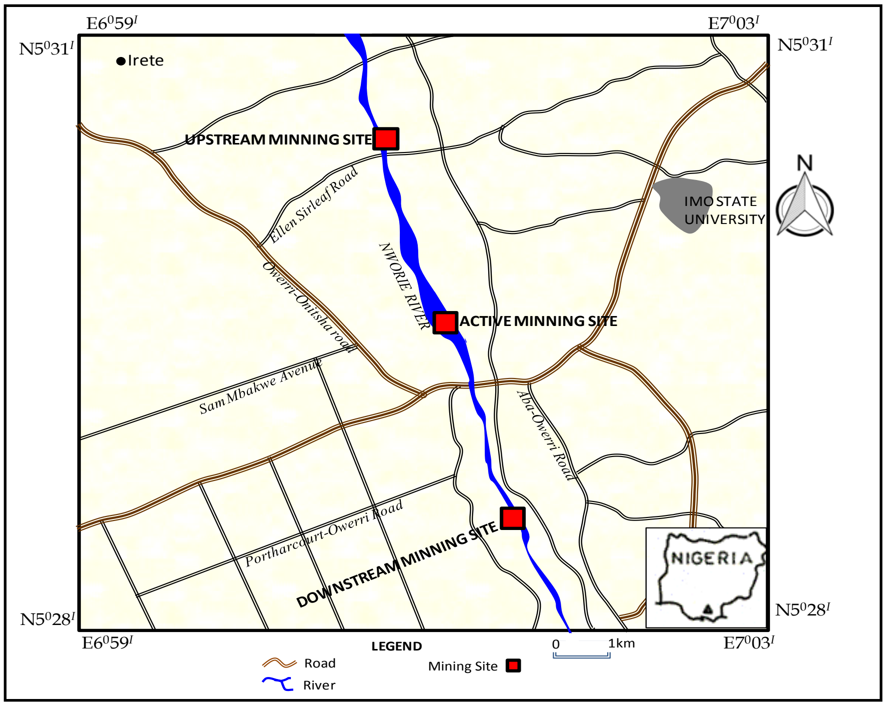


Fig. 3.1: Map showing Nworie river mining site

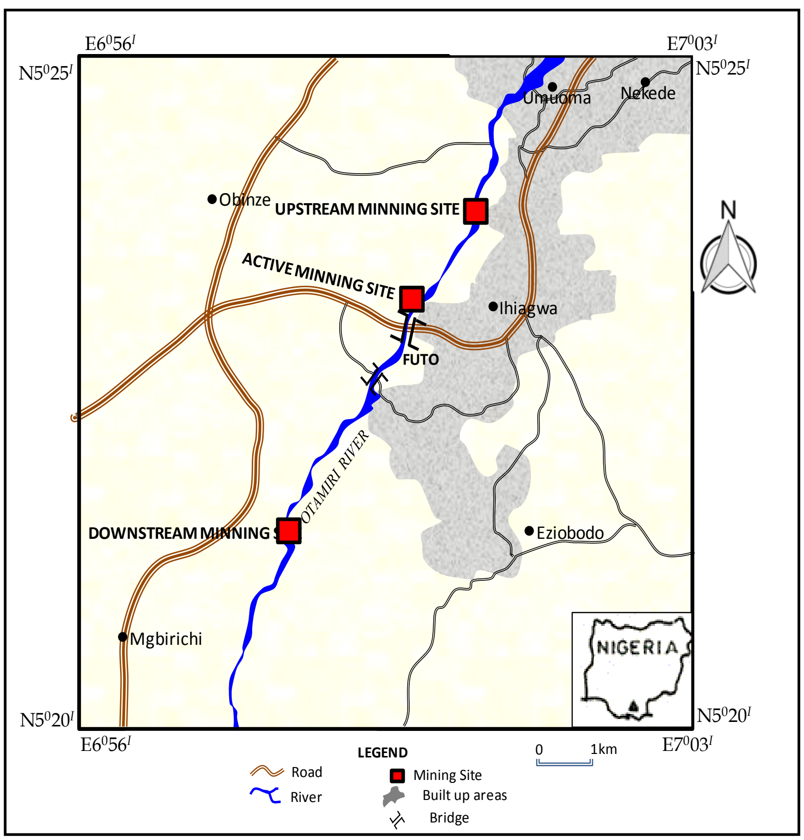


Fig. 3.2: Map showing Otamiri mining site

3.2 Measurement of Parameters

3.2.1 Analysis of Quality of Crushed-rock Aggregates

Aggregate Impact Value Test

This test measures the aggregatesresistance to disintegration due to impact.

Oven dried aggregates that pass through 14mm and are retained on 10mm British Standard Sieves were used for the test.

A cylindrical cup of known weight is filled with the aggregates in 3 layers, with each layer receiving 25 gentle blows using the tamping rod. The weight of the cup and sample is noted after which the aggregates are transferred to the impact mould in one layer and then placed firmly in position at the base of the impact machine. The samples are then given 15 blows using the impact machine rammer. The crushed materials are removed from the mould and passed through a 2.36mm sieve (see appendix).

The fractions passing the 2.36mm sieve are weighed and the weight noted. The impact value is calculated as the ratio of the weight of the fraction passing 2.36mm sieve to the weight of the sample expressed in percentage.

$$AIV = \frac{M_2 \times 100}{M_1} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where M1 = the mass of the test specimen in grams

M2 = the mass of the material passing the 2.36mm test sieve in grams

The procedure is repeated a second time and the average taken.

Los Angeles Abrasion Test

This test is used to determine the resistance to wearing of aggregates. Oven dried aggregates were placed in a cylindrical drum and then mounted horizontally in the machine. A charge of 11 steel balls (4584±25g) is added to the drum and the drum is rotated at a speed of 20 to 33rpm until 500 revolutions is completed. The tumbling and dropping action of the aggregates and balls result in attrition and abrasion of the aggregates. The crushed aggregate is sieved using 1.70mm sieve with the fraction retained on the sieve washed, oven dried and weighed.

The LAAV is calculated as the difference between the original weight and the final weight expressed as a percentage of the original weight of the test sample

Water Absorption

Water is added to a known weight of the aggregate retained on 1.75mm sieve in a vessel and allowed to soak for 24 hours. The water in the aggregate is drained and allowed to dry under room temperature. The aggregate is reweighed and oven dried for 24 hours and then reweighed again.

The water absorption is calculated as the difference between the weight of the air dried aggregate and oven dried aggregate expressed as a percentage of the weight of the oven dried aggregate.

Bulk Density

Weigh and record the mass of the empty container, with the scoop fill the container with concrete in six layers using at least 60 evenly distributed strokes to compact each layer either by using the compacting bar or a vibrator. After the top layer has been compacted, smooth it level with the top of the container using the plasterer's float, skim the surface with the straight edge and wipe clean the nearest 0.1g and by subtracting the mass of the empty container calculate and record the mass of the fully compacted concrete to the nearest 10g

Using $D = \frac{M}{V}$ ………………………………………………2

Where M = mass of the concrete sample in the container in kg

V= volume of the container in m^3

Aggregate Crushing Value

The aggregate crushing value (ACV) test is a laboratory procedure designed to measure the ability of aggregate to resist crushing. The apparatus consists of a case hardened steel cylinder 154mm diameter and 125mm high with a plunger that just fits inside the cylinder and a base plate. Other tools required for the experiment include a steel tamping bar 16mm diameter by 450 to 600mm long and a metal measuring cylinder 115mm diameter by 180mm deep. In addition to these, is a compression testing machine capable of applying a force of up to 500 KN and giving uniform rate of loading force for 10mm.

The required volume of aggregate tested was obtained by filling the measuring cylinder in three layers, each layer tamped 25 times with rod and the top leveled. The volume was then weighed and recorded.

A steel mould (plate 3) and a steel plunger were then inserted into the mould on top of the chipping in the cylinder, and the specimen was subjected to a force rising to 400KN, over a period of 10mins. The intention was to produce a total penetration of about 20mm within the 10mins. The fine material produced was then sieved over a 2.36mm BS sieve. The produced fine materials (passing a 2.36mm BS sieve), expressed as a percentage of the original mass was recorded as the aggregate crushing value (ACV) following the mathematical relationship below

$$ACV = \frac{M_2 \times 100}{M_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where M_1 = the weight of the tested specimen in gram

M_2 = the weight of the material passing the 2.36mm test sieve in gram

Concrete Compressive Test

"This test gives us an idea about all the characteristics of concrete. With the help of this test we can check that whether Concreting has been done properly or not. And compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc. Mainly 150mm cubes were used and the mounds were properly cleaned and oil was applied inside the cube frame (see appendix).

The concrete in the molds was later filled in layers approximately 50mm thick and compacted each layer with not less than 35 strokes per layer using a tamping rod (steel bar 16mm diameter and 600 mm long), the top surface was leveled and then smoothen with a trowel; then the concrete cubes were removed from the moulds between 16 to 72 hours, usually done after 24 hours. The specimen was removed from water after specified curing time and wiped out excess water from the surface. Taken the dimension of the specimen to the nearest 0.2mm and then placed the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast. Then the specimen was aligned centrally on the base plate of the machine. The movable portion was rotated gently by hand so that it touched the top surface of the specimen. The load was applied gradually without shock and continuously at the rate of 140 $kg/cm^2/min$. till the specimen failed. Then the maximum load was recorded and noted"(Nwaimo, 2021).

Specific Gravity (SG)

"The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specific temperature. The pyconometer method was used in determining the specific gravity. The empty and dry pyconometer was weighed to the nearest 0.01g and recorded as weight W1, after which about 100g of the sample was placed in the pyconometer. The pyconometer and the sample were the weighed to the nearest 0.01g and recorded as the weightW2. Water was added in the pyconometer until about it was two-third filled. Gently and carefully, the mixture was agitated; more water was added in the pyconometer until the bottom of the meniscus was exactly as the volume marked. The pyconometer was weighed and recorded as W3. The pyconometer was emptied and washed then filled with water up to the mark and weighed as W4. The above procedure was repeated three times, the temperature of the sample-water mixture was recorded by the thermometer. The specific gravity of aggregates normally used in road construction ranges from about 2.50 to 2.90"(Nwaimo,2021).

3.2.2 Analysis of Heavy Metals in Surface Water

"About 100ml of a well-mixed water sample was measured into a 150ml beaker and 5.0ml of conc. HNO_3 was added. The solution was evaporated to near dryness on a hot plate, making sure that the sample does not boil. The beaker and the contents were allowed to cool. Another 5ml of conc. HNO_3 was added to the beaker and the beaker was covered immediately with a watch glass. And the beaker was returned with the hot plate by increasing the temperature of the hot plate (medium to high). Heating was continued with the addition of HNO_3 as necessary until light colour residue was obtained (digestion is completed).

1ml of conc. HNO_3 was added to the residue, then washed with distilled water and filtered into 100ml volumetric flask to remove silicate and other insoluble materials and in measurement with the distilled water and later the solution was stored in 125ml polypropylene bottle.

The solution, the standard and the blank were aspirated respectively into the air-acetylene flame of Atomic Absorption Spectrometer"(Okeke and Agubom, 2015).

3.2.3 Determination of pH

The pH of the samples was measured using AGB- 4001 UP pH meter. The beaker was washed first with deionized water and the samples were poured into it after thoroughly shaking. The electrode was placed in the sample and readings were taken. Electrode was rinsed with distilled water after each measurement.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The results of the several parameters analyzed/ measured are presented in this section of this research work. They include the descriptive statistics of the width and depth characteristics measured in the three sites namely Njaba, Nworie and Otamiri rivers (Fig. 3.0,3.1&3.2) which show clearly the upstream of the active mining, the downstream of the active mining and the active mining site(table 4.2, 4.2.1; 4.3, 4.3.1; 4.4, and 4.4.1); Table 4.5, 4.5.1 and 4.5.2 show the results of Surface Water Analysis of Heavy Metal in Njaba , Nworie and Otamiri Rivers respectively.

Table 4.6, 4.6.1, 4.6.2, 4.7 and 4.7.1 show the results of Result of Air Quality, SPM and Noise level analysis of Lokpaukwu, Amasiri and Afikpo Quarry Sites respectively.

Table 4.8, 4.12 and 4.13 show the results of strength and durability parameters of crushed rock aggregates from Afikpo, Uturu , Lokpaukwu and Ishiagu, including Okigwe and Ihitte-Uboma(Elugwu/ Umuchienta) sandstone aggregates respectively.

4.1 Assessment of Morphological Changes of Njaba River at Okwudor

The dominant form of sand mining in Njaba River channel is wet pit mining in which diggers and shovels are used to remove sand from below the water table down to the bedrock floor of the channel. Mining points are carefully selected and observations indicate areas of natural slope where sand is deposited naturally are the areas of mining activity along the channel. Although sand mining in Njaba river is manual in operation, in contrast to other places where heavy dredgers are used, the continuous removal over a long period of time results in the loss of considerable amount of sediments from the river system. The excavated sand is deposited as slurry without any sorting and deposited on the bank of the river to drain before eventually being loaded onto trucks to the market.

The wider channel in the active mining site is a direct consequence of the mining activity which disrupts the structure and cohesion of the river bed. "The constant digging to collect the materials at the bottom of thechannel is particularly damaging as it removes the river bed armoring thereby disrupting the river bed stability which is the most important aspect of a river system's ecology" (Kundolf, 1994; Kondolf., 2002). It is known that natural stream channels develop the armoring along the bottom and sides over several years and the armoring protects the channel from erosion and if it is destroyed, even small rises in normal channel level can lead to erosion that widens the channel. A further cause of the widening channel in the mining site is the removal of riparian vegetation which weakens the channel bank leading to collapse as seen in photo (Appendix). It has been observed in this study that the flattening of the river channel associated with the increased width resulting from mining results in the river water to spread out over a larger area creating a much shallower water depth than would normally be present and the isolated deep pools tend to fill with fine sand leading to shallow depth (Kondolf, 1994; 1997). "A significant consequence of the widening channels in the mining affected areas is that widened channels have larger cross-sectional areas, so flooding exceeding bank-full capacity may be less frequent, since the effective capacity of the stream is increased" (Kondolf, 1997).

The descriptive statistics of the depth characteristics of the three sites in Table 4.1 indicate uniformity between the upstream and downstream sites. The apparent uniformity in depth between the two sites is to be expected as the channel is eroded laterally more than vertically due to mining induced lateral erosion.

Table 4.2 to table 4.2.1 illustrates vividly the width and depth characteristics of the sites. Specifically, this revealed that the mining site has attained a depth of 1.82m lower than the riverbed depth, downstream it is 1.15m lower, while it is 3.8ft in the upstream site. However, the width of the active mining site of the study area is 6.23m and it is 4.8m and 4.6m of upstream and downstream respectively."The significantly lower depth measured in the active mining site is due to the fact that removal of a sizeable quantity of sand within the site results in the excessive movement of sand down slope to fill the hole within immediately in the mined area, but as the erosion extends further downstream, the same impacts are repeated and the erosion becomes self-perpetuating"(Aliyu, 2014)

This condition continuously produce increase in stream flow velocities which results in sediments from upstream to depositing at the active mining site and reduced deposition at the downstream mining site of Okwudor, Njaba river.

4.2 Assessment of Morphological Changes of Nworie River at Owerri

The sand mining in Nworie River channel is wet pit mining where dredgers are used to remove sand from below the water table of the channel of the river. Here, there are numbers of dredgers for commercial sand mining. Mining points are carefully selected based on private arrangement with the land owners. Sand mining in Nworie river is operated with heavy dredgers therefore, there are considerable amount of loss of sediments from the river system. The excavated sand is deposited as slurry without any sorting and deposited on the bank of the river to drain before eventually being loaded onto trucks to the market.

"The wider channel in the active mining site is a direct consequence of the mining activity which disrupts the structure and cohesion of the river bed. The constant dredging to collect the materials at the bottom of thechannel is particularly damaging as it removes the river bed armoring thereby disrupting the river bed stability which is the most important aspect of a river system's ecology" (Kondolf, 1994; Kondolf, 2002). A further cause of the widening channel in the active mining site of Nworie river is the removal of riparian vegetation which weakens the channel bank leading to collapse as seen in the appendix. It is also observed that the riparian vegetation in this study site has a poor green leafs which may be as a result of the fumes and diesel oil coming out from the dredgers."A significant consequence of the widening channels in the mining affected areas is that widened channels have larger cross-sectional areas, so flooding exceeding bank-full capacity may be less frequent, since the effective capacity of the stream is increased" (Kondolf, 1997).The descriptive statistics of the Nworie river depth of the three sites in Table 4.3.1 indicate uniformity between the upstream and downstream sites, too. The apparent uniformity in depth between the two sites is to be expected as the channel is eroded laterally more than vertically due to mining induced lateral erosion including the closeness of the dredgers. Tables 4.3 to table 4.3.1 illustrate vividly the width and depth characteristics of the sites. Specifically, this revealed that the mining site has attained a depth of 15.03m lower than the riverbed depth, downstream it is 1.29m lower, while it is 1.02m in the upstream site. However, the width of the active mining site of the study area is 60.67m and it is 7.05m and 6.67m of upstream and downstream respectively The significantly higher depth measured in the active mining site is due to the multiple dredgers which are closely spaced in the river channel, this therefore reduces the deposition of sand from the upstream and subsequent decrease in stream flow velocities.

4.3 Assessment of Morphological Changes of Otamiri River at FUTO

The dominant form of sand mining in Otamiri River channel is wet pit mining in which dredgers are used to remove sand from below the water table down to the bedrock floor of the channel. Mining points are selected according to arrangement with FUTO management in which considerations were not on the consequences of sand mining on the Futo Bridge and the Ihiagwa Bridge. Observations indicated piles of the bridge foundation appearing and the soil washed out around the piles, also affecting the abutment as seen in the appendix.The Ihiagwa Bridge is completely collapsed due to excessive water scouring around the two bridge abutments. Otamiri River is operated with heavy dredgers therefore, the continuous removal over a long period of time resulted in the loss of considerable amount of sediments from the river system. The excavated sand is deposited as slurry without any sorting and deposited on the bank of the river to drain before eventually being loaded onto trucks to the market.

"The wider channel in the active mining site is a direct consequence of the mining activity which disrupts the structure and cohesion of the river bed. The constant dredging to collect the materials at the bottom of the channel is particularly damaging as it removes the river bed armoring thereby disrupting the river bed stability which is the most important aspect of a river system’s ecology" (Kundolf, 1994; Kondolf , 2002). It is known that natural stream channels develop the armoring along the bottom and sides over several years and the armoring protects the channel from erosion and if it is destroyed, even small rises in normal channel level can lead to erosion that widens the channel. Another cause of the widening channel in the active mining site is the removal of riparian vegetation which weakens the channel bank leading to collapse. "A significant consequence of the widening channels in the mining affected areas is that widened channels have larger cross-sectional areas, so flooding exceeding bank-full capacity may be less frequent, since the effective capacity of the stream is increased" (Kondolf, 1997). The descriptive statistics of the depth characteristics of the three sites in Table 4.4.1 indicate uniformity between the upstream and downstream sites. The apparent uniformity in depth between the two sites is to be expected as the channel is eroded laterally more than vertically due to mining induced lateral erosion.

Table 4.4 to table 4.4.1 illustrates vividly the width and depth characteristics of the sites. Specifically, this revealed that the mining site has attained a depth of 9.0m lower than the riverbed depth, downstream it is 1.26m lower, while it is 1.55m in the upstream site. However, the width of the active mining site of the study area is 45.57m and it is 10.98m and 11.51m of upstream and downstream respectively.The significantly lower depth measured in the active mining site is due to the fact that removal of a sizeable quantity of sand within the site results in the excessive movement of sand down slope to fill the hole within immediately in the mined area, but as the erosion extends further downstream, the same impacts are repeated and the erosion becomes self-perpetuating

This condition produce increase stream flow velocities that results in sediments from upstream to deposit at the active mining site and reduced deposition at the downstream mining site.

4.4 Heavy Metal Concentration of Njaba River

The concentration of heavy metal results from the Njaba river sample as shown in table 4.5 along with the National limits and represented in Fig.3.0. The Njaba river sample showed high concentration on the following metals both at the upstream and downstream of the active mining sites mercury Hg(0.276mg/l, 0.303mg/l), Lead Pb (0.17mg/l, 0.19mg/l) when compared with the national limits of 0.006mg/l and 0.05mg/l. The health effect of mercury could lead to emotional changes such as mood swings, irritability, nervousness, excessive shyness; Neuromuscular changes such as weakness, muscle atrophy and twitching; headaches, disturbances in sensation and changes in nerve responses. The most devastating effect of mercury in the nervous system is interference with the production of energy which can impair cellular detoxification processes causing the cell to either die or live in a state of chronic malnutrition. However, other studies have shown that high exposure to mercury induces changes in the central nervous system, potentially resulting in irritability, fatigue, behavioral changes, tremors, hearing and cognitive loss, in-coordination, hallucinations, and death.

