ASSESSMENT OF THE EFFECTS OF QUARRYING ACTIVITIES ON SOME SELECTED COMMUNITIES IN THE LOWER MANYA KROBO DISTRICT

BY

NANOR JACOB NENE

(10297266)

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DECLARATION

I hereby declare that with the exception of references made to other people's work which I have duly acknowledged, this work is produced from my own research and that it has neither been partially nor wholly presented elsewhere for the award of a degree.

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Date……………………….

Jacob Nene Nanor

(Student)

……………………………………

Date..

Prof. V. K. Nartey

(Principal Supervisor)

………………………….............

Date...

Dr. Frank K. Nyame

(Co-Supervisor)

DEDICATION

This work is dedicated to my wife, Hannah Avedzi, my children, Eugene and Eugenia and all environmentalists worldwide.

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ABSTRACT

This study assessed the effects of quarrying activities on some selected communities in the Lower Manya Krobo District. Questionnaires targeting inhabitants around the quarry sites, observations, collection of health records from well patronized hospitals/clinics and dust (PM_{10}) sampling were used as data gathering instruments. The study revealed that some of the men have been employed as quarry workers and a substantial number of women in the area have become food vendors at the quarry sites. In terms of infrastructural development, the Bueryonye-Klo-Begoro road has been gravelled and made motorable even in the wet season. The District Assembly collects tolls from haul trucks as a means of generating revenue. Despite these benefits quarrying activities in the study area have distorted the balance of the environment. The distortions include encroachment upon limited prime agricultural land, destruction of buildings, pollution of water bodies, incapacitation of farmlands by run offs due to poor drainage, air pollution from quarry dust and noise from vehicles, machinery and blasting. Environmental parameters such strong winds and dry weathers have facilitated emission of dust.

Gravimetric concentrations of PM_{10} measured during the period of study were very high. Results of the study showed that PM_{10} concentrations recorded in the study area in January are 125μgm^{-3}, 116.2μgm^{-3}, and 109.3μgm^{-3} for Bueryonye, Odugblase and Klo-Begoro respectively. Only two concentrations, 69.4μgm^{-3} and 54.6μgm^{-3}, recoded in June are below EPA's permissible limit of 70μgm^{-3}. This means that PM_{10} concentration is high during the dry season and quite low during the wet season. Thus, dust suppression during the dry season should be very effective. The controlled sampling site, Oterkpolu, had 50.5μgm^{-3} in January and 29.0μgm^{-3} in June. The distance of Oterkpolu from the quarries may have accounted for the low impact of dust

on the community. The indication is that communities close to quarries are impacted by quarrying activities more than those far away from the sites.

The data collected from hospital records of the inhabitants portrayed their health profile. The prevalent health problems of the residents were elicited from a questionnaire survey conducted in three selected neighbouring communities of the quarries. Records obtained from health facilities most patronized have shown that respiratory tract infections and malaria have hiked since the establishment of the quarries in 2004/2005. Health problems suffered by the residents before the advent of the quarries include cough (33.3%), catarrh (25%), asthma (30%), headache (40%), malaria (5%) etc. These health problems hiked during the quarrying period as cough, catarrh, asthma and headache increased to 60%, 45%, 39%, 57%, and 40% respectively. Although, the residents of neighbouring communities are aware of risks associated with living near quarry sites, their general low socio-economic status made them incapable of taking any decisive measure towards relocating elsewhere. Approval for quarry operation should mandate environmental impact assessment and ensure strict implementation of outlined mitigation measures so as to guarantee environmental sustainability. Enforcement of regulations and laws through effective monitoring by the required institutions will create a balanced and sustainable environment.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

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

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

Quarrying is the process of obtaining quarry resources, usually rocks, found on or below the land surface (Banez et al, 2010). The difference between mining and quarrying is that quarrying extracts nonmetallic rocks and aggregates while mining excavates the site for mineral deposits. Some of the stones extracted are sandstone, limestone, perlite, marble, ironstone, slate, granite, rock salt and phosphate rock. The suitability of the stone for quarrying depends on its quality, the possibility of cheap and ready conveyance to a large market and its inclination and depth below the surface.