The health effects of lead contaminated environment may cause anemia, weakness, kidney and brain damage. Very high lead exposure can cause death. It can cross the placenta barrier which means pregnant women who are exposed to lead also expose their unborn child. Lead can damage a developing baby's nervous system. It can seriously harm a child's health, including damage to the brain and nervous system, slowed growth and development, learning and behavior problems. Therefore, children swimming on this Njaba river may likely have ill-health associated with lead and mercury.

Other parameters analyzed were in their acceptable limits as indicated satisfactory.

4.4.1 Heavy Metal Concentration of Nworie River

The concentration of heavy metal results from the Nworie river sample as shown in table 4.5.1 along with the National limits and represented in Fig. 3.1.The Nworie river sample showed high concentration on the following metals both at the upstream and downstream of the active mining sites mercury Hg(0.18mg/l, 0.20mg/l), Iron Fe (0.20mg/l, 0.30mg/l) when compared with the national limits of 0.006mg/l and 0.1mg/l. The health effect of mercury could lead to emotional changes such as mood swings, irritability, nervousness, excessive shyness; Neuromuscular changes such as weakness, muscle atrophy and twitching; headaches, disturbances in sensation and changes in nerve responses. The most devastating effect of mercury in the nervous system is interference with the production of energy which can impair cellular detoxification processes causing the cell to either die or live in a state of chronic malnutrition. However, other studies have shown that high exposure to mercury induces changes in the central nervous system, potentially resulting in irritability, fatigue, behavioral changes, tremors, hearing and cognitive loss, in-coordination, hallucinations, and death.

The aeration of iron- containing layers in the soil can affect the quality of both groundwater and surface water if the groundwater table is lowered or nitrate leaching takes place. Dissolution of iron can occur as a result of oxidation and decrease in pH. When this high iron gets into the groundwater and taken by humans it can cause diabetes, hemochromatosis, stomach problems, and nausea. It can also damage the liver, pancreas and heart. The presence of high iron in this Nworie river may be connected to the presence of iron content in some of the water boreholes around the vicinity of the Nworie river.

Other parameters analyzed were in their acceptable limits as indicated satisfactory.

4.4.2 Heavy Metal Concentration of Otamiri River

The concentration of heavy metal results from the Otamiri river sample as shown in table 4.5.2 along with the National limits and represented in Fig. 3.2. The Otamiri river sample showed high concentration on the following metals both at the upstream and downstream of the active mining sites mercury Hg(0.23mg/l, 0.28mg/l), Lead Pb (0.62mg/l and 0.72mg/l), manganese Mn (0.76mg/l and 0.58mg/l) when compared with the national limits of 0.006mg/l , 0.1mg/l and 0.50mg/l respectively. The health effect of mercury could lead to emotional changes such as mood swings, irritability, nervousness, excessive shyness; Neuromuscular changes such as weakness, muscle atrophy and twitching; headaches, disturbances in sensation and changes in nerve responses. The most devastating effect of mercury in the nervous system is interference with the production of energy which can impair cellular detoxification processes causing the cell to either die or live in a state of chronic malnutrition. However, other studies have shown that high exposure to mercury induces changes in the central nervous system, potentially resulting in irritability, fatigue, behavioral changes, tremors, hearing and cognitive loss, in-coordination, hallucinations, and death.

The health effects of lead contaminated environment may cause anemia, weakness, kidney and brain damage. Very high lead exposure can cause death. It can cross the placenta barrier which means pregnant women who are exposed to lead also expose their unborn child. Lead can damage a developing baby’s nervous system. It can seriously harm a child’s health, including damage to the brain and nervous system, slowed growth and development, learning and behavior problems. Therefore, children swimming on this Otamiri river may likely have ill-health associated with lead, manganese and, mercury.

High manganese concentration affects both toxicity and deficiency symptoms in plants, when the pH of soil is low manganese deficiencies are more common. Highly toxic concentrations of manganese in soils can cause swelling of cell walls, withering of leafs and brown spots on leafs. High presence of this manganese can enter into the groundwater and tapped through the nearby water borehole causing health challenges such as memory loss, loss of attention and motor skills in both children and adults.

Other parameters analyzed were in their acceptable limits as indicated satisfactory.

4.4.3: Comprehensive Pollution Index (CPI)

Comprehensive pollution index (CPI) is used to access the level of pollution in a specific watershed by using monitoring statistics (Liu & Zhu,1999). The formula to calculate CPI is presented as follows:

$$CPI = \frac{1}{n}\sum_{i=1}^{n} P1i \text{......................................Eqn 5}$$

Where CPI= Comprehensive Pollution Index; *n* = number of monitoring parameters; PIi = the pollution index number *i*.

PIi is calculated according to the following equation:

$$PIi = \frac{Ci}{Si} \qquad \text{..Eqn 6}$$

Where Ci = measured concentration of parameter number in water; Si= permitted limitation of parameter number according to environmental standard.

In this study, we calculated CPI using 9 water parameters: chromium, mercury, lead, nickel, cadmium, copper, zinc, sodium and ammonia. These parameters were analyzed in the Njaba , Nworie and Otamiri rivers surface water monitoring program and the following results were recorded both at their upstream and downstream respectively as shown in table 4.5.3 which revealed that at Njaba river the upstream and downstream is slightly polluted and heavily polluted with 0.713 and 5.59 values respectively; Nworie river both the upstream and downstream heavily polluted with 3.2 and 3.68 values respectively; andOtamiri river both the upstream and downstream is heavily polluted with 3.26 and 3.95 values respectively when compared with the comprehensive pollution index classification, and also represented in comprehensive pollution index map in fig. 4.7. Comprehensive pollution index is aimed at identifying the sources of water pollution and develop a strategy for sustainable water source management (Cao., Nguyen, Trieu,Nguyen, and Vo, 2020)

4.5 Noise Level Measurement at Lokpaukwu Quarry Site

The result of noise level measurement conducted with dosimeter as shown in table 4.6 revealed that the noise level is satisfactory in the following locations the entrance gate, admin block, staff quarters, aggregate dump, blasting pit except at the primary crusher, generator house and the secondary crusher which recorded 89d(B), 94d(B) and 90d(B) respectively when compared with the NESREA limits of 85d(B). However, the noise level ranged from 47d(B) to 94d(B).The main sources of noise in this quarry site include noise from rock blasting site, crush rock processing plants, haulage trucks, diesel power generating plant, heavy duty trucks, welding machines, heavy traffic on the highway, human activities in the neighbourhood etc.Therefore, excessive noise level can lead to sleep disturbance, induced hearing impairment, cardiovascular and physiological effects and mental health effects. Noise pollution could be continuous, intermittent, impulsive or low frequency. Low frequency noise is the hardest type of noise to reduce at source, so it easily spread for miles around. . Noise has been found to interfere with our activities at three levels: radiological level, biological level and behavioral level affecting the sociological behavior of the objects.

"It is unfortunate that once noise gets established in air, there has been almost no way in which it can be controlled by using a power-driven device. However, it could be controlled by passive means that do not consume energy. Noise control can be done mainly by planning and fore thought, control of noise in mines can be achieved by reducing sound at source, interrupting the path of noise and protecting the receiver. General methods of noise pollution control" (Narayanan, 2009) are: (a) Removal of the source (b) Reduction of the decibel level (c) Minimizing the vibratory parts of the gadgets and machines by better design, fastening and padding with noise insulators.

Noise Pollution is undesirable sound measured in terms of pressure levels (decibel) by sound level meters.

4.5.1 Air Quality Measurement at Lokpaukwu Quarry Site

The result of air quality measured in the quarry vicinity as shown in theTable 4.6.1 above indicates that some parameters were within the Federal Ministry of Environment permissible limits while others were above the permissible limits meaning some level of pollution, resulting from emission from plants and vehicular movement, generator and other machines. Eight sampling points were selected for the study which include the following locations primary crusher, generator house, secondary crusher, blasting pit, admin block, staff quarters, entrancegate, and aggregate dump. The results revealed that the suspended particulate matter ranged from 2.80μg/m^{3}to 214μg/m^{3}which recorded high levels at the primary crusher, generator house and secondary crusher with 214μg/m^3, 67.2μg/m^3 and 212 μg/m^3 respectively when compared with National limits of 140μg/m^3.

"Dust is a generic term used to describe dryparticulate matter (PM) suspended in the atmosphere. Dust is formed when fine particles become entrained in the atmosphere by turbulent action of wind, by the mechanical disturbances of fine materials, through the release of particulate-rich gaseous emissions or other physical disturbances"(Barik, 2004). Dust pollution are generated in mines and quarries through wind blowing on mine tailings, removal of vegetation and top soil, onsite blasting and drilling operations, use of crushing and screening equipment, construction activities and the driving of vehicles on access and haul roads. Dust levels are significantly influenced by climatic factors such as rainfall, temperature and wind. Hot and dry environmental conditions generally result in more dust.

Dust control needs to be a key priority on any quarry operation. Prevention and control measures should not be applied in an ad hoc manner but integrated into comprehensive, wellmanaged and sustainable programs. Dust Prevention and effective Dust Control Systems should be implemented to protect workers' health, surrounding communities, and the environment. Bag filters (fabric filters) used for controlling particulate matter operate like a vacuum cleaner. Dirty gas is blown or sucked through a fabric filter bag, which collects dust. The dust is removed periodically when bag is shaken. Fabric filters can be very efficient collectors for even sub-micron sized particles and are widely used in industrial applications. A lot of large particles of dust and pollen in the atmosphere can lead directly to greater precipitation in clouds. Particles from pollution are needed as catalysts to form ice in clouds, which can influence precipitation and cloud dynamics. These particles can serve as the center, or nuclei, for cloud droplets that combine to form raindrops. Scrubbers are air pollution control devices that use liquid to remove particulate matter or gases from an industrial exhaust or flue gas stream. This atomized liquid (typically water) entrains particles and pollutant gases in order to effectively wash them out of the gas flow. Industrial scrubbers are of three major types which include wet scrubbers, dry scrubbers and electrostatic precipitators.

Cyclones separators (or simply cyclones) are separation devices that use the principle of inertia to remove particle matter from flue gases. Cyclone is one of many air pollution control devices known as pre-cleaner since they generally remove larger pieces of particulate matter. Cyclone separators work much like a centrifuge, but with a continuous feed of dirty air.

On the other hand, the air quality analysis results revealed that only CO was above the threshold value which varied from 2.9ppm to 10.5ppm with highest level of 10.5ppm recorded at the generator house when compared with the National limits of 10.0ppm. This could be as a result of smoke coming out from the exhaust. Generally, heavy duty machines including generators and light vehicles are the major sources of CO in the mines.

4.5.2 Noise Level Measurement at Amasiri Quarry Site

The result of noise level measurement conducted with dosimeter as shown in Table 4.7 The main sources of noise in Amasiri quarry site include noise from rock blasting site, crush rock processing plants, haulage trucks, diesel power generating plant, heavy duty trucks, welding machines, heavy traffic on the highway, human activities in the neighbourhood etc. The values recorded at blasting pit 124d(B) and crusher site 91d(B) exceed the FMEV threshold value of 90d(B)A and NESREA limit of 85d(B) while the admin block, Amasiri settlement and the generator house were below the threshold value. However, the noise level ranges from 30d(B) to 124d(B). The high noise level recorded at the blasting pit and the crusher site could be as a result of not confining the equipment with heavy noise emissions in sound proof cabins, so that noise is not transmitted to other areas. Therefore, excessive noise level can lead to sleep disturbance, induced hearing impairment, cardiovascular and physiological effects and mental health effects.

Noise generation may be for an instant, intermittent or continuous periods, with low to high decibels. Low frequency noise is the hardest type of noise to reduce at source, so it easily spread for miles around. . Noise has been found to interfere with our activities at three levels: radiological level, biological level and behavioral level affecting the sociological behavior of the objects.

"Unfortunately, there is almost no way in which noise can be controlled by using a power-driven device once noise gets established in air. However, it could be controlled by passive means that do not consume energy. Noise control can be done mainly by planning and fore thought, control of noise in mines can be achieved by reducing sound at source, interrupting the path of noise and protecting the receiver. General methods of noise pollution control" (Narayanan, 2009) are: (a) Removal of the source (b) Reduction of the decibel level (c) Minimizing the vibratory parts of the gadgets and machines by better design, fastening and padding with noise insulators.

Noise Pollution is undesirable sound measured in terms of pressure levels (decibel) by sound level meters.

4.5.3 Air Quality Analysis at Amasiri Quarry Site

The results revealed that the suspended particulate matter rangedfrom 14μg/m^{3}to700μg/m^3 which recorded high levels at the crusher site and blasting pit with 700μg/m^3 and 220μg/m^3 respectivelywhen compared with National limits, while other location were under the acceptable limits as shown in Table 4.7.1. However, the high level of dust recorded at the primary crusher to the quarry site not using Dust suppression systems like water spraying. Dust is a generic term used to describe dry particulate matter (PM) suspended in the atmosphere. "Dust is formed when fine particles become entrained in the atmosphere by turbulent action of wind, by the mechanical disturbances of fine materials, through the release of particulate-rich gaseous emissions or other physical disturbances"(Barik, 2004). Dust pollution are generated in mines and quarries through wind blowing on mine tailings, removal of vegetation and top soil, onsite blasting and drilling operations, use of crushing and screening equipment, construction activities and the driving of vehicles on access and haul roads. Dust levels are significantly influenced by climatic factors such as rainfall, temperature and wind. Hot and dry environmental conditions generally result in more dust.

Dust control needs to be a key priority on any quarry operation. Prevention and control measures should not be applied in an ad hoc manner but integrated into comprehensive, wellmanaged and sustainable programs. Dust Prevention and effective Dust Control Systems should be implemented to protect workers' health, surrounding communities, and the environment. Bag filters (fabric filters) used for controlling particulate matter operate like a vacuum cleaner. Dirty gas is blown or sucked through a fabric filter bag, which collects dust. The dust is removed periodically when bag is shaken. Fabric filters can be very efficient collectors for even sub-micron sized particles and are widely used in industrial applications. A lot of large particles of dust and pollen in the atmosphere can lead directly to greater precipitation in clouds. Particles from pollution are needed as catalysts to form ice in clouds, which can influence precipitation and cloud dynamics. These particles can serve as the center, or nuclei, for cloud droplets that combine to form raindrops. Scrubbers are air pollution control devices that use liquid to remove particulate matter or gases from an industrial exhaust or flue gas stream. This automized liquid (typically water) entrains particles and pollutant gases in order to effectively wash them out of the gas flow. Industrial scrubbers are of three major types which include wet scrubbers, dry scrubbers and electrostatic precipitators.

Cyclones separators (or simply cyclones) are separation devices that use the principle of inertia to remove particle matter from flue gases. Cyclone is one of many air pollution control devices known as precleaner since they generally remove larger pieces of particulate matter. Cyclone separators work much like a centrifuge, but with a continuous feed of dirty air.

On the other hand, the air quality analysis results revealed that NO_2, SO_2 and NH_3 were high in various locations including in the admin block, crusher site, generator house and blasting pit. NO_2 recorded high levels at admin block 0.1ppm, crusher site 0.2ppm, generator house 0.1ppm, blasting pit 0.1ppm, the same with SO_2admin block 0.1ppm, crusher site 0.2ppm, generator house 0.3ppm and blasting pit 0.06ppmwhile NH_3recorded high concentration only in the generator house 1.0ppm when compared with the NESREA limits of 0.06, 0.01 and 0.2 ppm respectively.The main reasons for these emissions may be as a result of Poor quality of explosives having large oxygen imbalance due to manufacturing defect, use of expired explosives in which ingredients have disintegrated, and incomplete detonation, which may be due to low Primer to column ratio.

4.5.4 Noise Level Measurement at Okpojo, Afikpo Quarry Site

The result of noise level measurement conducted with dosimeter as shown in theTable 4.7.2. The main sources of noise in this quarry site include noise from rock blasting site, crush rock processing plants, haulage trucks, diesel power generating plant, heavy duty trucks, welding machines, heavy traffic on the highway, human activities in the neighborhood etc. The value 97.6d(B) recorded at the Crusher site exceeds the FMEV threshold value of 90d(B)A and NESREA limit of 85d(B). However, the noise level ranges from 65.1d(B) to 97.6d(B). The high noise level recorded at the blasting pit and the crusher site could be as a result of not confining the equipment with heavy noise emissions in sound proof cabins, so that noise is not transmitted to other areas. Therefore, excessive noise level can lead to sleep disturbance, induced hearing impairment, cardiovascular and physiological effects and mental health effects. Noise pollution could be continuous, intermittent, impulsive or low frequency. Low frequency noise is the hardest type of noise to reduce at source, so it easily spread for miles around. . Noise has been found to interfere with our activities at three levels: radiological level, biological level and behavioral level affecting the sociological behavior of the objects.

"It is unfortunate that once noise gets established in air, there has been almost no way in which it can be controlled by using a power-driven device. However, it could be controlled by passive means that do not consume energy. Noise control can be done mainly by planning and fore thought, control of noise in mines can be achieved by reducing sound at source, interrupting the path of noise and protecting the receiver. General methods of noise pollution control" (Narayanan, 2009) are: (a) Removal of the source (b) Reduction of the decibel level (c) Minimizing the vibratory parts of the gadgets and machines by better design, fastening and padding with noise insulators.

Noise pollution is undesirable sound measured in terms of pressure levels (decibel) by sound level meters.

4.5.4 Air Quality Analysisof Afikpo Quarry Site

The results revealed that the suspended particulate matter ranged from 250μg/m^{3}to 1400μg/m^3 which recorded high levels at all locations including quarry site 750μg/m^3, stockpile area 1400μg/m^3, admin block 250μg/m^3, crusher site 1350μg/m^3, generator house 300μg/m^3 and primary crusher 1200μg/m^3 when compared with National limitsof 140μg/m^3 as shown in Table 4.7.2. The high values of SPM in this quarry site may be attributed to the neglect of necessary environmental measures of mitigating dust. On the other hand, the air quality parameters analyzed were within their respective regulatory limits of 0.01ppm except for SO_2 which is high at the crusher site (0.07ppm) and the primary crusher (0.3ppm).

"Dust is a generic term used to describe dry particulate matter (PM) suspended in the atmosphere. Dust is formed when fine particles become entrained in the atmosphere by turbulent action of wind, by the mechanical disturbances of fine materials, through the release of particulate-rich gaseous emissions or other physical disturbances"(Barik, 2004). Dust pollution are generated in mines and quarries through wind blowing on mine tailings, removal of vegetation and top soil, onsite blasting and drilling operations, use of crushing and screening equipment, construction activities and the driving of vehicles on access and haul roads. Dust levels are significantly influenced by climatic factors such as rainfall, temperature and wind. Hot and dry environmental conditions generally result in more dust. Dust control needs to be a key priority on any quarry operation. Prevention and control measures should not be applied in an ad hoc manner but integrated into comprehensive, wellmanaged and sustainable programs. Dust Prevention and effective Dust Control Systems should be implemented to protect workers' health, surrounding communities, and the environment. Bag filters (fabric filters) used for controlling particulate matter operate like a vacuum cleaner. Dirty gas is blown or sucked through a fabric filter bag, which collects dust. The dust is removed periodically when bag is shaken. Fabric filters can be very efficient collectors for even sub-micron sized particles and are widely used in industrial applications. A lot of large particles of dust and pollen in the atmosphere can lead directly to greater precipitation in clouds. Particles from pollution are needed as catalysts to form ice in clouds, which can influence precipitation and cloud dynamics. These particles can serve as the center, or nuclei, for cloud droplets that combine to form raindrops. Scrubbers are air pollution control devices that use liquid to remove particulate matter or gases from an industrial exhaust or flue gas stream. This automized liquid (typically water) entrains particles and pollutant gases in order to effectively wash them out of the gas flow. Industrial scrubbers are of three major types which include wet scrubbers, dry scrubbers and electrostatic precipitators.

Cyclones separators (or simply cyclones) are separation devices that use the principle of inertia to remove particle matter from flue gases. Cyclone is one of many air pollution control devices known as pre-cleaners since they generally remove larger pieces of particulate matter. Cyclone separators work much like a centrifuge, but with a continuous feed of dirty air.

4.5.5: Air Quality Index (AQI) of Lokpaukwu and Amasiri

Air quality index (AQI) was calculated to demonstrate the health effects of emissions on people in the target population. To calculate AQI, an average concentration level of SPM, NO_2,SO_2,CO,

C_XH_Y, H_2S,NH_3 and HCN at different locations at the quarry sites were obtained in table 4.7.3, 4.7.4 and 4.7.5 respectively, and also represented in spatial variation maps (Fig.4.8 and 4.9). The observed average concentrations of pollutants were applied in equation 4 to get AQI for the target population according to the sampling design.

$$I_P = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_P - BP_{Lo}) + I_{Lo}$$

Where: I_P = the index for pollutant P

C_P = the rounded concentration of pollutant P

BP_{Hi} = the breakpoint that is greater than or equal to C_P

BP_{Lo} = the breakpoint that is less than or equal to C_P

I_{Hi} = the AQI value corresponding to BP_{Hi}

I_{Lo} = the AQI value corresponding to BP_{Lo} ……………….Eqn 4

The calculation revealed that the SPM at Lokpaukwu is good and moderate at the locations; the Afikpo quarry site revealed very unhealthy at the stockpile quarry site, crusher site and primary crusher while at the generator house is classified as unhealthy while at the Amasiri the SPM is very unhealthy at the crusher site and unhealthy at the blasting pit.

Table 4: Acceptance limits for test results of roadstones (after BS 882, 1973 and Government of East Central State of Nigeria, 1972)

Test	Acceptance Limits
Aggregate crushing value (ACV) (%)	Maximum 30
Aggregate impact value (AIV) (%)	Maximum 30
Los Angeles abrasion value (LAAV) (%)	Maximum 40
Water absorption (%)	Less than 3
Bulk density (Mg/m^3)	More than 2.6

Concrete compression test	15-30 MPa

Table 4.1: Aggregate Impact value and rating

AIV	RATING
>10%	Exceptionally strong
10 – 20%	Strong
20 – 30%	Satisfactory (for road work)
35% or more	Weak

Table 4.1.1: Air quality index classification

Descriptor	AQI	Risk Message
Good	0 - 50	No message
Moderate	51 - 100	Unusually sensitive individuals (ozone)
Unhealthy for Sensitive Groups	101 - 150	Identifiable groups at risk – different groups for different pollutants
Unhealthy	151 - 200	General public at risk; groups at greater risk
Very Unhealthy	201 - 300	General public at greater risk; groups at greatest risk

Table 4.1.2: CPI Classification

S.N	CPI	REMARK
1	0 – 0.20	Clean
2	0.21 – 0.40	Sub clean
3	0.41 – 1.00	Slightly polluted
4	1.01 -2.00	Medium polluted
5	2.01 >	Heavily polluted

4.6 Analysis of Crushed-rock Aggregate of Afikpo Quarry Site

The analysis of physico-mechanical tests on crushed rock aggregates dolerite in Afikpo were carried out as shown in Table 4.8 to determine their strength, durability and suitability characteristics as materials for engineering construction. The results showed that all the parameters fall within the acceptance limit including ACV, AIV, LAAV, WA and SG which confirmed the fact that they are good for road aggregates.

4.7 Analysis of Crushed-rock Aggregate of Uturu Quarry Site

The analysis of physico-mechanical tests on crushed rock aggregates Andesite in Uturu were carried out as shown in Table 4.8 to determine their strength, durability and suitability characteristics as materials for engineering construction. The results showed that all the parameters fall within the acceptance limit including ACV, AIV, LAAV, WA and SG which confirmed the fact that they are good for road aggregates.

4.8 Analysis of Crushed-rock Aggregate of Lokpaukwu Quarry Site

The analysis of physico-mechanical tests on crushed rock aggregates diorite in Lokpaukwu was carried out as shown in Table 4.8 to determine their strength, durability and suitability characteristics as materials for engineering construction. The results showed that all the parameters fall within the acceptance limit including ACV, AIV, LAAV, WA and SG which confirmed the fact that they are good for road aggregates.

4.9 Analysis of Crushed-rock Aggregate of Ishiagu Quarry Site

The analysis of physico-mechanical tests on crushed rock aggregates diorite in Ishiagu was carried out as shown in Table 4.8 to determine their strength, durability and suitability characteristics as materials for engineering construction. The results showed that all the parameters fall within the acceptance limit including ACV, AIV, LAAV, WA and SG which confirmed the fact that they are good for road aggregates.

4.10 Analysis of Sandstone Aggregate of Okigwe Sandstone Site

The analysis of physico-mechanical tests on sandstone aggregates in Okigwe wascarried out as shown in Table4.9 to determine their strength, durability and suitability characteristics as materials for engineering construction. The results showed that the mechanical parameters including bulk density (BD) did not fall within the acceptance limit except for water absorption and concrete compression whose values 0.60% and 16.65N/mm^3 respectivelyare within the acceptance limit of maximum of 3% and between 15-30N/mm^3 respectively. This clearly shows that they are good for concrete aggregates.

4.10.1 Field Observation

The field observation of this Okigwe sandstone quarry location revealed considerable physical environmental impacts which include:

1. Farm and grazing land reduction: Sandstone cannot be mined without the removal of the vegetation cover of the area which is also a surface mining method. This vegetation serves as source of food to cattle, and economic trees are cut down as well which has denied the community members their means of livelihood (appendix). However, farming and animal rearing is one of the major occupations of the people living in the area therefore the continuation of this sandstone in the area will gradually be reducing their farmland and food for their animals subsequently reduce farmers and herders conflict in this mining community.
2. Destruction of landscape: The continued sandstone mining in the area has destroyed the aesthetic nature of the environment thereby altering the original landscape. It has turned the area into a water logged area making it a breeding ground for mosquitoes which in turn affects the lives of those working in the mine site during the raining seasons. This raining season however, positively helps them in easy excavation of sandstone and the reduction of air pollution because the whole is area wet.
3. Collapse of overburden: There is steady collapse of the mine site due to overburden. Precautionary measures are always taken to prevent collapsing which include excavating from top to your desired bottom of the mine in the angle of 90^0. This collapse usually leads to injuries or loss of lives.

4.11 Analysis of Sandstone Aggregate of Ihitte-Uboma(Elugwu/ Umuchienta) Sandstone Site

The analysis of physico-mechanical tests on sandstone aggregatesin Ihitte-Uboma(Elugwu/ Umuchienta)were carried out as shown in Table4.10 to determine their strength, durability and suitability characteristics as materials for engineering construction. The results showed that the mechanical parameters including bulk density (BD) did not fall within the acceptance limit except for water absorption and concrete compression whose values 0.90% and 18.90N/mm^3 respectively are within the acceptance limit of maximum of 3% and between 15-30N/mm^3 respectively. This clearly shows that they are good for concrete aggregates.

4.11.1 Field Observation

The field observation of this Ihitte-Uboma (Elugwu/ Umuchienta)sandstone quarry location revealed considerable physical environmental impacts which include:

1. Farm and grazing land reduction: Sandstone cannot be mined without the removal of the vegetation cover of the area which is also a surface mining method. This vegetation serves as source of food to cattle, and economic trees are cut down as well which has denied the community members their means of livelihood (appendix). However, farming and animal rearing is one of the major occupations of the people living in the area therefore the continuation of this sandstone in the area will gradually be reducing their farmland and food for their animals subsequently reduce farmers and herders conflict in this mining community.
2. Destruction of landscape: The continued sandstone mining in the area has destroyed the aesthetic nature of the environment thereby altering the original landscape. It has turned the area into a water logged area making it a breeding ground for mosquitoes which in turn affects the lives of those working in the mine site during the raining seasons. This

raining season however, positively helps them in easy excavation of sandstone and the reduction of air pollution because the whole is area wet.

3. Collapse of overburden: There is steady collapse of the mine site due to overburden. Precautionary measures are always taken to prevent collapsing which include excavating from top to your desired bottom of the mine in the angle of 90^0. This collapse usually leads to injuries or loss of lives.

Table 4.2 Descriptive statistics of the width of Njaba River at Okwudor

	No	Value (m)	Min	Max	Mean
Upstream	4	4,4.6, 5,5.6	4	5.6	**4.8**
Mining site	4	5.3,6,6.6,7	5.3	7	**6.23**
Downstream	4	3.6,4.3,4.6,6	3.6	6	**4.6**

Table 4.2.1 Descriptive statistics of the depth of Njaba River at Okwudor

	No	Value (m)	Min	Max	Mean
Upstream	4	1.06,1.16,1.33,1.5	1.06	1.5	1.26
Mining site	4	1.83,1.93,2.03,2.16	1.83	2.16	1.99
Downstream	4	1.0,1.06,1.2,1.33	1	1.33	1.15

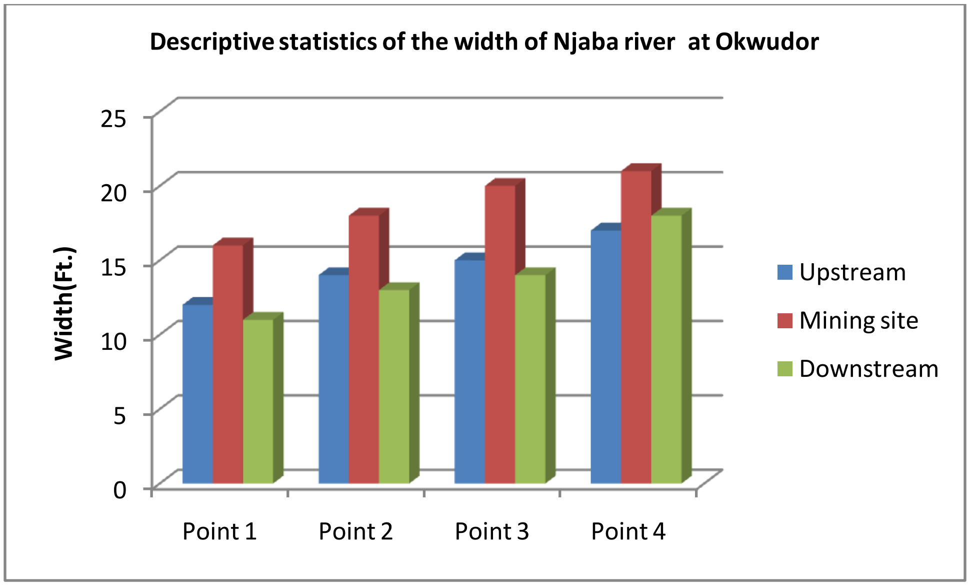


Fig.4.0: Comparison of width of upstream, active mining site and downstream of Njaba river.

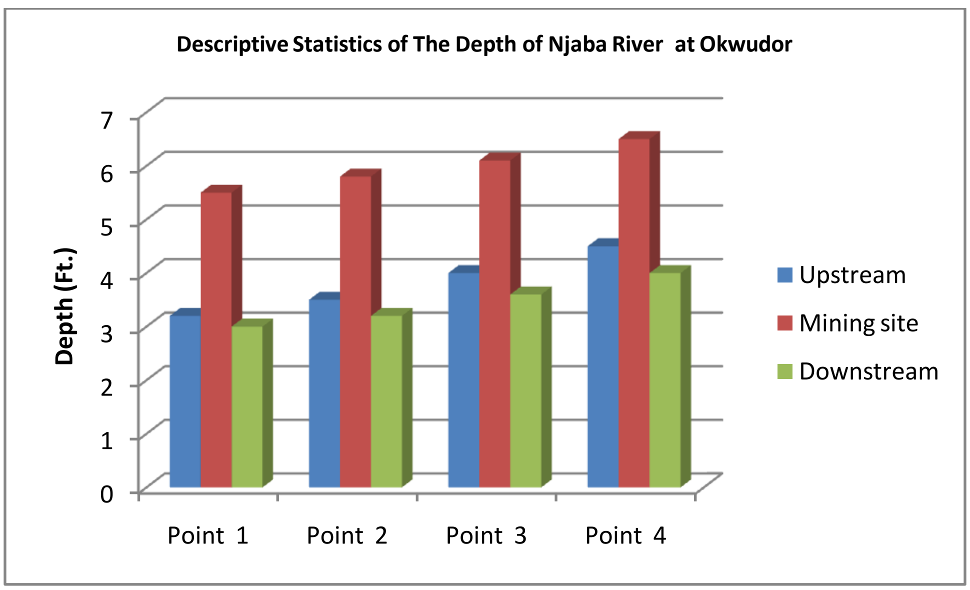


Fig.4.1: Comparison of depth of upstream, active mining site and downstream of Njaba river.

Table 4.3 Descriptive statistics of the width of Nworie river at Owerri

	No	Value (m)	Min	Max	Mean
Upstream	4	6.40,7.01,7.32,7.46	6.40	7.46	7.05
Mining site	4	57.01,59.15,62.5,64.02	57.01	64.02	60.67

Downstream	4	5.18,6.09,7.01,8.41	5.18	8.41	6.67

Table 4.3.1 Descriptive statistics of the depth of Nworie river at Owerri

	No	Value (m)	Min	Max	Mean
Upstream	4	1.13,1.22,1.31,1.52	1.13	1.52	1.29
Mining site	4	12.80,14.33,15.24,16.46	12.80	16.46	15.03
Downstream	4	0.82,1.0,1.04,1.22	0.82	1.22	1.02

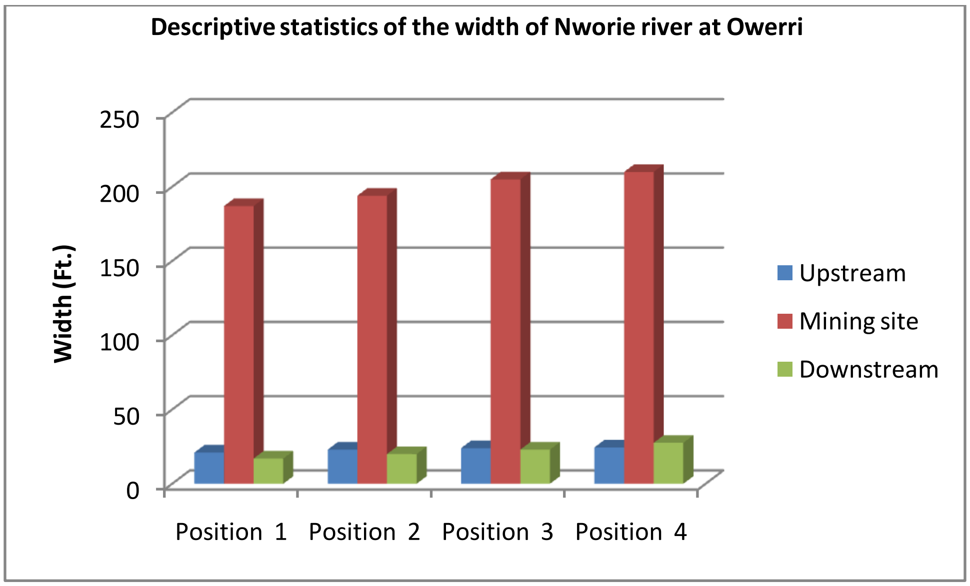


Fig.4.2: Comparison of width of upstream, active mining site and downstream of Nworie river.

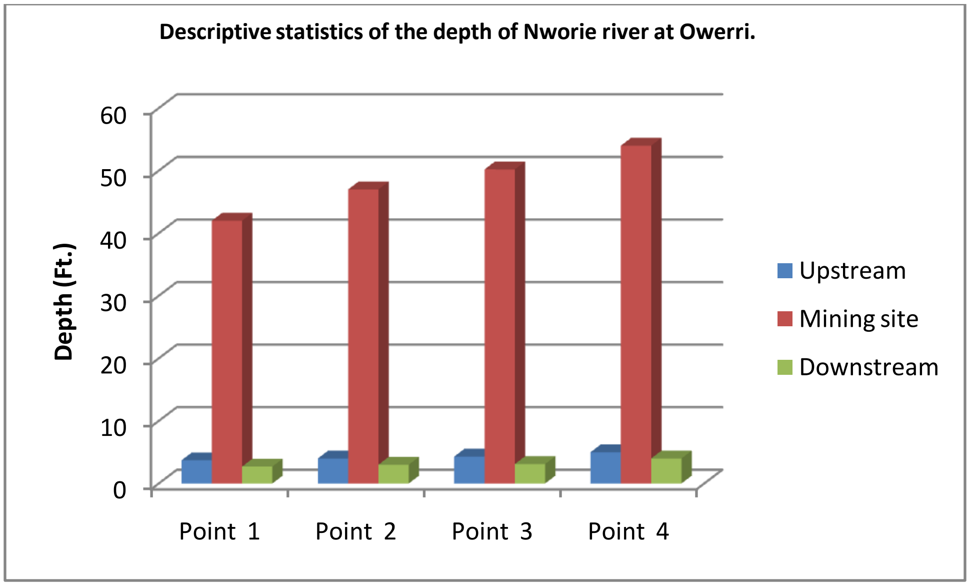


Fig. 4.3:Comparison of depth of upstream, active mining site and downstream of Nworie river.

Table 4.4: Descriptive statistics of the width of Otamiri River at FUTO

	No	Value (m)	Min	Max	Mean
Upstream	4	9.75,10.67,11.0,12.50	9.75	12.5	10.98
Mining site	4	42.98,44.80,46.34,48.17	42.98	48.18	45.57
Downstream	4	9.75,11.51,12.0,12.8	9.75	12.80	11.51

Table 4.4.1 Descriptive statistics of the depth of Otamiri at FUTO

	No	Value (m)	Min	Max	Mean
Upstream	4	1.31,1.46,1.58,1.86	1.31	1.86	1.55,
Mining site	4	8.23,8.84,9.14,9.75	27	9.75	9.00
Downstream	4	1.15,1.2,1.31,1.41	1.15	1.41	1.26

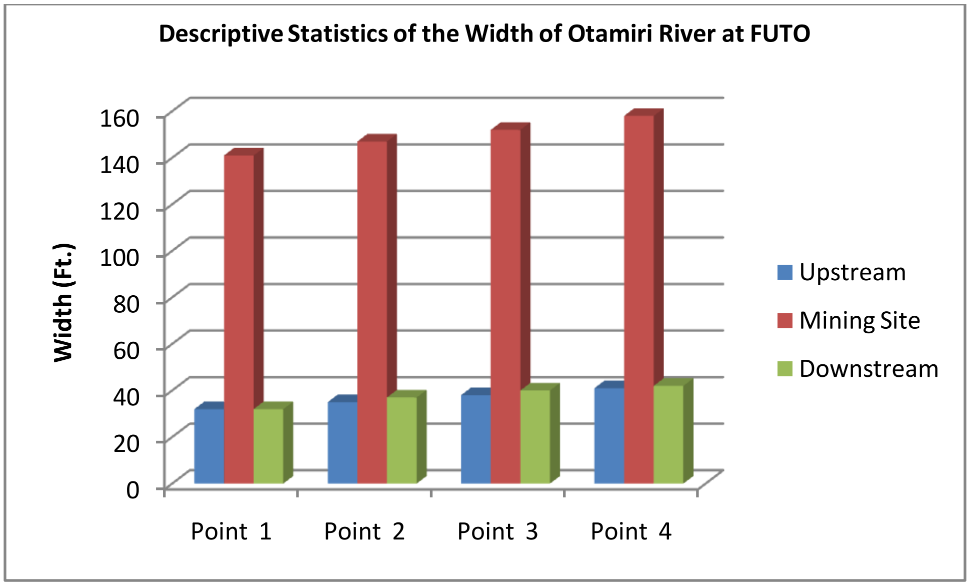


Fig.4.4: Comparison of width of upstream, active mining site and downstream of Otamiri river.

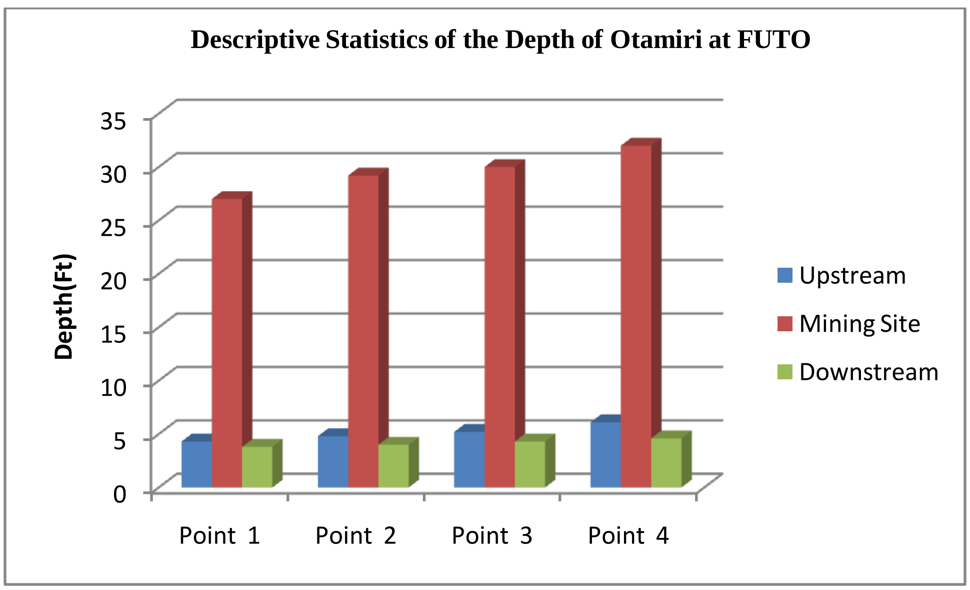


Fig.4.5: Comparison of depth of upstream, active mining site and downstream of Otamiri river.