The two principal branches of the industry are the dimension stone and crushed-stone quarrying. In the former, blocks or sheets of stone, such as marble, are extracted in different shapes and sizes for different purposes. In the crushed stone industry, granite, limestone, sandstone, or basaltic rocks are crushed for use principally as concrete aggregate or roadstone. During the commissioning of the largest quarry in West Africa in the Brong-Ahafo Region on the 29th of May, 2009, the then Minister for Lands and Natural Resources, Alhaji Collins Dauda, reiterated that the Ministry was mindful of the legitimate concerns of the surrounding communities of the potential impacts usually associated with quarry operations such as blasting vibrations, noise, fly rocks, and dust, among others (Ghanaian Chronicle, 2009).

. Particulates are the tiny solid or liquid particles that are suspended in air and which are usually individually invisible to the naked eyes (Baird, 1997). The particulates include soot, smoke, ash from fuel (mainly coal) combustion, dust released during industrial processes like quarrying and other solids from accidental and deliberate burning of vegetation (Montgomery,1992). Quarrying generates a lot of particulate matter (dust) with diameter 1 - 75µm (micron). Particles with aerodynamic diameters less than 50 µm termed Total Suspended Particulate (TSP) matter can become suspended in the atmosphere, and those with aerodynamic diameters less than 10µm termed PM_{10} (inhalable particles) can be transported over long distances and enter the human respiratory system (Montgomery,1992).

TSP is the concentration of all particles in the atmosphere. Particles with aerodynamic diameters less than 2.5 µm (respirable particles) are most effective at scattering light and have a great effect on visibility or visual intrusion, impairment and the earth's radiation balance (Charlson et al., 1992). PM_4 and $PM_{2.5}$ of inhaled penetrate deeply into the lungs and are capable of making their way to the air sacs deep within the lungs where they may be deposited and cause respiratory problems(Audrey K. Quaye, 2004). Air pollution also causes damage to man-made materials and structures, changes the weather and interferes with comfortable enjoyment of life, property or human activities (Elsom, 1992.

Air pollutants such as dust are unhealthy particles (solids, liquid gas mixtures) that are liable to harm both living and non-living things (Ward, 2000). The main source of airborne particulate matter include the following activities: site clearing, road construction, top soil stripping and dumping, open pit drilling and blasting, stripping, loading and haulage (Akabzaa, 2000). When air quality is monitored, the most common measure of the concentration of suspended particles is the PM index which is the amount of particulate matter that is present in a given volume of air (Baird, 1997).

1.2 PROBLEM STATEMENT

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

Bueryonye, Odugblase and Klo- Begoro are communities cited close to Ghana Cement Manufacturing Limited (GHACEM), Kamsad and Love Enterprise quarries in the lower Manya-Krobo District. Dust pollution and other related problems in this enclave might be due to quarrying activities. The quarries are located behind Yogwa Mountain about 500m away from

Odumase – Asesewa main road. Exposure to mineral dust can cause a wide range of respiratory problems. The potential health effects of dust are closely related to particle size. Dust pollution has caused respiratory tract infections in the study area. Inhabitants are suffering from cough, common cold, chest pains and other respiratory diseases. The indigenes in the area have confirmed the impacts and attributed them to quarrying activities in the area. These assertions were made known during an interaction with the Assemblyman, Mr. Ebenezer Ogbojo, and some elders of Klo-Begoro.

Particulate matter, noise, vibrations and run-offs from are impacting negatively on the health and property of the people living around the cluster sites. These are most likely to generate environmental problems such as cracks in buildings which may collapse and destroy life, outbreak of malaria infection and other water-borne or water- related diseases, loss of fauna and flora (biodiversity), land degradation and decline in crop yield.