Table 4.5: Surface Water Result of Heavy Metal of Njaba River

S/N	PARAMETER	NATIONAL LIMIT	UPSTREAM	DOWNSTREAM	Remarks	
					Upstream	Downstream
1	Appearance(apparent colour)	NS	Brown	Brown	Unsatisfactory	Unsatisfactory
2	Temperature (^{0}C)	<40	29.7	29.5	Satisfactory	Satisfactory
3	pH	5.5-9.0	6.65	6.72	Sat.	Sat.
4	Chromium(hexa)mg/l	0.1	<0.001	<0.001	Sat.	Sat.
5	Mercury (mg/l)	0.006	0.276	0.303	Unsat.	Unsat.
6	Lead(mg/l)	0.1	0.17	0.019	Unsat.	Unsat.
7	Nickel(mg/l)	3.0	0.030	0.028	Sat.	Sat.
8	Manganese(mg/l)	NS	0.050	0.053	Sat.	Sat.
9	Cadmium(mg/l)	0.03	<0.001	<0.001	Sat.	Sat.
10	Cobalt(mg/l)	NS	0.014	0.013	Sat	Sat
12	Copper(mg/l)	3.0	0.005	0.004	Sat	Sat.
13	Zinc(mg/l)	5.0	0.120	0.133	Sat	Sat.
14	Sodium(mg/l)	200	22	12	Sat	Sat.
15	Ammonia(mg/l)	50	0.09	0.06	Sat	Sat.

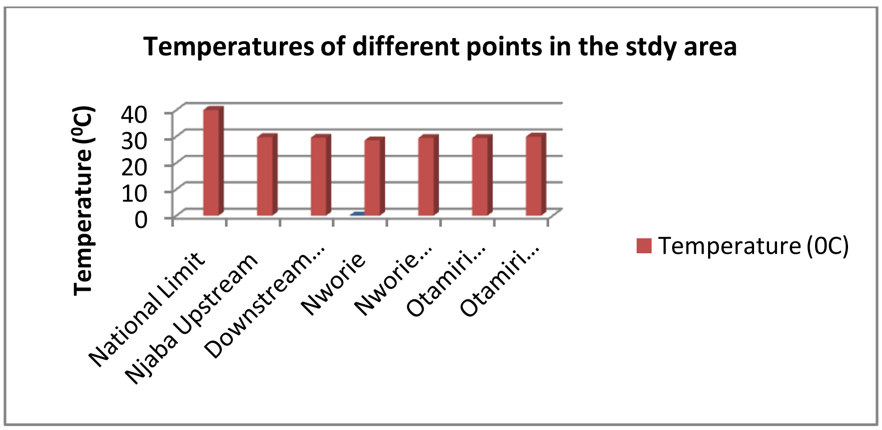
Table 4.5.1: Surface Water Analysis of Heavy Metals of Nworie River

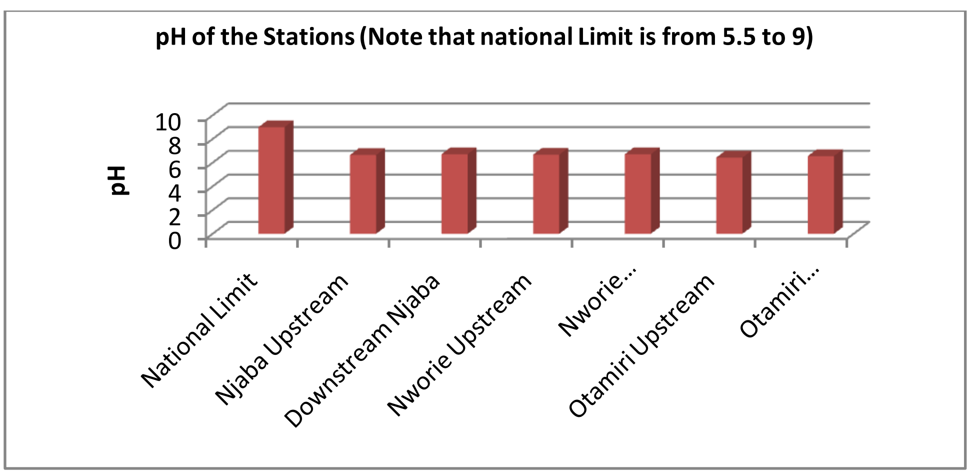
S/N	PARAMETER	NATIONAL LIMIT	UPSTREAM	DOWNSTREAM	Remarks	
					Upstream	Downstream
1	Appearance(apparent colour)	NS	Clear	Clear	Sat	Satisfactory
2	Temperature (^{0}C)	<40	28.5	29.4	Sat.	Sat.
3	pH	5.5-9.0	6.68	6.71	Sat	Sat.
4	Chromium(hexa)mg/l	0.1	<0.001	<0.001	Sat	Sat.
5	Mercury (mg/l)	0.006	0.18	0.20	Unsat	Unsat
6	Lead(mg/l)	0.1	0.002	0.002	Sat.	Sat.
7	Nickel(mg/l)	3.0	0.003	0.003	Sat	Sat
8	Manganese(mg/l)	0.5	0.071	0.055	Sat	Sat.
9	Cadmium(mg/l)	0.03	<0.001	<0.001	Sat	Sat
10	Cobalt(mg/l)	NS	0.02	0.010	Sat	Sat
11	Copper(mg/l)	3.0	0.005	0.006	Sat	Sat
12	Zinc(mg/l)	5.0	0.13	0.700	Sat	Sat.
13	Iron (mg/l)	0.10	0.20	0.30	Unsat.	Unsat.
14	Sodium(mg/l)	NS	3.76	3.21	Sat	Sat
15	Ammonia(mg/l)	50	0.04	0.07	Sat	Sat

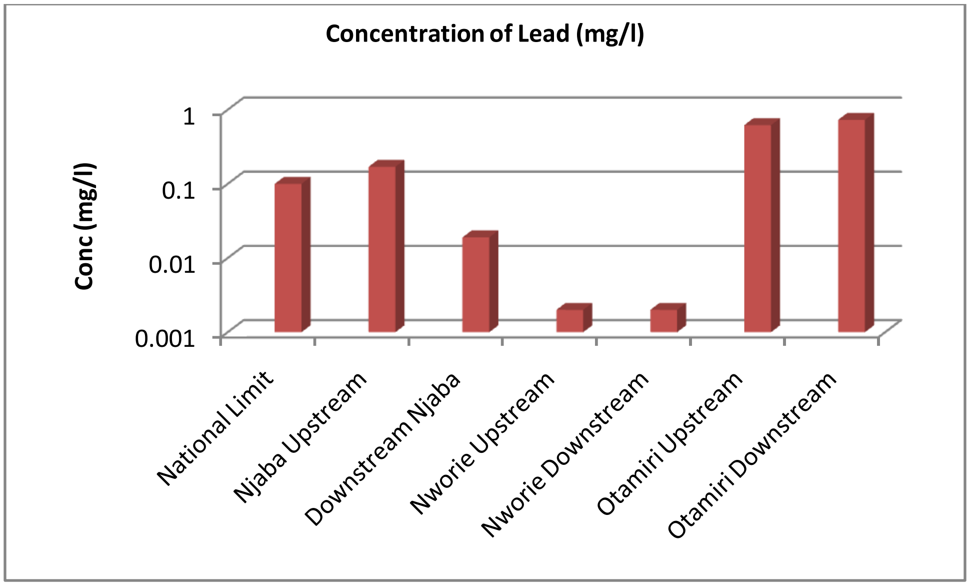
Table 4.5.2 : Surface Water Analysis of Heavy Metals of Otamiri River

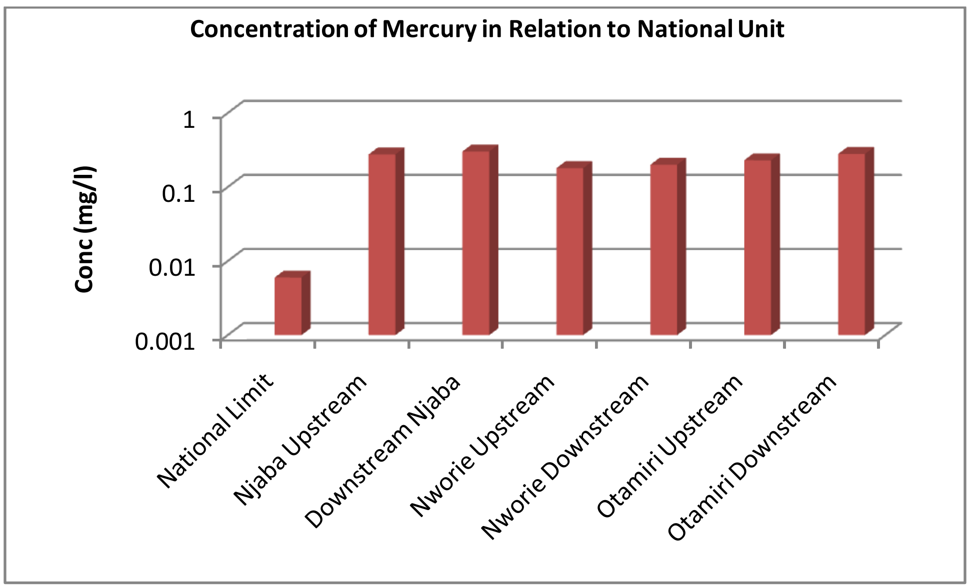
S/N	**PARAMETER**	**NATIONAL LIMIT**	**UPSTREAM**	**DOWNSTREAM**	**Remarks**	
					Upstream	**Downstream**
1	Appearance(apparent colour)	NS	clear	Sky blue	Sat	Unsat.
2	Temperature (^{0}C)	<40	29.4	29.9	Sat	Satisfactory
3	pH	5.5-9.0	6.43	6.56	Sat	Sat.
4	Chromium(hexa)mg/l	0.1	<0.001	<0.001	Sat	Satisfactory
5	Mercury (mg/l)	0.01	0.23	0.28	Unsat.	Unsat.

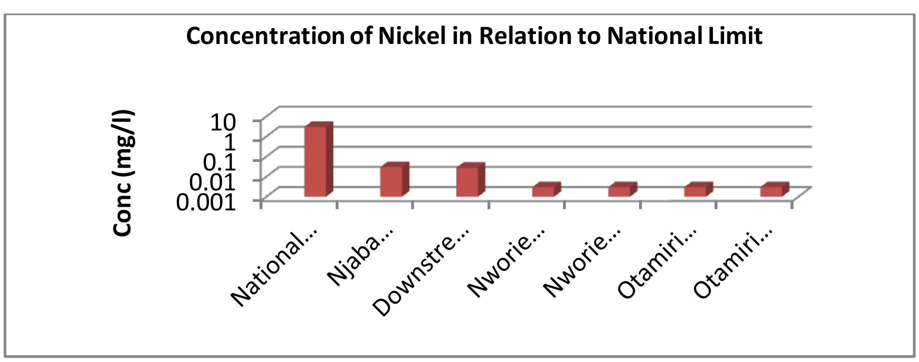
6	Lead(mg/l)	0.1	0.62	0.73	Unsat.	Unsat.
7	Nickel(mg/l)	3.0	0.003	0.003	Sat	satisfactory
8	Manganese(mg/l)	0.50	0.76	0.58	Unsat	Unsat.
9	Cadmium(mg/l)	0.03	<0.001	<0.001	Sat	satisfactory
10	Cobalt(mg/l)	NS	0.02	0.010	Sat	Satisfactory
11	Copper(mg/l)	3.0	0.04	0.06	Sat	Satisfactory
12	Zinc(mg/l)	5.0	0.23	0.37	Sat.	Satisfactory
13	Iron(mg/l)	0.10	0.18	0.30	Unsat	Unsat.
14	Sodium(mg/l)	NS	4.85	3.61	Sat.	Satisfactory
15	Ammonia(mg/l)	50	0.06	0.09	Sat.	Satisfactory

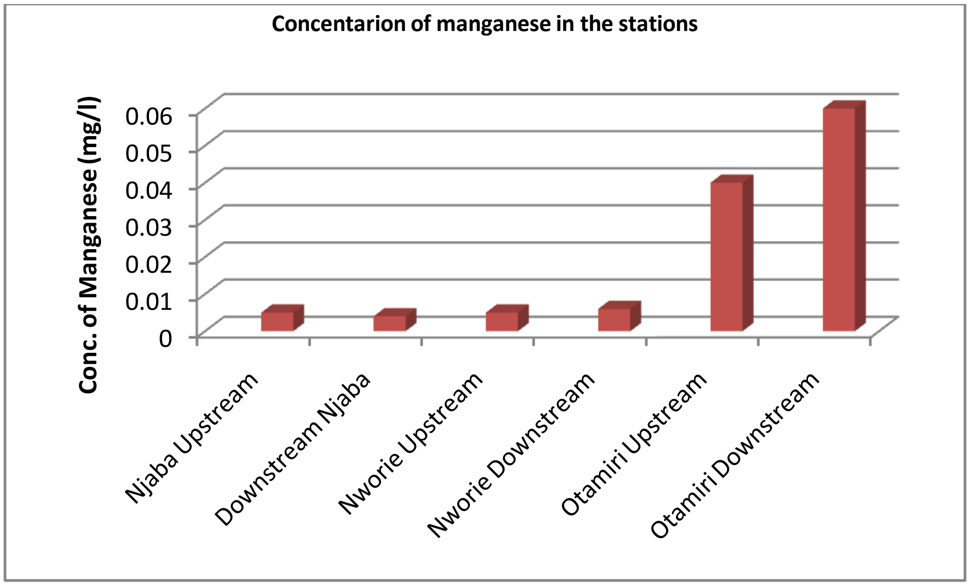


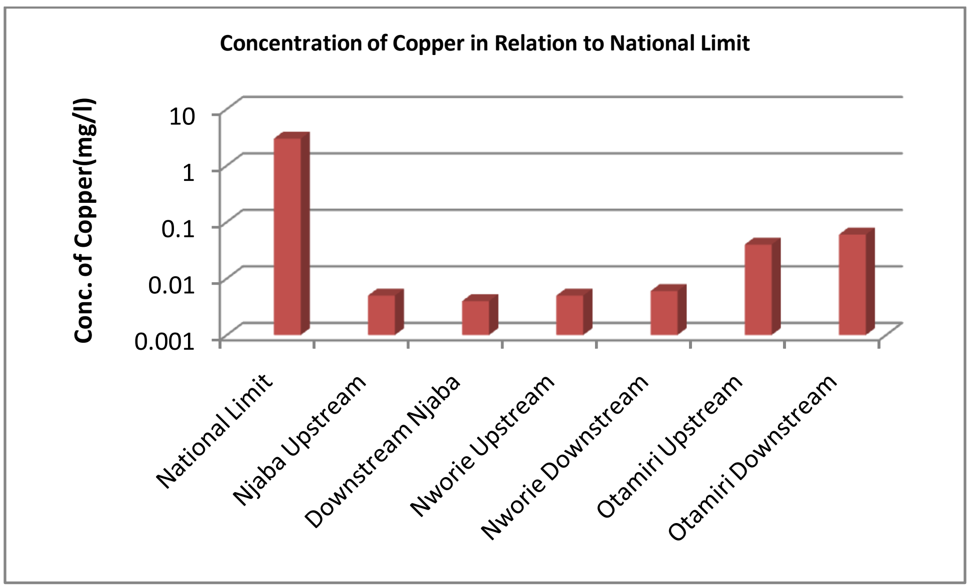


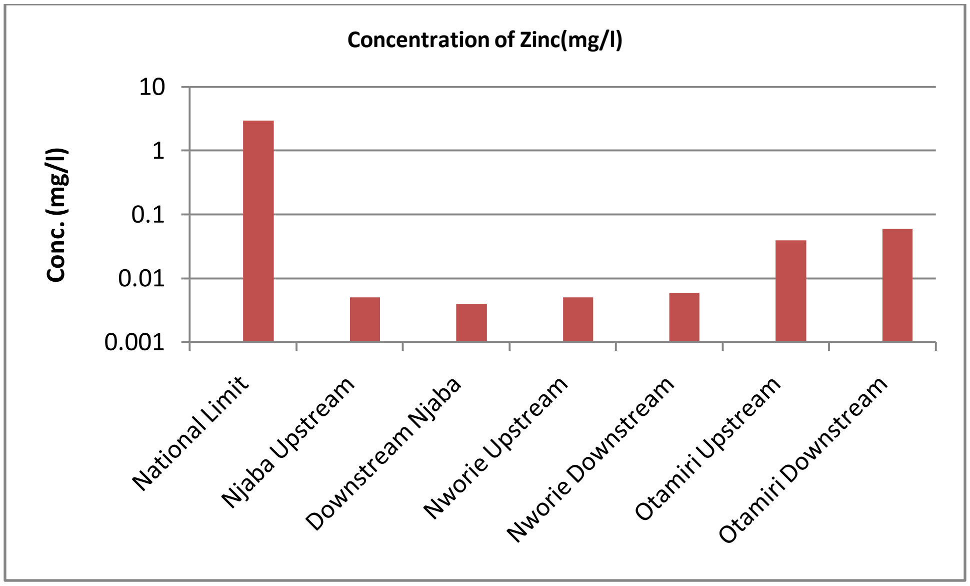

Concentration of Lead (mg/l)
Conc (mg/l)
1
0.1
0.01
0.001
National Limit
Njaba Upstream
Downstream Njaba
Nworie Upstream
Nworie Downstream
Otamiri Upstream
Otamiri Downstream


Concentration of Mercury in Relation to National Unit
Conc (mg/l)
1
0.1
0.01
0.001
National Limit
Njaba Upstream
Downstream Njaba
Nworie Upstream
Nworie Downstream
Otamiri Upstream
Otamiri Downstream

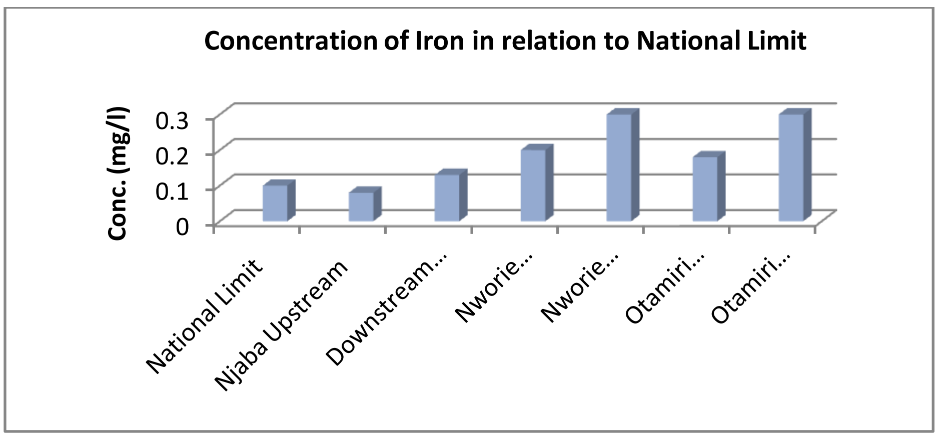

Concentration of Nickel in Relation to National Limit
Conc (mg/l)
10
1
0.1
0.01
0.001
National...
Njaba...
Downstre...
Nworie...
Nworie...
Otamiri...
Otamiri...


Concentarion of manganese in the stations
Conc. of Manganese (mg/l)
0.06
0.05
0.04
0.03
0.02
0.01
0
Njaba Upstream
Downstream Njaba
Nworie Upstream
Nworie Downstream
Otamiri Upstream
Otamiri Downstream

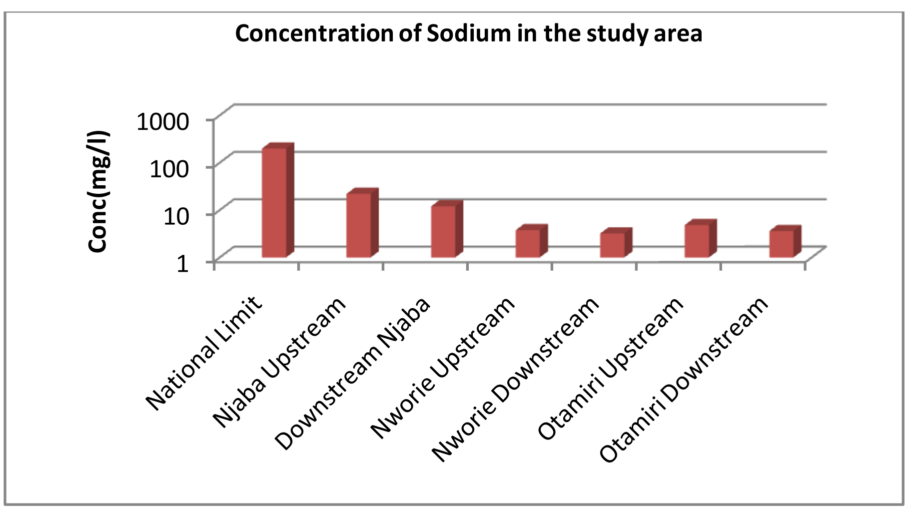

Concentration of Copper in Relation to National Limit
Conc. of Copper(mg/l)
10
1
0.1
0.01
0.001
National Limit
Njaba Upstream
Downstream Njaba
Nworie Upstream
Nworie Downstream
Otamiri Upstream
Otamiri Downstream



Concentration of Zinc(mg/l)
Conc. (mg/l)
10
1
0.1
0.01
0.001
National Limit
Njaba Upstream
Downstream Njaba
Nworie Upstream
Nworie Downstream
Otamiri Upstream
Otamiri Downstream



Concentration of Iron in relation to National Limit
Conc. (mg/l)
0.3
0.2
0.1
0
National Limit
Njaba Upstream
Downstream...
Nworie...
Nworie...
Otamiri...
Otamiri...



Concentration of Sodium in the study area
Conc(mg/l)
1000
100
10
1
National Limit
Njaba Upstream
Downstream Njaba
Nworie Upstream
Nworie Downstream
Otamiri Upstream
Otamiri Downstream

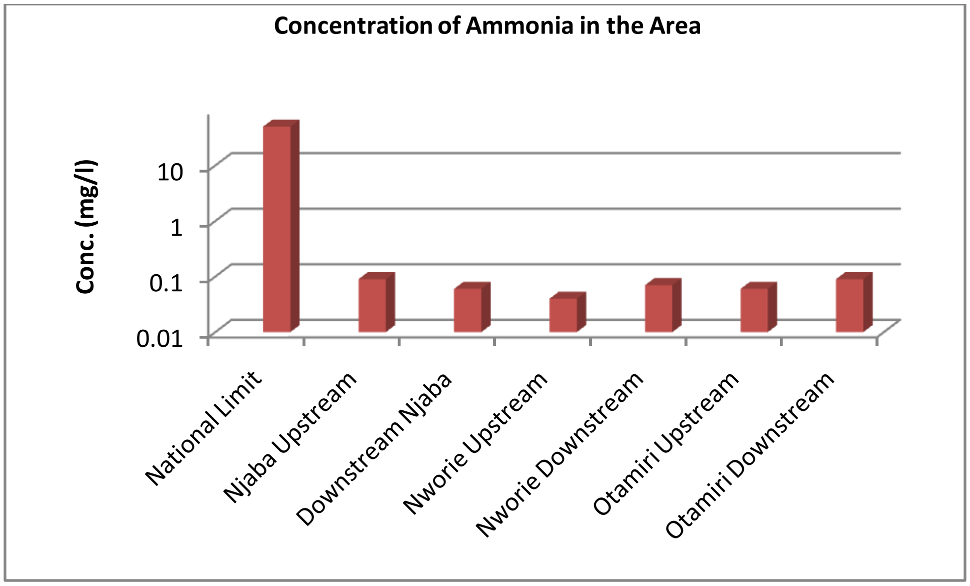


Fig.4.6: Heavy metal concentration of Njaba, Nworie and Otamiri River

Table 4.5.3: Comprehensive pollution index of Njaba, Nworie and Otamiri rivers

	NJABA	NWORIE	OTAMIRI
UPSTREAM	0.713	3.2	3.26
DOWNSTREAM	5.59	3.68	3.95
REMARK	Slightly /Heavily polluted	Heavily polluted	Heavily polluted

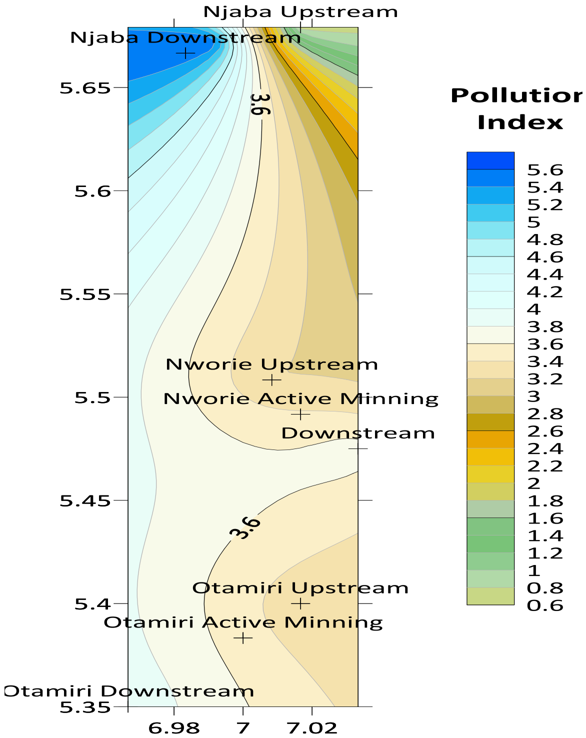


Fig.4.7. Pollution Index map of Njaba, Nworie and Otamiri rivers

Table 4.6: Result of Noise Level Analysis Conducted at Lokpaukwu Quarry Site.

Location	**Coordinates**	**Noise Level**	**NESREA Limit**	**Remarks**
Pit	N05°54'45.9" E007°26'47.8"	72	85	Satisfactory
Primary Crusher	N05°54'77.7" E007°26'49.9"	89.0	85	Satisfactory
Secondary Crusher	N05°54'47.3" E007°26'26.8"	90	85	Satisfactory
Generator House	N05°54'45.6" E007°26'29.3"	94.0	85	Unsatisfactory
Aggregate	N05°54'49.3"	61.4	85	Satisfactory

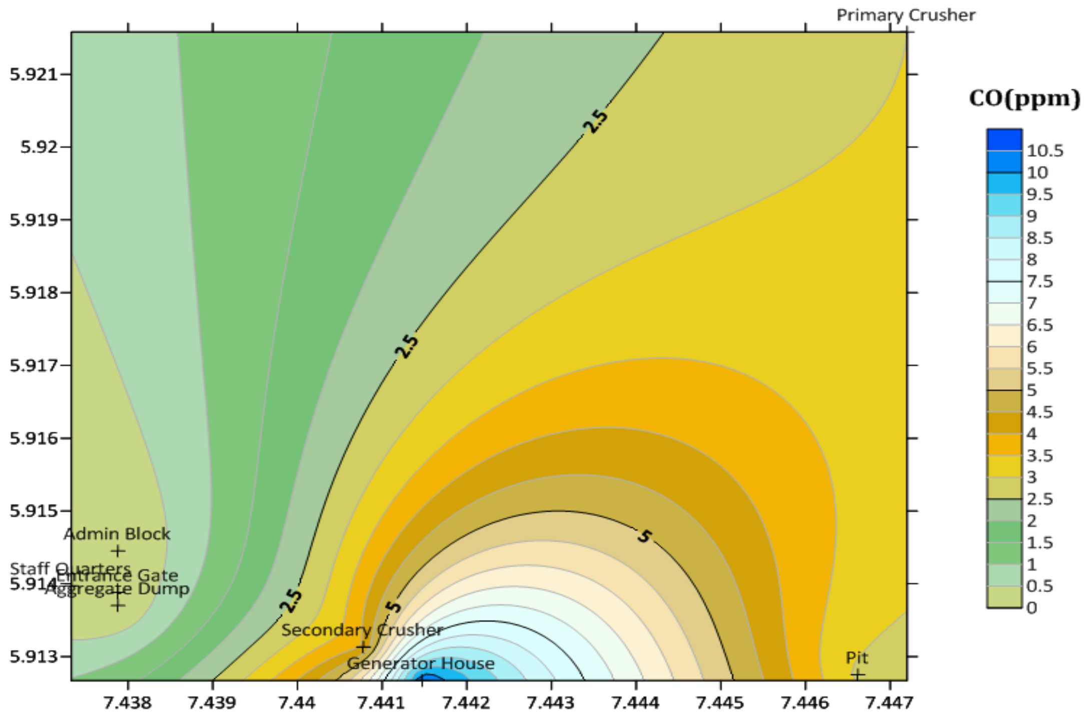
Dump	E007°26'20.1"			
Admin Block	N05°54'52.0" E007°26'16.4"	47.0	85	Satisfactory
Staff Quarters	N05°54'50.3" E007°26'14.4"	49.4	85	Satisfactory
Entrance Gate	N05°54'50.0" E007°26'16.4"	58.1	85	Satisfactory

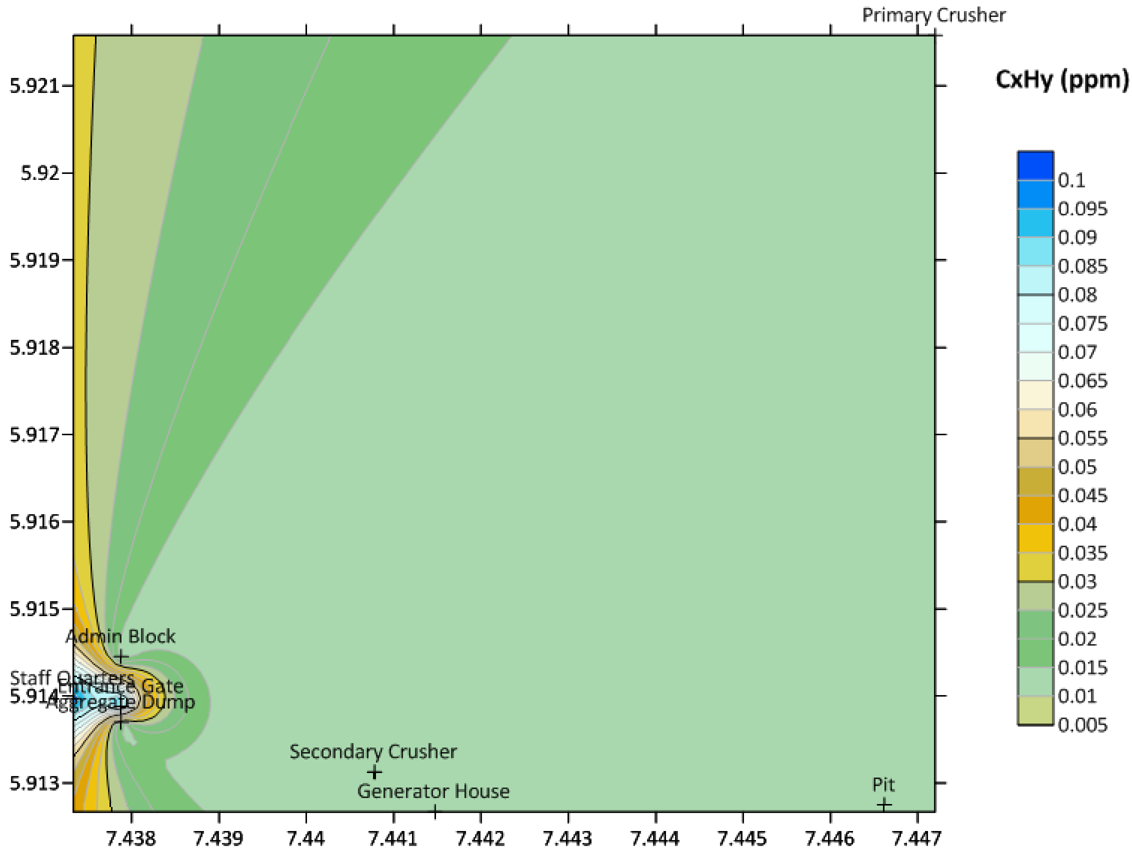
Table 4.6.1: Result of Air Quality at Lokpaukwu Quarry Site

Location	Coordinates	Nox (ppm)	Sox (ppm)	CO(ppm)	H_2S (ppm)	O_2 (ppm)	CxHy (ppm)	SPM(μg/m^3)
Pit	N05°54'45.9" E007°26'47.8"	<0.01	<0.01	2.90	<0.01	20.9	<0.01	23.2
Primary Crusher	N05°54'77.7" E007°26'49.9"	<0.01	<0.01	3.00	<0.01	20.9	<0.01	214
Secondary Crusher	N05°54'47.3" E007°26'26.8"	<0.01	<0.10	4.00	<0.01	21.0	<0.01	212
Generator House	N05°54'45.6" E007°26'29.3"	<0.10	<0.10	10.5	<0.01	20.8	<0.01	67.2
Aggregate Dump	N05°54'49.3" E007°26'16.4"	<0.01	<0.01	<0.01	<0.01	20.9	<0.01	45.0
Admin Block	N05°54'52.0" E007°26'16.4	<0.01	<0.01	<0.01	<0.01	20.8	<0.01	22.8
Staff	N05°54'50.3"	<0.10	<0.10	<0.10	<0.10	20.8	<0.10	2.80

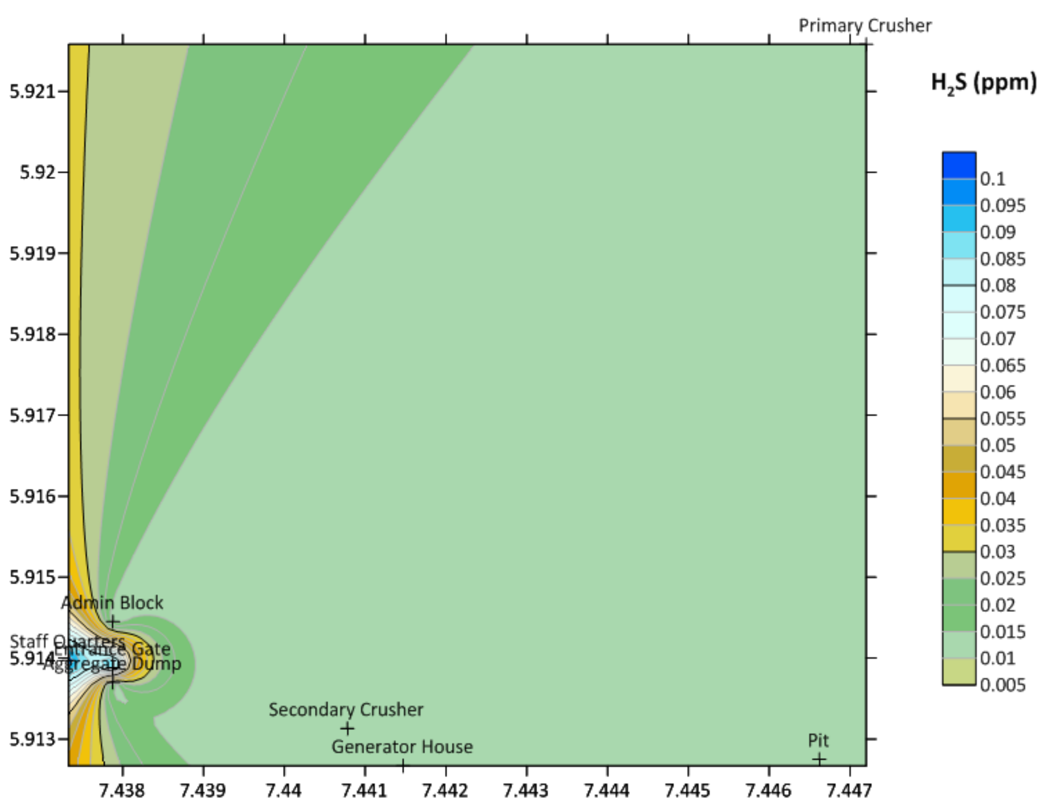
Quarters	E007°26'14.4"							
Entrance Gate	N05°54'50.0" E007°26'16.4"	<0.10	<0.10	<0.10	<0.10	20.8	<0.10	13.1

Fig. 4.8: Spatial Variation Map of Lokpaukwu

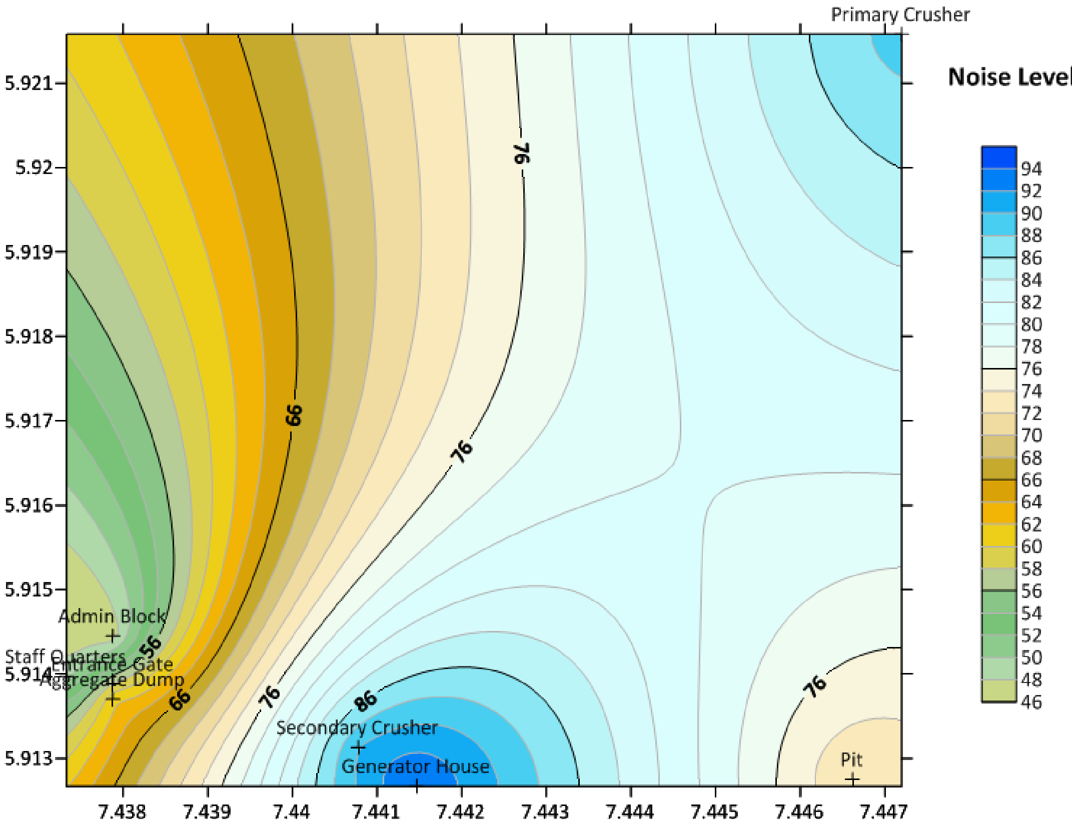




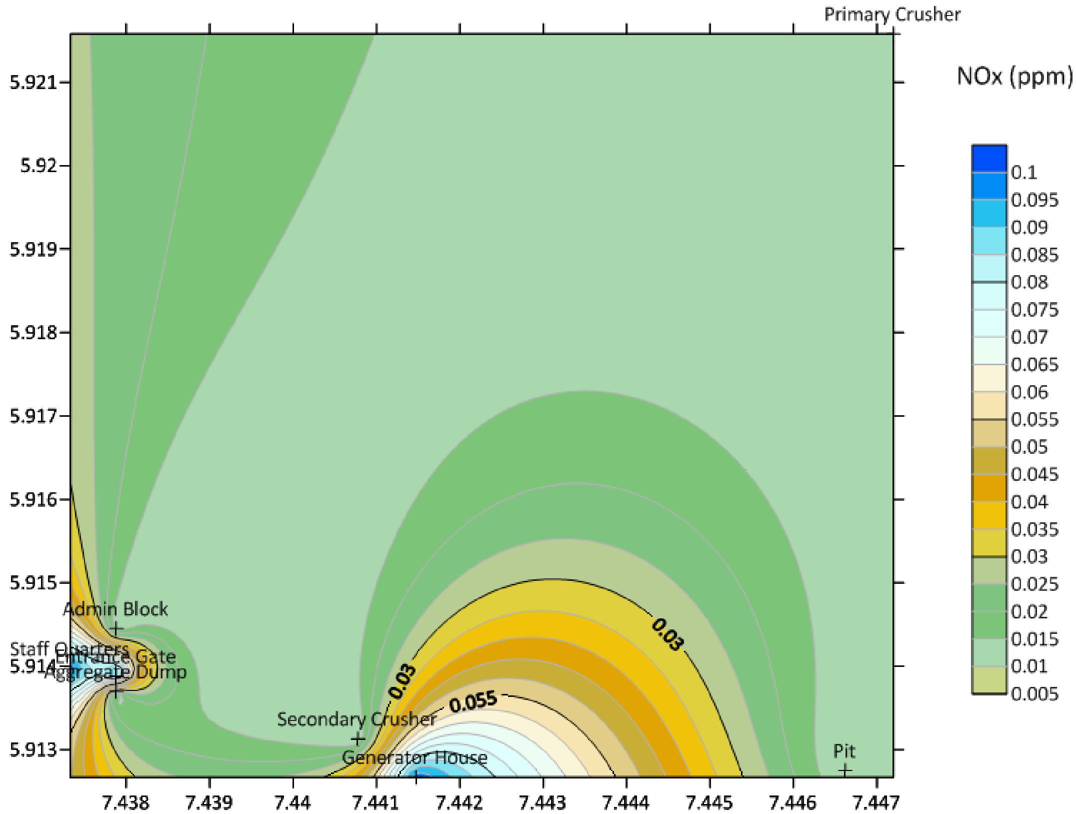
Primary Crusher
CxHy (ppm)
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
5.921
5.92
5.919
5.918
5.917
5.916
5.915
5.914
5.913
Admin Block
Staff Quarters
Entrance Gate
Aggregate Dump
Secondary Crusher
Generator House
Pit
7.438
7.439
7.44
7.441
7.442
7.443
7.444
7.445
7.446
7.447