1.3 JUSTIFICATION FOR THE STUDY

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

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

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

1.4 OBJECTIVES

The main objective of this research is to assess the effects of quarrying activities and the methods of mitigating them.

Specific objectives are:

i To identify the processes involved in quarrying that generate dust and other environmental effects.

ii To investigate the concentration of PM_{10}.at the four sampling sites.

iii To assess dust fall (deposition) nuisance impacts.

iv To examine the health implications of quarrying activities in the selected communities

v To identify mitigation measures to reduce environmental effects of quarrying activities

.1.5 RESEARCH QUESTIONS

1. Which quarrying processes degrade the environment?
2. What is the concentration of PM_{10} in dust generated from the quarry?
3. What are the effects of dust on the health of the people?
4. How is quarrying affecting plant growth?
5. What are the effects of blasting vibrations, noise, and quarry run-off on the people?
6. What mitigation measures can be instituted to reduce the impact of quarrying activities on the people?

1.6 HYPOTHESES

i Quarrying activities have the potential to destroy the environment.

ii PM_{10} concentration is likely to cause respiratory tract infection.

iii Enforcement of safety environmental regulations can reduce the impact of quarrying activities.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

A quarry is a large deposit of rock such as granite which is mined for use in construction projects**.** Quarries are established when large deposits of commercially useful minerals or rock are found near the Earth's surface **(**www.knowledgerush.com/ks/encyclopedia**).** Quarrying is the surface exploitation and removal of stones or mineral deposits from the earth's crust. It is the process of extracting stone for commercial use from natural rock deposits (Sci-Tech Encyclopedia, 2005). Quarrying is a form of mining and is also known as open pit mining or strip mining. The industry has two major branches which are dimension stone and crushed stone. The dimension-stone branch, involves extraction of large chunks of rocks of various sizes and shapes for use as building stone, monumental stone, paving stone, curbing, counters, roofs, flagstones and other projects which require large slabs of uniform stone. The crushed-stone branch, involves preparation of crushed and broken stone (gravel and particulate matter) for use as a basic construction, chemical, paint and metallurgical raw material.

The general objective of dimension stone quarrying is to produce large rectangular blocks suitable for cutting into smaller, regularly-shaped products (Gale and Groat, 2001).

Unlike other types of mines, a quarry is usually not dug out underground, and rarely reaches a depth greater than 60 feet (18 metres). A shallow pit is excavated into a deposit of rock which runs close to the surface, and the pit is slowly expanded to remove valuable rock material. If the quarry is being used to extract gravel or fill, explosives may be used to break it up before it is removed and loaded into trucks. If dimension stone is required, the excavation process is more painstaking to ensure that the stone is not damaged **(http://www.hm-treasury-gov.ule/home.htm).**

Plate 1: Cymain Quarry at Buoho in the Ashanti Region

2.2 QUARRY PROCESSES

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

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

i. Drilling/channeling and wedging

ii. Blasting and cutting of rocks

iii. Crushing and grading (sieving/screening)

iv. Conveyance or transfer

v. Loading and transportation

2.2.1 Drilling or channeling and wedging

According to Gale and Groat (2001), two of the oldest methods of quarrying are channel cutting, and drilling and broaching. A channeling machine cuts a channel in the rock using multiple chisel-edged cutting bars that cut with a chopping action. In drilling and broaching, a drilling tool first drills numerous holes in an aligned pattern. The broaching tool then chisels and chops the web between the drill holes, freeing the block. Both channel cutting, and drilling and broaching are slow and the cutting tool requires frequent sharpening.

Channeling and wedging is a process of quarrying in which channeling machines are used in cutting long, narrow channels in the rock which is deep enough for the insertion of wedges. The rock is then split through the fracture. The channeling and wedging process of quarrying is extensively used in quarrying marble, sandstone, limestone and other softer rocks but is not successful for granite and other hard rocks. Another method of cutting is by the combination of a power saw, an abrasive, and water as a lubricant and a coolant. The saw cuts a narrow channel; the primary or initial cut is then either expanded by a wedge or is blasted. This method is used in slate, granite, and limestone quarries.