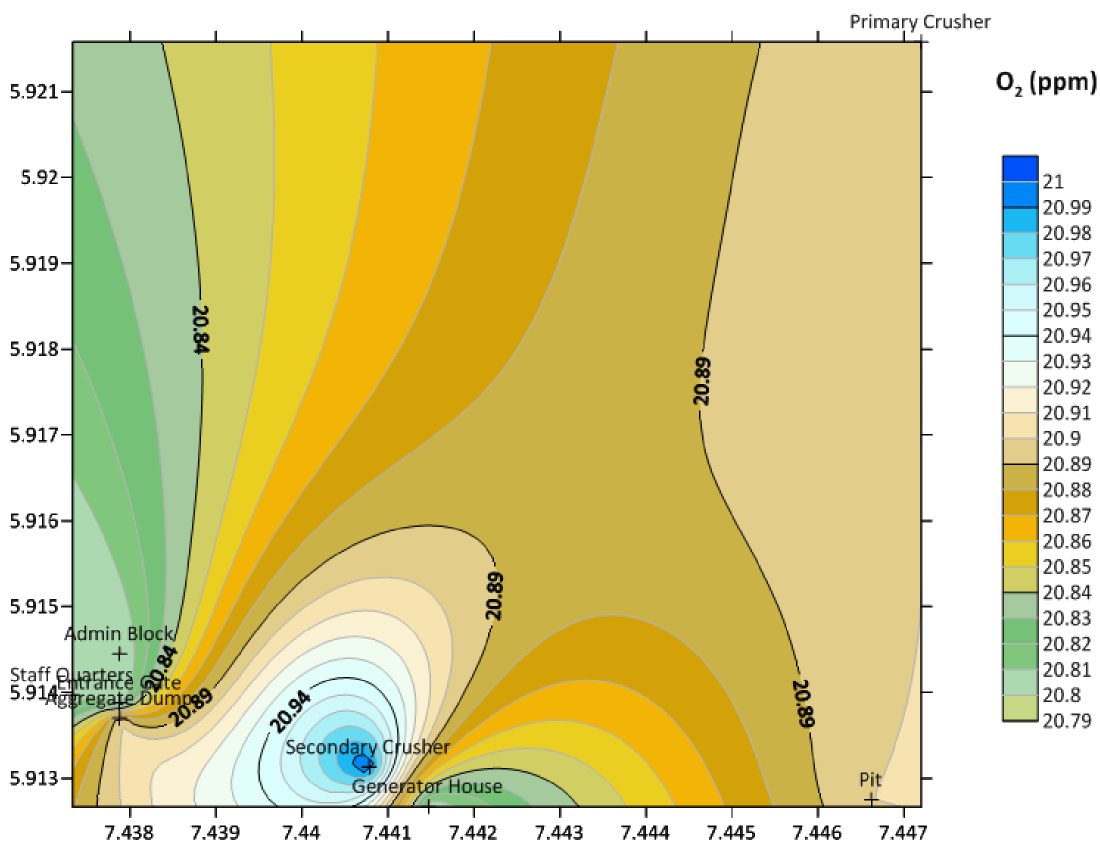


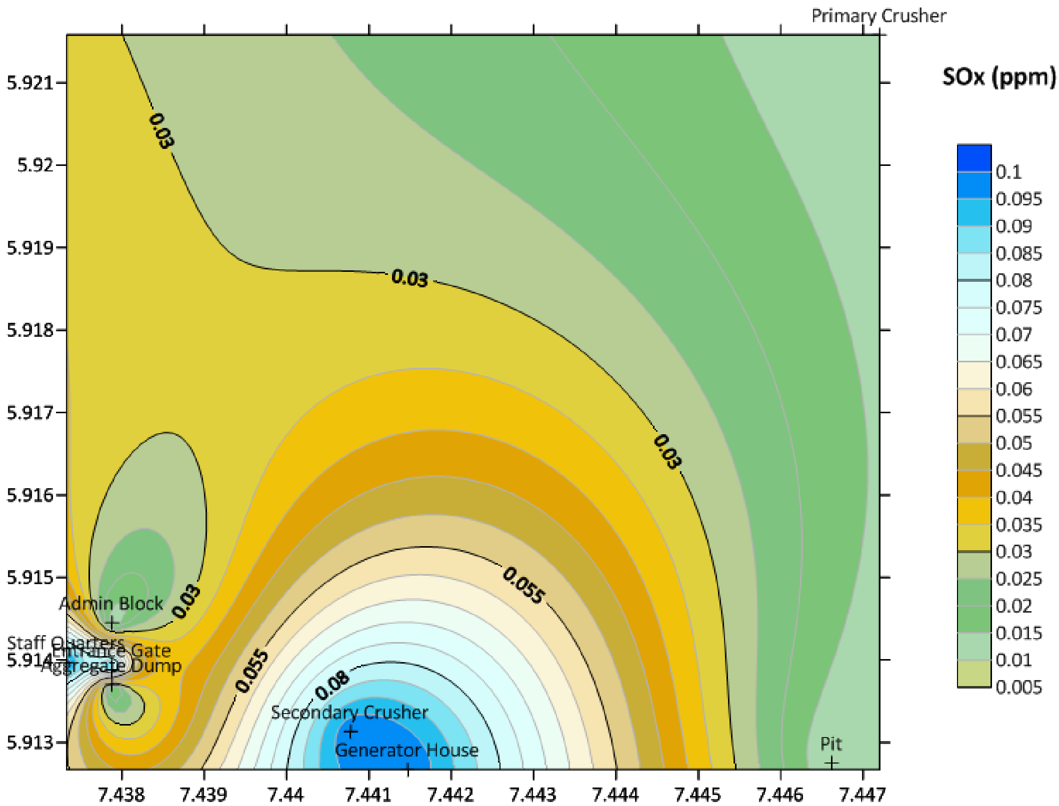
Primary Crusher
H2S (ppm)
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
5.921
5.92
5.919
5.918
5.917
5.916
5.915
5.914
5.913
Admin Block
Staff Quarters
Entrance Gate
Aggregate Dump
Secondary Crusher
Generator House
Pit
7.438
7.439
7.44
7.441
7.442
7.443
7.444
7.445
7.446
7.447



Primary Crusher
Noise Level
5.921
5.92
5.919
5.918
5.917
5.916
5.915
5.914
5.913
7.438
7.439
7.44
7.441
7.442
7.443
7.444
7.445
7.446
7.447
Admin Block
Staff Quarters
Entrance Gate
Aggregate Dump
Secondary Crusher
Generator House
Pit
76
66
56
86
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46


Primary Crusher
NOx (ppm)
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
Admin Block
Staff Quarters
Entrance Gate
Aggregate Dump
Secondary Crusher
Generator House
Pit
0.03
0.055
5.921
5.92
5.919
5.918
5.917
5.916
5.915
5.914
5.913
7.438
7.439
7.44
7.441
7.442
7.443
7.444
7.445
7.446
7.447


Primary Crusher
O_2 (ppm)
21
20.99
20.98
20.97
20.96
20.95
20.94
20.93
20.92
20.91
20.9
20.89
20.88
20.87
20.86
20.85
20.84
20.83
20.82
20.81
20.8
20.79
Admin Block
Staff Quarters
Entrance Gate
Aggregate Dump
Secondary Crusher
Generator House
Pit
20.84
20.89
20.94
5.921
5.92
5.919
5.918
5.917
5.916
5.915
5.914
5.913
7.438
7.439
7.44
7.441
7.442
7.443
7.444
7.445
7.446
7.447


Primary Crusher
SOx (ppm)
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0.03
0.055
0.08
Admin Block
Staff Quarters
Entrance Gate
Aggregate Dump
Secondary Crusher
Generator House
Pit
5.921
5.92
5.919
5.918
5.917
5.916
5.915
5.914
5.913
7.438
7.439
7.44
7.441
7.442
7.443
7.444
7.445
7.446
7.447

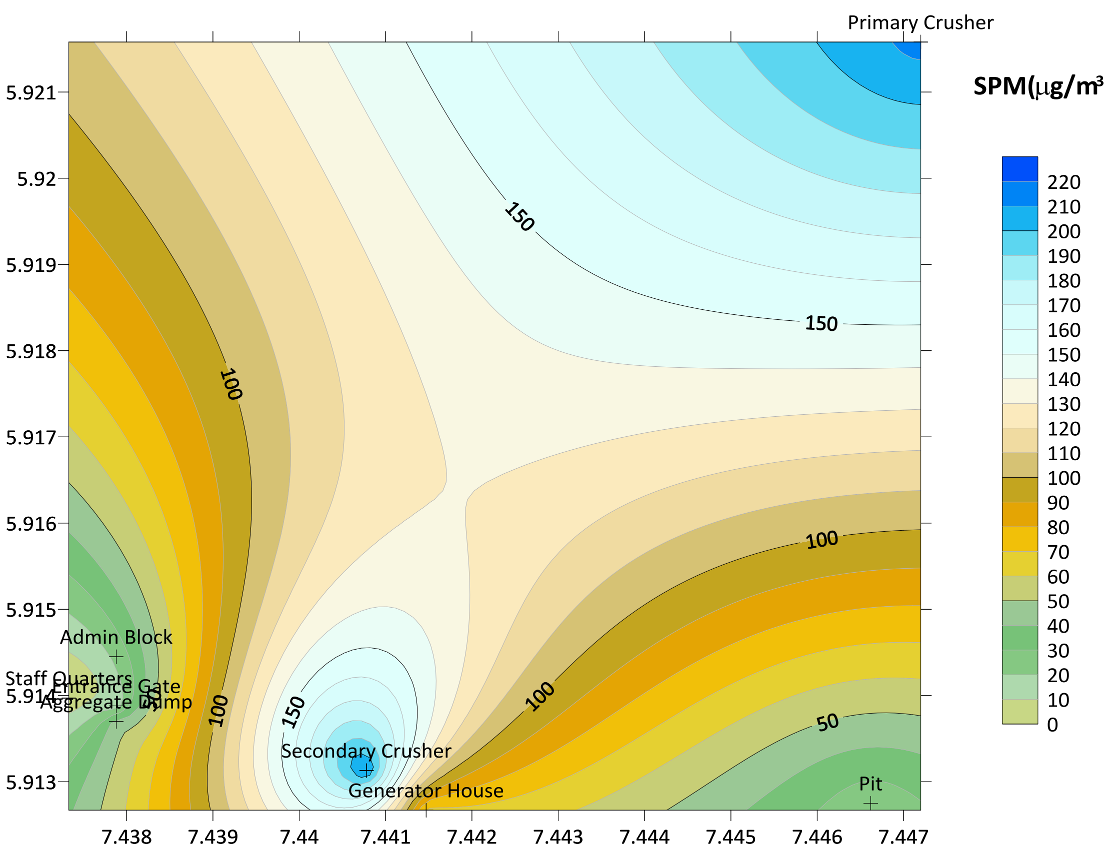

Primary Crusher
SPM(μg/m³)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
150
100
50
Admin Block
Staff Quarters
Entrance Gate
Aggregate Dump
Secondary Crusher
Generator House
Pit
5.921
5.92
5.919
5.918
5.917
5.916
5.915
5.914
5.913
7.438
7.439
7.44
7.441
7.442
7.443
7.444
7.445
7.446
7.447

Table 4.7: Result of Noise Level Analysis Conducted at Amasiri Quarry Site

Location	Coordinates	Noise Level	NESREA Limit	Remarks
Admin Block	N05o90'32.2" E07o87'07.3"	48	85	Satisfactory
Crusher Site	N05o90'34.3" E07o86'95.2"	91	85	Unsatisfactory
Generator House	N05o90'31.7" E07o82'94.9"	80	85	Satisfactory
Blasting Pit	N05o90'73.1" E07o87'0.03"	124	85	Unsatisfactory
Amasiri Settlement	N05o90'73.1" E07o88'24.8"	30	85	Satisfactory

Table 4.7.1: Result of Air Quality Analysis at Amasiri Quarry Site

Location	Coordinates	SPM(ug/m^3)	CO(ppm)	NO_2 (ppm)	SO_2 (ppm)	NH_3 (ppm)	HCN(ppm)	Cl_2(ppm)
Admin Block	N05o90'32.2" E07o87'07.3"	32	0.01	0.1	0.1	0	0.78	0
Crusher Site	N05o90'34.3" E07o86'95.2"	700	5	0.2	0.2	0	1	0
Generator House	N05o90'31.7" E07o82'94.9"	21	0.76	0.1	0.3	1.0	2.02	0
Blasting Pit	N05o90'73.1" E07o87'0.03"	220	2	0.1	0.06	0.001	0.7	0
Amasiri Community	N05o90'73.1" E07o88'24.8"	14	0.89	0.05	0.01	0.002	0.002	0
National Limit		140	10	0.06	0.01	0.2	-	0.03

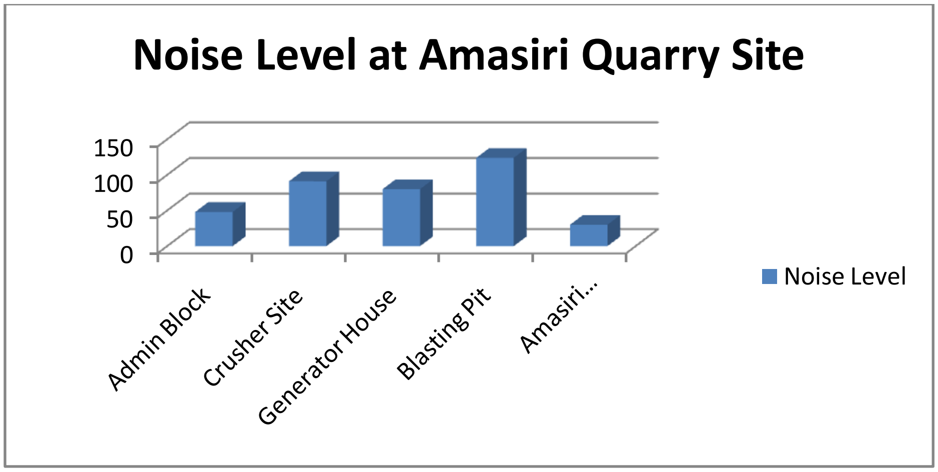
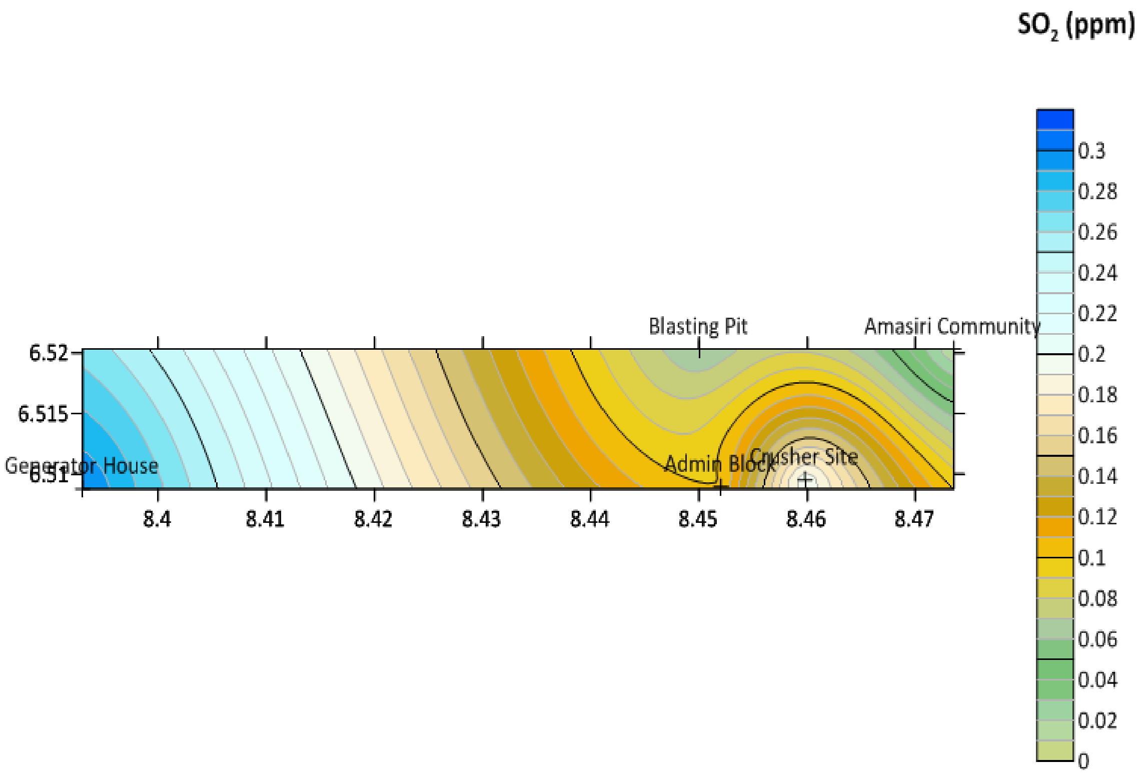
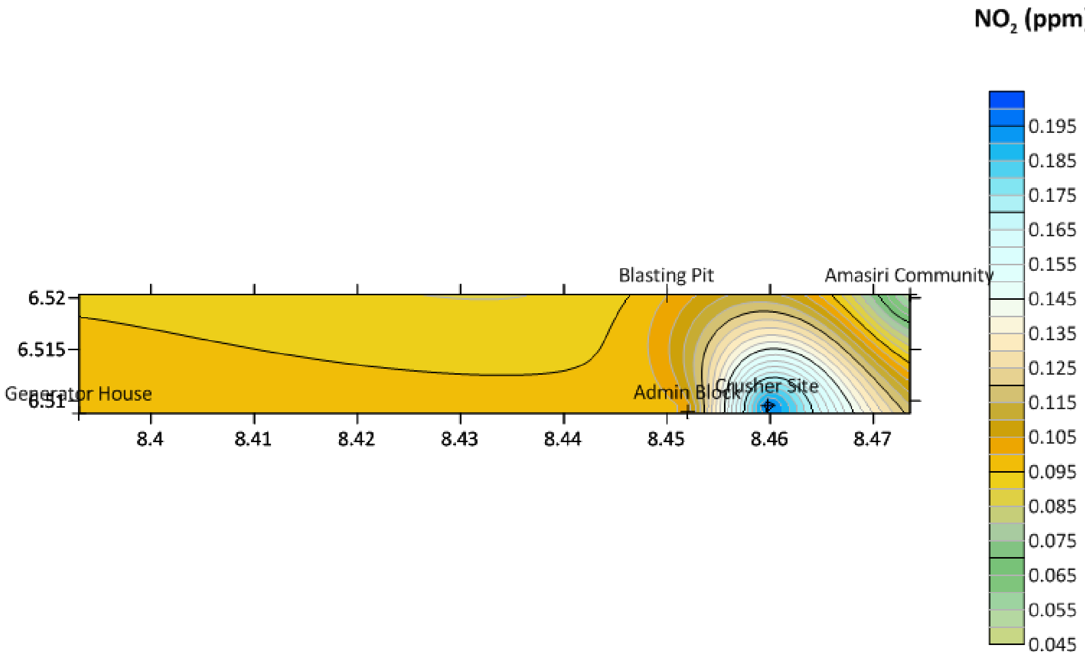
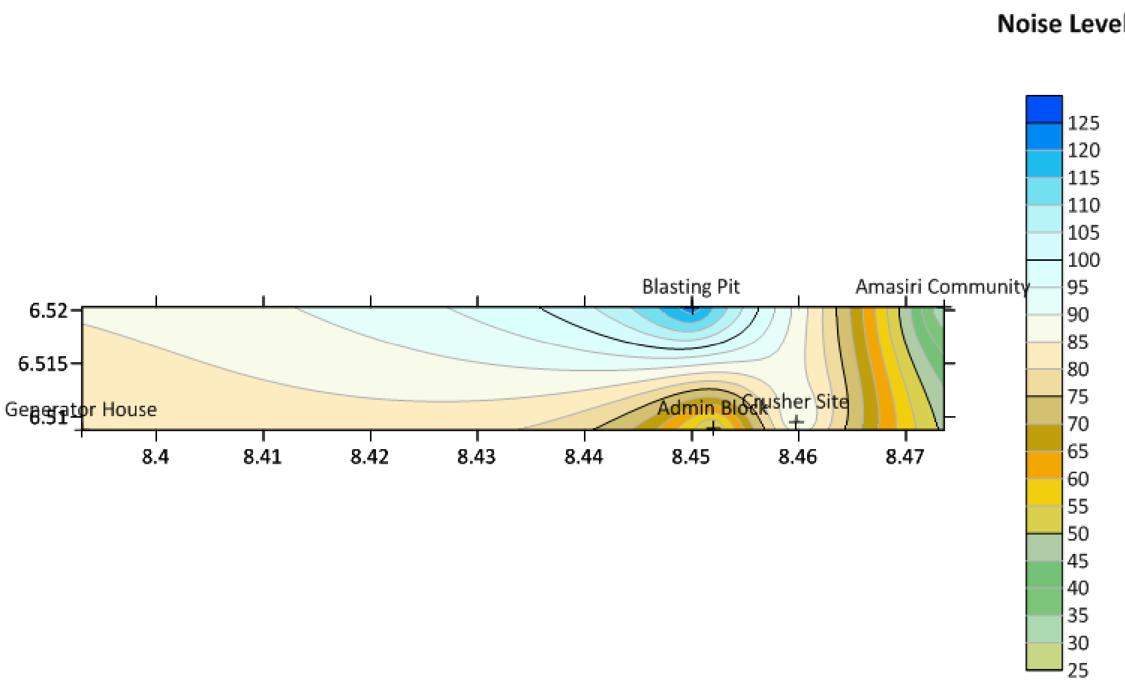
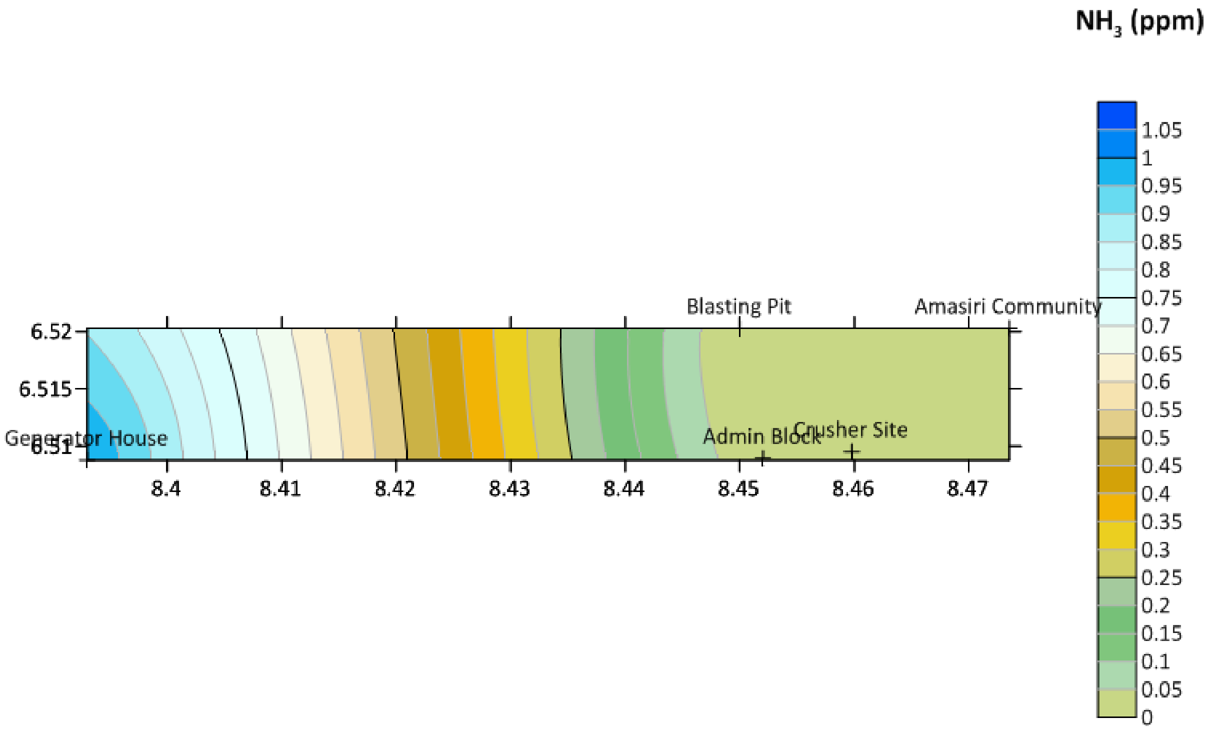


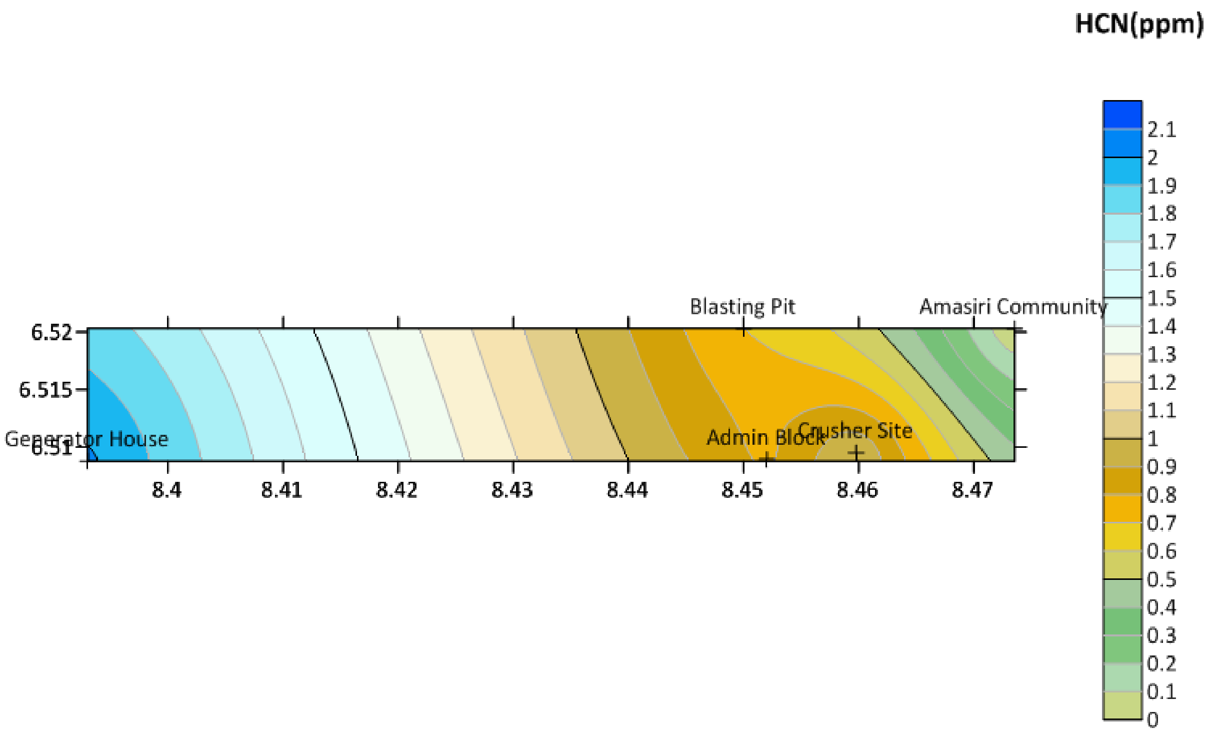
Fig. 4.9: Air quality Index spatial variation map of Amasiri quarry site

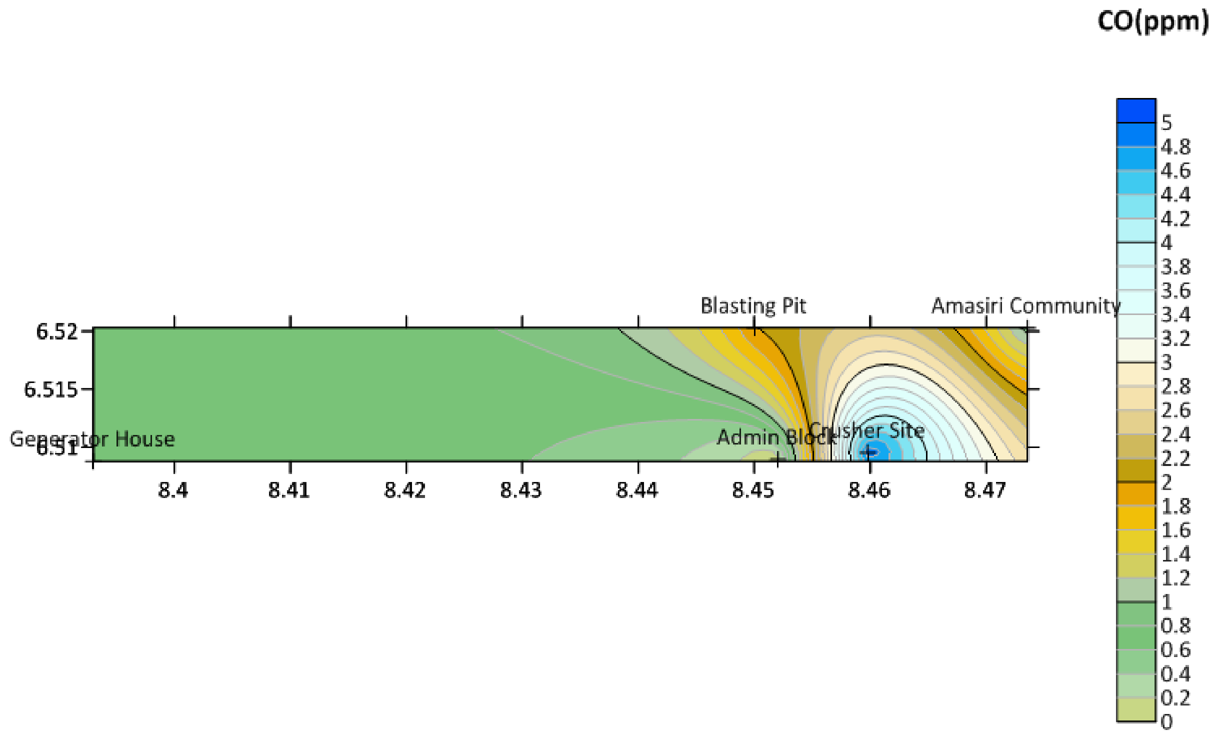



NO2 (ppm)
0.195
0.185
0.175
0.165
0.155
0.145
0.135
0.125
0.115
0.105
0.095
0.085
0.075
0.065
0.055
0.045
Blasting Pit
Amasiri Community
Generator House
Admin Block
Crusher Site
6.52
6.515
6.51
8.4
8.41
8.42
8.43
8.44
8.45
8.46
8.47


Noise Level
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
Blasting Pit
Amasiri Community
Generator House
Admin Block
Crusher Site
6.52
6.515
6.51
8.4
8.41
8.42
8.43
8.44
8.45
8.46
8.47


NH$_3$ (ppm)
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Blasting Pit
Amasiri Community
Generator House
Admin Block
Crusher Site
6.52
6.515
6.51
8.4
8.41
8.42
8.43
8.44
8.45
8.46
8.47


HCN(ppm)
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Blasting Pit
Amasiri Community
Generator House
Admin Block
Crusher Site
6.52
6.515
6.51
8.4
8.41
8.42
8.43
8.44
8.45
8.46
8.47


CO(ppm)
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Blasting Pit
Amasiri Community
Generator House
Admin Block
Crusher Site
6.52
6.515
6.51
8.4
8.41
8.42
8.43
8.44
8.45
8.46
8.47

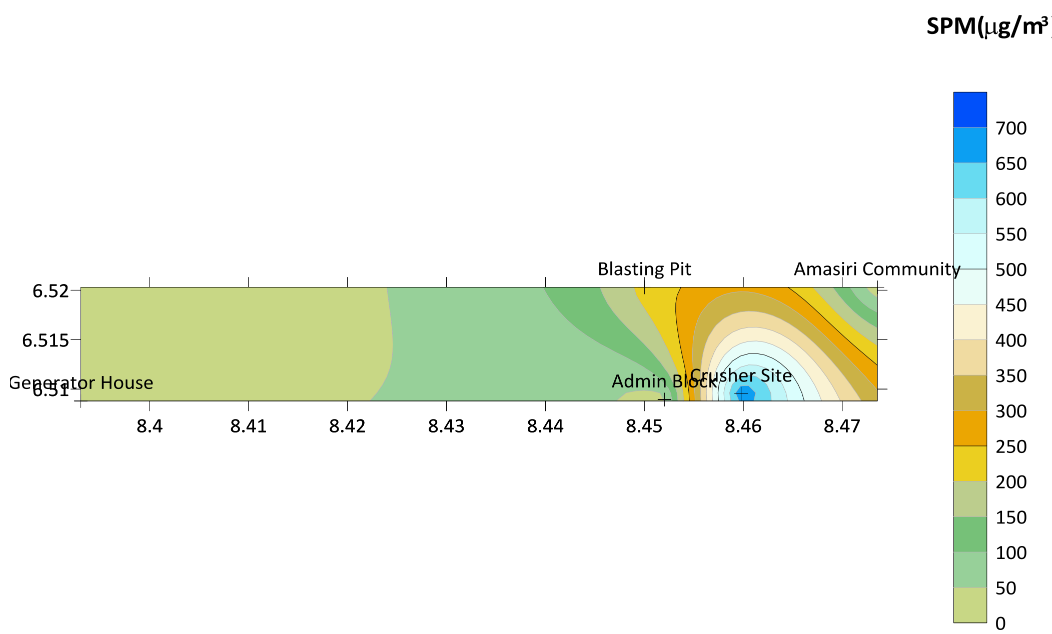
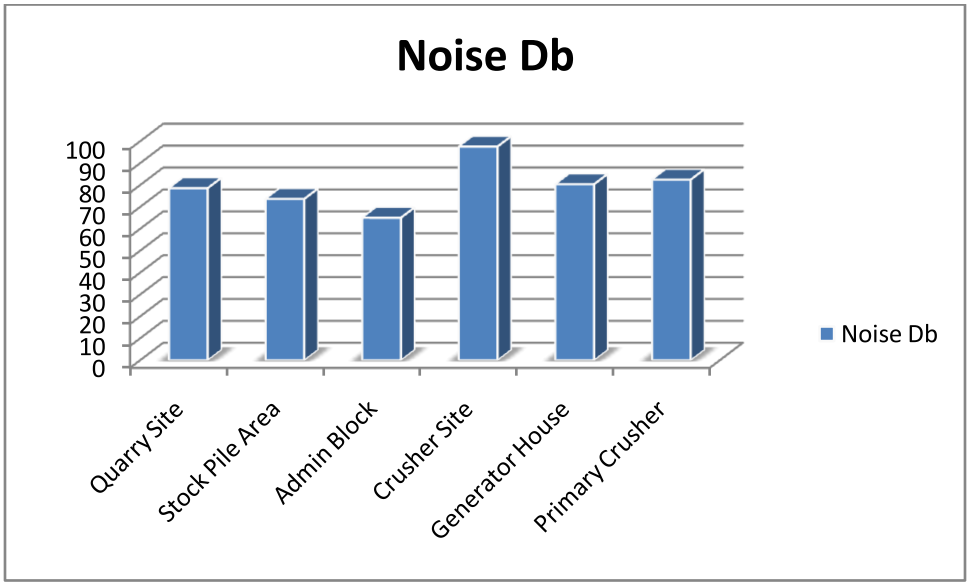

SPM(μg/m³)
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Blasting Pit
Amasiri Community
Generator House
Admin Block
Crusher Site
6.52
6.515
6.51
8.4
8.41
8.42
8.43
8.44
8.45
8.46
8.47

Table 4.7.2: Result of Air Quality and Noise level analysis at Afikpo Quarry Site

Location	SPM (μg/m^3)	CO (ppm)	SO_2 (ppm)	CO_2(ppm)	CxHy(ppm)	H_2S (ppm)	Noise Db
Quarry Site	750	<0.01	0.01	0.01	<0.01	<0.10	78.6
Stock Pile Area	1400	<0.11	0.01	0.01	<0.01	<0.10	73.7
Admin Block	250	<0.01	0.001	0.01	<0.01	<0.01	65.1
Crusher Site	1350	<0.12	0.07	0.02	<0.01	0.30	97.6
Generator House	300	<0.13	0.01	0.04	<0.01	<0.10	80.4
Primary Crusher	1200	<0.10	0.3	0.03	<0.01	<0.10	82.5
FMENV Limit	140		0.01		2.0	-	90db



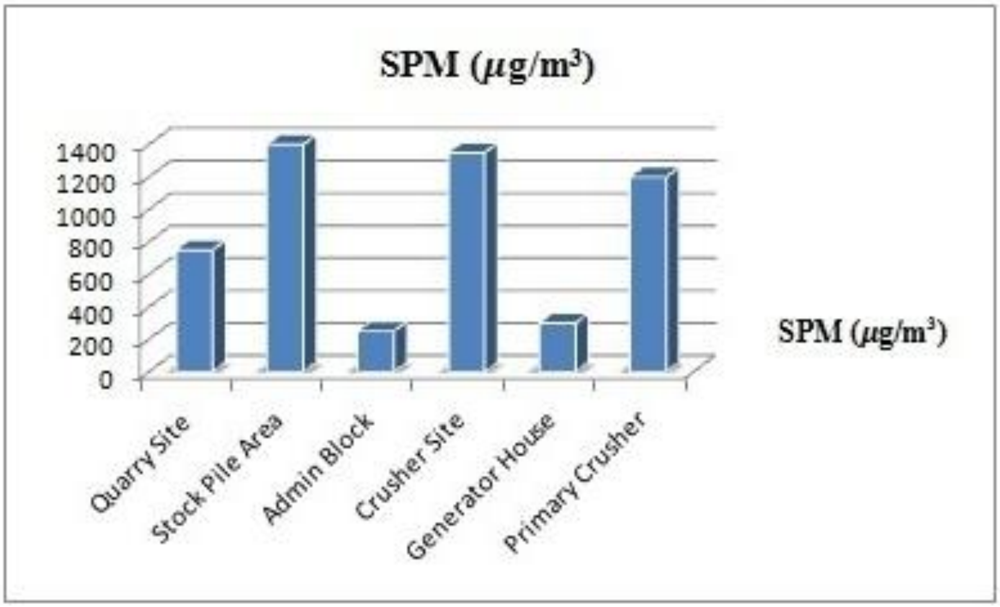


Table 4.7.3: AQI of SPM concentration at Lokpaukwu

Location	Conditional Pollutant	AQI
Pit	SPM	19
Primary Crusher	SPM	68
Secondary Crusher	SPM	68
Generator House	SPM	40
Aggregate Dump	SPM	29
Admin Block	SPM	18
Staff Quarters	SPM	4
Entrance Gate	SPM	13

Table 4.7.4: AQI of SPM concentration at Afikpo

Location	Conditional Pollutant	AQI
Quarry Site	SPM	367647
Stock Pile Area	SPM	686275
Admin Block	SPM	100
Crusher Site	SPM	661765
Generator House	SPM	117
Primary Crusher	PM2.5	588235

Table 4.7.5: AQI of SPM concentration at Amasiri

Location	Conditional Pollutant	AQI
Admin Block	SPM	28
Crusher Site	SPM	343137
Generator House	SPM	21
Blasting Pit	SPM	90
Amasiri Community	SPM	15

Table 4.8:The Physico-Mechanical Properties of Raodstone Aggregates from Some Quarries in Parts of Southeastern Nigeria.

S/N	**Quarries/ Location**	**Rock type**	**Geologic formation intruded**	**Physico-mechanical properties**				
				ACV (%)	**AIV (%)**	**LAAV (%)**	**WA (%)**	**SG**
1	Lokpaukwu	Diorite	Ezeaku Formation	15.60	13.70	26.30	0.54	2.75
2	Uturu	Andesite	Ezeaku Formation	19.20	19.01	19.50	0.10	2.67
3	Ishiagu	Diorite	Asu River Group	15.50	17.40	23.50	1.20	2.75
4	Afikpo	Dolerite	Ezeaku Formation	13.80	14.40	33.70	0.50	2.81
FMW 1997 Standard				<30.00	<30.00	<40.00	<3.0	>2.60

Table 4.9:Strength and durability parameters of Okigwe Sandstone aggregates

PARAMETER	**RESULT/ VALUE**
Aggregate crushing value (ACV) (%)	34.50
Aggregate impact value (AIV) (%)	36.40
Los Angeles abrasion value (LAAV) (%)	60.70
Water absorption (%)	0.60
Bulk density (Mg/m^3)	1.63
Concrete Compression test	16.65

Table 4.10: Strength and durability parameters of Ihitte-Uboma (Elugwu/ Umuchienta) sandstone aggregates

PARAMETER	RESULT/ VALUE
Aggregate crushing value (ACV) (%)	35.70
Aggregate impact value (AIV) (%)	32.60
Los Angeles abrasion value (LAAV) (%)	46.48
Water absorption (%)	0.90
Bulk density (Mg/m^3)	1.42
Concrete compression test	18.90

4.12 Aggregate Parameter Explanations

The Aggregate Crushing Value is a value which indicates the ability of an aggregate to resist crushing under a gradually applied compressive load (a California Bearing Ratio (CBR) machine or concrete crushing apparatus) over a period of 10 minutes, after passing through sieve 14.0mm, and retained on 10.0mm sieve.