Line drilling and sawing, according to Gale and Groat, (2001), are more modern techniques for quarrying. Line drilling (also called slot drilling) consists of drilling a series of overlapping holes using a drill that is mounted on a quarry bar or frame that aligns the holes and holds the drill in position.

Plate 2: A machine drilling holes for blasting

2.2.2 Blasting, Cutting and Transportation of rocks

Once the mineral is exposed, it can then be extracted. Some minerals such as sand, gravel, clay and coal can be extracted by direct use of an excavating shovel on the mineral. Other materials such as sandstone and limestone will need to be broken up by blasting or ripping before they can be excavated. Blasting may also occur where overburden is too strong to be excavated directly by shovel.

Blasting commonly breaks the rock into pieces suitable for crushing. An explosive charge is detonated in a shot hole and a rapid discharge of energy takes place within a short duration causing a tremendous rise in pressure and temperature. The majority of energy released will be used in the breakage of rock, but a significant percentage is wasted. This wasted energy is dissipated away in the form of noise, dust, heat and noxious gases together with the formation of a number of more significant environmental impacts. Quarry blocks are then transported off the hills with bulldozers or caterpillars.

Plate 3: (a) Dimension stone blasting (b) Crushed stone blasting

There are three main environmental impacts at this stage. These are:

i. **Ground vibration –** caused by seismic waves travelling through the ground.

ii. **Overpressure –** caused by pressure waves travelling through the air.

iii. **Fly rocks –** individual rock fragments being thrown long distances from the site by the force of the explosion.

There are various ways to get a quarry block off the hillside. The picture below shows an example of the machines involved.

Plate 4: Caterpillar E650 moving quarry blocks downhill

2.2.3 Crushing and Grading (sieving or screening)

- **Crushing**

The general objective of crushed stone quarrying is to produce relatively small pieces of rock that are suitable for crushing into gravel-sized particles. The JOYAL Crushing plant includes vibrating feeder, jaw crusher, impact crusher or cone crusher, vibrating screen, belt conveyor and centrally electric controlling system. The big materials are transferred into the jaw crusher evenly and gradually by vibrating feeder through a hopper for the primary crushing. After first crushing, the material is transferred to impact crusher or cone crusher by belt conveyor for secondary crushing. The crushed material is then transferred to a vibrating screen for separation. After crushing, comes screening.

Plate 5: (a) A hydraulic pecker breaking rocks (b) A crushing plant at Cymain Quarry (Buoho-Ashanti)

- **Screening**

As the rocks are broken down into smaller sizes, screens are used to separate them into piles that are the same size. Some screens are larger and they allow the bigger rocks to pass through. The smaller screens let only the small rocks through. Rocks may be crushed and screened many times before they are put in a stockpile with other rocks of the same size. Screened stone is known as screenings or aggregate.

A  B  C

Plate 6: Different product sizes of woven wire screen mesh (A&B) and stone aggregate (C)

After the separation, the parts that meet the required standard are taken away as final products, while the other parts will be returned to the impact crusher, thus forming a closed circuit. The size of final products can be combined and graded according to customer's specific requirement. The stone is then stored in huge stockpiles according to the aggregate such as rock, sand or gravel. Crushing, conveyance and separation of rock particles generate a lot of dust.

2.2.4 Conveyance and Transfer of gravel

As the rocks pass through the crushers, they are moved around the processing plant on conveyor belts. For rocks to get from one place to another at a plant, they travel on long, continuously moving conveyor belts. The conveyors help move rocks in an economical way, saving money and time.

Plate 7: Conveyance of rock particles on conveyor belts at GHACEM Quarry

2.2.5 Loading and Transportation of gravel

Caterpillars and bulldozers load quarry products using their buckets into haulage trucks to various destinations such as cement factories like GHACEM in Ghana which use them. During the loading of products into trucks, wind blows dust away and the emission of dust increases with increase in drop height.

Dust kicked up by vehicles traveling on roads, may make up 33% of air pollution . Road dust consists of deposition of vehicle exhausts and industrial exhausts, tire and brake wears, dust from unpaved roads or potholes, and dust from construction sites. Road dust represents a significant source contributing to the generation and release of particulate matter into the atmosphere (Holmes, 2001). Road dust may be suppressed by mechanical methods like sweeping vehicles, cleaning vehicles with vegetable oils or with water sprayer.

Plate 8: a) Loading a truck with gravel b) Transportation of gravel

2.3 QUARRY WASTE

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

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

Plate 9: Quarry waste or stockpile

2.4 ENVIRONMENTAL ISSUES

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

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

2.4.1 Air Pollution

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

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

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

PM_{10} is the term given to the fraction of total particles suspended in the air having diameters less than 10µm. The PM_{10} samples will contain all particles less than 2.5µm in diameter ($PM_{2.5}$) as well as particles in the 2.5µm to 10µm fraction. Analysis of the silica content of PM_{10} particles rather than $PM_{2.5}$ particles could lead to a greater crystalline silica mass due to the possible presence of silica particles in the 2.5µm to 10µm size range on the filter (State of Queensland Environmental Protection Agency, 2008). Wind direction is a critical factor in the measurement of the impacts of dust from quarrying operations at monitoring sites.

According to Banez et al, (2010) the effect that dust will have is determined by a number of variables, including:

- the concentration of dust particles in the ambient air and its associated deposition rates.
- characteristics of the vegetation and leaf surface. This can influence the rates of dust deposition on the vegetation, such as surface roughness and wetness.
- meteorological and local microclimate conditions and degree of penetration of dust into vegetation;
- size distribution of dust particles;
- dust chemistry - ranging from highly alkaline dusts e.g. from limestone quarries, to inert, and acidic dusts, such as dusts from coal mining.

Dust may have physical effects on plants such as blockage and damage to stomata, shading, abrasion of leaf surface or cuticle, and cumulative effects such as drought stress on already stressed species. The chemical effects of dust, either directly on the plant surface or on the soil, are likely to be more important than any physical effects. Areas of high ecological value or agricultural resources may be more sensitive to dusts than other areas. Examples of sensitive areas include designated nature conservation areas containing sensitive species, intensive horticultural areas, and fruit growing areas.

Plate10: (a) Fugitive dust from haul trucks (b) Dust from transfer and screening at Vision Quarry, Wenchi- Brong-Ahafo

Health Effects

The potential health effects of dust are closely related to particle size. The size range of airborne particles varies from less than 0.1µm up to about 500µm or half a millimetre. Human health effects of airborne dust are mainly associated with particles less than 10µm in size (commonly termed PM_{10}), which are small enough to be inhaled into the lower respiratory tract.

PM_{10} particles pose a greater hazard to human health because they are small enough to pass through the filtration mechanisms in the upper respiratory tract and penetrate beyond the larynx to the lower airways. Exposure to PM_{10} particles has been linked with conditions including heart and lung disease, pneumonia, loss of lung function and asthma. PM_{10} particles in urban areas can arise from combustion processes (State of Queensland Environmental Protection Agency, 2008.)