Aggregate Impact Value (AIV) gives a relative measure of the resistance of an aggregate to sudden shock or impact. Aggregate impact value can be determined for aggregates in dry condition or in socked condition. Aggregates larger than 14mm are not appropriate to the aggregate impact value test. It is another form of evaluating the strength and durability of aggregates used for engineering construction.

Los Angeles Abrasion Value is the measurement of resistance to attrition. However, the principal of Los Angeles Abrasion Value test is to find the percentage of wear due to relative rubbing action between the aggregate and steel balls used as abrasion charge.

"Water Absorption is the increase in the weight of aggregate due to water in the pores of the material(excluding water adhering to the outside surface of the particles) expressed as a percentage of the dry weight. Aggregates used in roadstones normally range from 0 to about 3% for materials used in road surfacing" (BS.882, 1973). "It however, controls the amount of binder required in highway surfacing design (high water absorption value will need more binder materials after the ingredients have been mixed). The water absorption was obtained by expressing the difference between the weights of the saturated and oven dried samples in air as a percentage of the latter "(O'Flaherty, 1974).

"The Concrete Compression Strength of aggregate is a measure of the capacity of concrete to resist a compressive force tending to crush it. It is the most common performance measure used by engineers in designing buildings and other structures. Compressive test results are used to determine that concrete mixture as delivered on site meets the requirements of the specified strength in the job specification. The concrete compression strength depends on the water to cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortar and aggregate, and grading, shape, strength and size of the aggregates" (Rocco and Elices, 2009). "Compression strength depends mostly on the size of the aggregates, bigger sizes (10-15 and 15-25mm) are generally good roadstone while smaller sizes (5-10mm) are generally poor roadstone" (O'Flaherty, 1974).

The bulk density of aggregates is indirect measurements of the strength and durability of the road construction. Dense aggregates with high specific gravity values are generally strong while density greater than 2.6mg/m^3 are good for road construction.

Strength and Shrinkage The strength of an aggregate is rarely tested and generally does not influence the strength of conventional concrete as much as the strength of the paste and the paste-aggregate bond. However, aggregate strength does become important in high-strength concrete. Aggregate stress levels in concrete are often much higher than the average stress over the entire cross section of the concrete. Aggregate tensile strengths range from 2 to 15 MPa (300 to 2300 psi) and compressive strengths from 65 to 270 MPa (10,000 to 40,000 psi). Different aggregate types have different compressibility, modulus of elasticity, and moisture-related shrinkage characteristics that can influence the same properties in concrete. Aggregates with high absorption may have high shrinkage on drying. Quartz and feldspar aggregates, along with limestone, dolomite, and granite, are considered low shrinkage aggregates; while aggregates with sandstone, shale, slate, hornblende, and graywacke are often associated with high shrinkage in concrete.

4.13 Environmental Effects of Some Pollutants

Suspended Particulate Matter (SPM)

The potential anthropogenic sources of SPM in the quarry site include fumes from processing/ crushing plant, blasting activities, haulage of crush rocks, welding activities, exhaust fumes from many sources e.g heavy duty vehicles, power generating plants etc.

Prolonged and excessive inhalation of fine particulates may cause cancer and aggravate morbidity and mortality from respiratory dyfunctions. Its high concentration is known to irritate the mucous membranes and may initiate different respiratory problems e.g cough and asthma. It can also cause materials damage through corrosion of metals at relatively humidity above 75% and discoloring painted surfaces.SPM constitutes a nuisance by interfering with sunlight and acting as a catalytic surface for reaction of absorbed chemicals.

Carbon Monoxide

Carbon monoxide (CO) is as result of incomplete oxidation of fossil fuels (hydrocarbon), though sources of CO in the quarry site include diesel powered generating plant, processing plant, vehicular emissions, diesel and petrol engines such as heavy duty equipment, welding machines, trucks etc. prolonged and excessive exposure to ambient accumulation of CO values higher than 877ppm could bring about formation of carboxy-haemoglobin and prevent oxygenation of the blood leading to suffocation and subsequent death. Individuals with cardiovascular diseases and respiratory problems are mostly at risk from exposure to this gas.

Sulphur dioxide (SO_2)

This is one of the major air pollutants. It is usually formed from the oxidation of sulphur containing fuels and biomass. Exposure to SO_2 at concentration above5.00ppm could stimulate broncho-constriction(asthma) and mucous secretion as well as irritate the eyes in human.

Hydrogen sulphide (H_2S)

This gas is extremely toxic, odorous and corrosive. It can be present in natural gas in certain areas and can be released by sulphate reducing bacteria in certain marine environment. Long time exposure to Hydrogen sulphide (H_2S) gas above 0.06pp, could result to death.

Nitrogen dioxide (NO_2)

The oxides of nitrogen are usually formed at higher temperature combustions e.g during blasting operations, industrial combustion and vehicle engines. It is readily formed by partial oxidation of nitrogen and it is usually emitted in exhaust pipe of motor vehicles and the manifold of power generating equipment where rapid oxidation to NO_2 takes place.

Long term exposure to nitrogen dioxide concentrations above 563ppm may cause pulmonary disease and increased susceptibility to bacterial infection in man.

Carbon dioxide (CO_2)

The exposure to CO_2 can produce a variety of health effects. These may include headaches, dizziness, restlessness, a tingling or pins or needles feeling, difficulty breathing, sweating, tiredness, increased heart rate, elevated blood pressure, coma, asphyxia and convulsions. The extra carbon dioxide in the atmosphere increases the greenhouse effect. More thermal energy is trapped by the atmosphere, causing the planet to become warmer than it would be naturally. This increase in the earth's temperature is called global warming.

C_XH_Y

Hydrocarbons are compounds consisting only of carbon or hydrogen. According to the definition of the World Health Organization (WHO) hydrocarbons represent the main part of the volatile organic compounds (VOC) where methane fosters the greenhouse effect.

Ammonia(NH_3)

Ammonia is one of the main sources of nitrogen pollution, alongside nitrogen oxides. Ammonia pollution also effects species composition through soil acidification, direct toxic damage to leaves and by altering the susceptibility of plants to frost, drought and pathogens. The major sources of ammonia include anaerobic decomposition of organic matter, animals and their wastes, biomass burning, soil humus formation and application of anhydrous ammonia to cultivated land. Other sources include industrial emissions. Ammonia reacts with strong acids e.g H_2SO_4 and HNO_3 to produce ammonium salts. Thus ammonia plays an important role in removing SO_2 and NO_2 from our atmosphere.

Exposure to high concentration of ammonia in air causes immediate burning of the eyes, nose, throat and respiratory tract and can result in blindness, lung damage or death. Inhalation of lower concentrations can cause coughing and nose and throat irritation.

Hydrogen cyanide (HCN)

Hydrogen cyanide occurs in the atmosphere in low background amounts. Long term exposure to hydrogen cyanide can rapidly fatal. It has whole-body effects, particularly affecting those organ systems most sensitive to low oxygen levels: the central nervous system (brain), the cardiovascular system (heart and the blood vessels), and the pulmonary system (lungs).The limits of this gas is not given by the FMENv. Therefore, the occurrence does not call for concern.

Chlorine (Cl_2)

Low concentration of Chlorine gas in the atmosphere e.g 3,000ug/m3 or 1ppm can cause irritation of the eyes, nose and throat; larger doses can cause damage to the lungs and produce pulmonary pneumonitis or bronchitis.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

i) Results of the tests (ACV, AIV, LAAV, WA and SG) as concrete strength for aggregate samples from the quarries Lokpaukwu (Diorite), Uturu (Andesite), Ishiagu (Diorite) and Afikpo (Dolerite) respectively showed that they are good to be used as concrete and highway pavement aggregates for road construction when compared with Federal Ministry of Works standards.

ii) Aggregates derived from sandstones from Elugwu/ Umuchienta (Ameka Formation) and Okigwe (NsukkaFormation) are not suitable as highway pavement aggregates but are suitable for concrete.

iii) Quarrying of sand in Njaba, Nwaorie and Otamiri rivers respectively has distorted their channel morphology both in depth and width thereby threatening the stability of nearby bridges.

iv) The unacceptable values of dust, air quality and noise when compared with NESREA limits in each of the quarry site are potential killers of quarry workers and inhabitants of the area.

5.2 Recommendations

i) Workers working very close to crushing and screening plants should be provided with filter masks, ear protection devices (ear plugs, ear muffs and helmets etc) and wearing them should be made mandatory.

ii) Plants can act as barriers for noise transmission. Development of green belt can reduce noise by its screening effect. The effectiveness increases with thickness, height and density of plantation. Hence plantations should be made mandatory.

iii) Treat the dust on its transmission path for example at stockpiling, crushers etc using dust suppression techniques (e.g. water sprays, chemical additives, local exhaust ventilation (LEV), and vacuum).

iv) Regular ambient air quality monitoring shall be carried out to ensure the air pollutants are kept under permissible limits always.

v) Poor quality of explosives and the use of expired explosives in which ingredients have disintegrated should not be used.

vi) Worker should be shifted from his work environment, if he progressively develops noise induced hearing loss i.e. rotation of job.

vii) Health education should be given to the workers. This can be done by social work organizations, educational institutions, NGOs and quarry owners.

viii) A respiratory dust monitoring program has to be developed as part of the mine's safety and health management plan

ix) The aggregates to be used for engineering construction should pass through the necessary aggregate quality assessment.

x) Specification should be drawn regarding the type or weight of vehicles that should ply through the roads constructed with these aggregates tofurther ensure road durability.

xi) For bridge sustainability, routine maintenance is required and, government should put into consideration of providing a specific annual budget for maintenance and improvement works.

5.3 Contribution to Knowledge

i) Potential hazardous areas in the studied sites have been identified through their various noise level and air quality constituents including SPM surveys conductedin the area.

ii) This work has established that individuals with cardiovascular diseases and respiratory issues should not be allowed to work in the quarry sites due to regular exposure to gases like hydrogen Cyanide, Chlorine, Ammonia, Carbon Monoxide.

iii) With the use of mechanical and physical properties, the strength and durability of aggregates have been determined.

iv) It has been established from this studies that dredging of sand near bridges (Otamiri river bridge at FUTO and Njaba river bridge at Okwudor) threatens the stability of the bridgesand its appearances (pillar, embankment and abutment) due to water scouring.

v) Aggregates derived from intrusive igneous rocks from Lokpaukwu (Eze-aku Formation) and Ishiagu (Asu River) are all good for highway pavement and concrete aggregates while sandstone aggregates derived from Elugwu/ Umuchienta (Ameki Formation) and Okigwe (Nsukka Formation) are suitable for only concrete aggregates on the basis of cube compression tests of concrete cubes, sandstone aggregates from Elugwu/ Umuchienta are better materials as concrete aggregates.

vi) This paper has been accepted and presented at NMGS conference in Port-Harcourt.

APPENDIX

This photo shows the western abutment of Njaba River Bridge being threatened by the water scouring.

Manual sand mining at Njaba River at Okwudor.

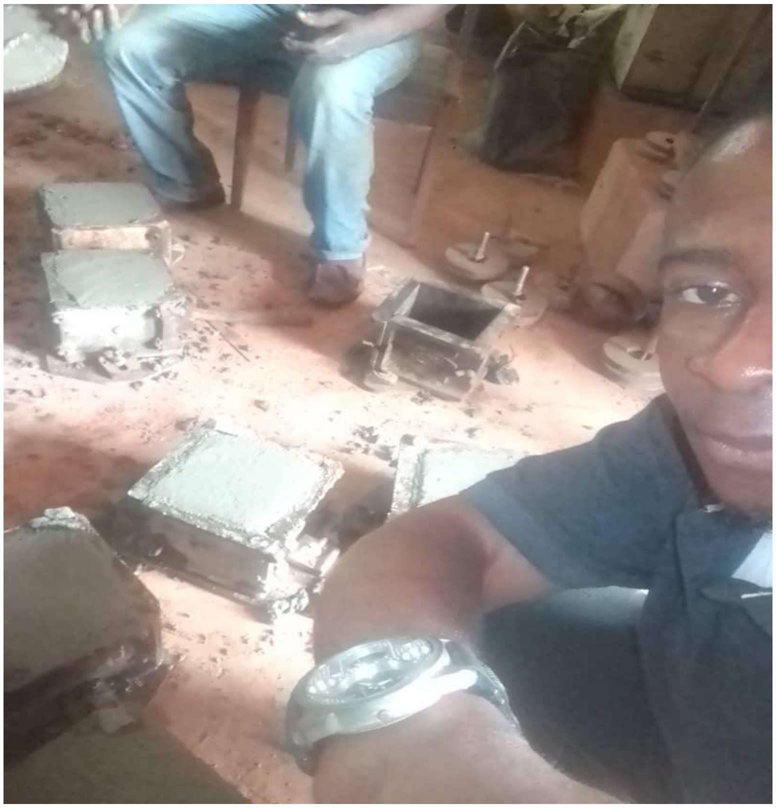


Photo showing the preparation of concrete compressive test (cube test) of aggregates.

Photo showing the experiment on aggregate impact value test of aggregate for road construction

Photo showing the sandstone quarry site at Okigwe

Photo showing the effect of sandstone mining (destruction of economic trees) at Ihitte-Uboma


Photo showing the sand dredging at FUTO Otamiri River

Photo showing the effect of sand dredging on Otamiri River on FUTO Bridge

REFERENCES

Adepoju, S. O.(2002). Time Effect of Organic Matter Accumulation in Restored Surface Layers of Limestone Mining Site. Nigeria Journal of Engineering Management, 33: 35-40

Ademola, J. A.(2008). Exposure to High Background Radiation Level in the Tin Mining Area of Jos, Plateau, Nigeria. Nigeria Journal of Radiology, 2(2): 10-20.

Agunwamba, J. C.(2001). Waste Engineering and Management Tools. Immaculate Business Support Services, Enugu, 403.

Aliyu, B.N.(2014). Morphologic Response of a Stream Channel to Extensive Sand Mining. Research Journal of Environmentaland Earth Sciences 6(2): 96-101

Akande, S. O (2011). Petroleum Technology Development Journal, 1: 3–13

AASHTO,(2001). Specific Gravity and Absorption of Coarse Aggregate. Washington DC. Technical specification. No. T85.

Aromolaram, A.K (2012). Effects of sand mining activities on land.*Journal of Water and Environment*6(1):41-49

Barksdale, R. D.(1991). The Aggregate Handbook. National Stone Association, 717.

Barik, O. T.(2004). Foundation of Air Quality. Arabian Press. No. 27

Berglund, B, Berglund, U, and Induall, T. (1974). Scaling of annoyance in epidemiological studies. International symposium; In proceedings of the CEC, WHO, USEPA International on recent advances in the assessment of the health effects of environmental pollution. Paris, 24-28 June 1-16

Cao, T.S., Nguyen, T.H.G., Trieu, P.T., Nguyen, H.N., and Vo, H.C.(2020). Assessment of Cau river water quality assessment using a combination of water quality and pollution indices. *Journal of Water Supply Research and Technology*. 69 (2): 160 – 172.

De-Swardt, A.J, Casey, O.P. (1963). The Coal Resources of Nigeria. Geological Survey of Nigeria Bulletin, No. 28. 100.

Dolar-Mantuani, L. (1983) Handbook of Concrete Aggregates, a Petrographic and Technological Evaluation. Park Ridge, NJ: Noyes Publications.

Fatoye, F. B., Gideon Y. B. (2013). Africa Geosciences Review, 20(1): 35 – 42.

Farrington.J.L.(1952). A preliminary description of the Nigeria Lead-Zinc field. Econ. Geology .47:538-608

Federal Ministry of Works.(1997). Materials specification for roads and bridges in Nigeria, gravel roads constructions and maintenance guide.215

FEPA.(1991). National Guidelines and Standards for Industrial Effluents, Gaseous Emission and Hazardous Waste Management in Nigeria, 59-66.

Kakulu, S. E.(2003). Trace Metals in Soils and Vegetable from some tin Mining Area in Nigeria. Global Journal of Pure and Applied Science, 9(3): 331-337.

Kamal E.Y.(2019). Evaluation of Air Quality in Sudanese Gold Mining Fields.University of Khartoum Engineering Journal .9(2):7-11.

Keeperman, S. O.(2000). Distribution and Forms of Copper,Zinc, Cadmium, Iron and Manganese in Soils near a Copper Smelter. Journal Soil Science, 135(2):101-109.

Kondolf, G.M, Williams, J.G, Horner, T.C. and Millan, D. (2008). Assessing physical quality of Spawning habitat American fisheries society symposium 65:000-000.

Kondolf, G.M. (1998a).Environmental effects of aggregate extraction from river channels and floodplains. In: Aggregate resources: a global perspective (P.T. Bobrowsky, ed.), 113-129. A.A. Balkema, Rotterdam. 470.

Langer, W. H. and Kolm, K. E. (2001) Hierarchical Systems Analysis of Potential Environmental Impacts of Aggregate Mining. Society for Mining, Metallurgy and Exploration Inc, Annual Meeting.

Liu, S. and Zhu, J.P.(1999). Comparison of Several Methods of Environment Quality Evaluation Using Complex Indices. *Environ.Monit.* 15, 33-37

Magdi M.E. and Hassan A.A. (2019). A Study on Scour Failure at Bridge Foundation. University of Khartoum Eng. Journal .9 (2):12-17.

Mgbemena, N.M (2017). Status of Heavy Metals Pollution in the Sediments of the New Calabar River in River State, *Nigeria. J. Chem. Soc. Nigeria, .42(2) 84-87.*

Musah, A.J (2009). Assessment of sociological and ecological impacts of sand and gravel mining- a case study of east Gonja district (Ghana) and Gunnarsholt (Iceland)unpublished first project environmental protection agency Ghana

Nigeria. Geological Survey of Nigeria (2004) Bulletin, No. 36. 100.

Nwimo C.E, Ohaegbulem M.C. (2021). Preliminary Investigation on the Quality of Amasiri Sandstone as Construction Material. JGMR 13:21-20

Olade, M. A. (1975).Evolution of Nigerian's Benue Trough (Aulacogen): A Tectonic model. Geological Magazine, 112: 575 – 583.

Okeke, O.C. (2017). Fundamentals of Mining Engineering and Metal Production, FAB Education Books, Awka.

Okeke, O.C. and Agubom, J.K.C.,(2015). Geoenvironmental Assessment of Lead-Zinc Mining in Abakallki Area, Southeastern Nigeria, in relation to Heavy Metal Pollution. FUTO Journal Series, Vol.1(2), 207-218

Oyedele E.O., Okeke O.C . And Israel H.O. (2020). Assessment and Control of Dust and Noise Pollution in Mines and Quarries:A Review. World Journal of Eng. Research and Tech 6(1):27-46

Okeke, O.C and Iwuoha, S.C (2005). Strength and durability characteristics of crushed-rock aggregates from Oban Massif, Southeastern Nigeria. *Journal of science Engineering and Technology 12(3): 6259-6269.*

Peters S.W.,(1978). Stratigraphic Evolution of the Benue trough and its implications for the Upper Cretaceous paleogeography of west Africa..*Journal of Geology* 86:311-322.

Prentice, J.E (1984). Geology of Construction Materials. Edward Arnold, London.

Reijers, T. J. A., Nwajide, C. S. (1998).Geology of the Southern Anambra Basin. Unpublished Report for Chevron Nigeria Limited. Field Course Note, 66.

Reyment, R. A.,(1965). Aspects of the geology of Nigeria, Ibadan University Press.

Simpson, A. (1954) The Nigerian Coalfield: The Geology of parts of Onitsha, Owerri and Benue Provinces.Bulletin Geological Survey of Nigeria, No 4.

Steve Blodgett, M.S (2004). Environmental impacts of aggregate and stone mining, Blue Press, London.

Uchendu, U.I and Kanu K.C.(2021).Survey of Workers Perception on Noise Pollution in Lokpaukwu Quarry Site, Abia State. FUTO Journal Series 7(1): 315-323.

Ukpong E.C.(2012). Environmental impact of aggregate mining of crush rock industryin Akampka, Cross River. Nigerian Journal of Technology 31(2)

Uzuakpunwa, A. B. (1974). The Abakaliki Pyroclastics, Eastern Nigeria. New Ageand Tectonic Implications. Geological Magazine 11: 65 – 70.

Vincent, K.N. (2012). Effects of quarry activities on some selected communities in the lower krobo district of the Eastern region of Ghana. *Journal of atmospheric and climate scienc*e.362-372.

Wills, M. C. (1995).Studies of Copper and Zinc forms in some Polish and Egyptian Soils, Part II, Distribution of some Copper and Zinc in Soil Profiles. *Polish Journal Soil Science* 2(1): 34-41.

William, J. H., and Vineyard, J. D.(1996). Geologic indicators of subsidence and collapse in karst terrain in Missouri. In National Academy of Science.

WHO. (1984). Water, Sanitation and hygiene, facts and figures. WHO, geneva.