Particulate air pollution is associated with a range of effects on health (from particles less than 10 µm in diameter, known as PM_{10}) including effects on the respiratory and cardiovascular systems, asthma and mortality (Banez et al , 2010). Current research suggests that asthma is caused by a combination of genetic and environmental factors but that particulate matter inhalation increases the severity of asthma (NASA, 2001). Mineral dust carries spores of a fungus (*Coccidioides immitis*) responsible for Valley Fever, a serious respiratory problem that can lead to fatigue, cough, fever, rash, and damage to internal organs, skin, bones, and joints**.**

Macrophages, a type of blood cell, collect foreign particles and carry them to where they can be coughed out or swallowed. If too much dust is inhaled over an extended period of time, some particles and dust- laden macrophages collect permanently in the lung. Dust deposits lead to scarring and inflammation which clogs passageways, obstructing airflow and causing chronic bronchitis (MHSA (Information Service, 2007). Asthma, a chronic condition consisting of airway inflammation and bronchoconstriction is an example where earth material particulate matter can have adverse health effects (USA National Academies of Sciences, 2007). Exposure to high concentrations of dust causes fibrosis a thickening of the lung walls leading to development of scar tissue. This scar tissue restricts the vital exchange of oxygen and carbon dioxide in the blood causing breathing to become laboured which in turn places a strain on the heart.

2.4.2 Reduced Photosynthesis

Dust deposition, or dust fall, is dust that settles out of the air and monitored by determining the amount of dust collected over an exposed surface in a fixed period of time. Wind suspends large amounts of dust in the atmosphere. Dust in the atmosphere settles back to the earth's surface and deposited on plant leaves when wind velocities decrease. Suspended dust blocks light in the atmosphere from reaching plants through air and also settles on plants and blocks sunlight by covering the stomata of plant leaves that needs to perform photosynthesis (Vardaka, 1995).

Dust may have physical effects on plants such as blockage and damage to stomata, shading, abrasion of leaf surface or cuticle, and cumulative effects like drought stress on already stressed species (Banez et al, 2010). The chemical effects of dust, either directly on the plant surface or on the soil, are likely to be more important than any physical effects. Dust deposited on the ground may produce changes in soil chemistry which may in the long-term result in changes in plant chemistry, species competition and community structure. Since the stomata have been blocked Carbon dioxide cannot enter plants to serve as a raw material for photosynthesis. Plants in this environment may undergo stunted growth. It is likely dust deposition on vegetation is increasing due to the increase in quarrying; open- cast mining and road traffic (Farmer, 1993). Dust may have physical or chemical effects on plant surface or dust effects on plants may occur through changes in the soil chemistry. Dust may affect photosynthesis, respiration and transpiration and aggravate secondary stress such as drought, the effects of insects and pathogens or allow penetration of toxic metals or phototoxic gaseous pollutants into plant tissues (Vardaka et al, 1994). Visual symptoms may occur and generally there is reduced productivity.

Plate11: Dust on plants reduces photosynthesis

2.4.3 Damage to Biodiversity

Mineral extraction represents a disturbance of the land, so there will always be an impact on the ecology of the area (http://www.goodquarry.com/article.aspx?id=24&navid=4). This impact must be assessed in advance and particular notice taken of rare or endangered species in the wider context of biodiversity. Biodiversity relates to all life forms - mammals, birds, reptiles, amphibians, fish, insects and other invertebrates, plants, fungi and micro-organisms. Conservation involves both the protection and enhancement of existing resources and the creation of new ones. Much of the effort needed for biodiversity conservation focuses on threatened habitats and species, but ensuring the conservation of the common and widespread species is also very important.

Potential Effects

The obvious potential negative effects of mineral extraction are that habitats are lost, together with the species that they support (Banez et al , 2010). They can be lost through direct removal by excavation, or indirectly through some of the environmental impacts. For example, dust generated during excavation, processing or storage can settle on sensitive habitats and have an adverse effect. Changes in the water regime (surface water or ground water) may cause some habitats to dry out or others to become flooded.

Noise may have no influence on some species, but may affect others. It is inevitable that there will be some disruption to animal populations living close by or within the operational site. However, observations suggest that species do become accustomed to the noise and disturbance within a mineral site and no significant impacts on reproductive success have been recorded. All of these potential impacts should be mitigated in order to minimize the negative impact on biodiversity. The duration of an impact is also a key consideration as all mineral developments will give rise to a combination of both short and long-term activities that will result in impacts that could be temporary and permanent. It is important to recognize that temporary impacts can also generate permanent impacts. Temporary loss of food and shelter due to some habitat loss can be reversed in as little as ten years. Most birds and mammals are sufficiently mobile and adaptable to accommodate the temporary change with no significant impact on populations. Conversely, the permanent loss of ancient ground flora from a woodland is likely to be irreversible (Banez et al , 2010).

a  b 

Plate 12 a and b: Loss of plants (biodiversity)

2.4.4 Nuisance Effects (Soiling of Property)

According to Mate (1992) in a United Nations Journal the dust problem related particularly to surface mines was found to have caused a nuisance to resources close to sites. Nuisance is generally related to the visual effects observed by receptors, such as the soiling of surfaces over days and weeks or the short-term visual effect of clouds of dust. Nuisance dust is the larger size fraction that is visible in the atmosphere. Dust effects on people have been identified as arising from increases in airborne dust concentrations, and deposition levels. Dust depositions on windows and roofing sheets, on the outside of the houses, on cars and clothing are the most frequently mentioned reasons for concern. Particulate matter can also cause considerable nuisance through soiling of property. Nuisance effects can be caused by particles of any size, but are most commonly associated with those larger than 20µm (EPA Victoria, 2007). Particulate matter can, however, be removed from the atmosphere through gravitational settling, impaction and washout or by wetting during precipitation (http:www.hm-treasury.gov.ule/bud99-prquarrying.htm.).

According to Banez et al (2010), factors that can determine whether surface soiling by dust is considered a nuisance or not include:

- Deposition on a surface which is usually expected to remain free from dust.
- The colour contrasts between the deposited dust and the surface upon which it settles.
- The nature of the illumination of the surface - "dinginess."
- The presence of a nearby clean 'reference' surface against which comparison may be made.
- The rate of change in the visual properties of a surface.
- The identity of the area and the composition of the local community social factors, such as lifestyle and patterns of working.
- The personal experiences and expectations of the observer

The rate of deposition and therefore the time taken for dust deposition to become visible are important influences on the perception of dust. The rates of deposition vary widely with emissions, variations in wind speed and direction and also variations in the background dust concentration. These background levels will determine the reaction of local people to any additional dust from specific mineral sources.

Plate: 13 Effect of nuisance dust on humans

2.4.5 Visual Intrusion

Suspended dust blocks light in the atmosphere from reaching plants through air (Vardaka, 1995). Quarry waste tips, quarry fines stockpiles and waste dumps can cause a significant visual intrusion, mainly when waste is dumped off-site (at or near site boundaries) or piled-up above the skyline especially when it is not landscaped or vegetated (Banez et al, 2001). Although, it is often used as a visual or noise screen, it can be considered an eyesore. Concerns arise about tip stability, including long term erosion and major short- term failures.

Plate 14: Stockpiles cause visual intrusion

2.4.6 Noise Pollution

One of the most frequent complaints the public makes to the crushed stone industry situated near population centres is about blasting noise (National Academy of Sciences, 1980). Noise is an inevitable consequence of the extraction of minerals, although whether this becomes environmental noise or not depends on whether it impinges on people outside the site (http://www.goodquarry.com/article.aspx?id=26&navid=6).

The primary source of noise from extraction of aggregate and dimension stone is from earth-moving equipment, processing equipment, and blasting. The truck traffic that often accompanies aggregate mining can be a significant noise source. The impacts of noise are highly dependent on the sound source, the topography, land use, groundcover of the surrounding site, and climatic conditions. The beat, rhythm, pitch of noise, and distance from the noise source affect the impact of the noise on the receiver (Langer, 2001). Topographic barriers or vegetated areas can shield or absorb noise. Sound travels farther in cold, dense air than in warm air and travels farther when it is focused by atmospheric inversions than when inversions are not present.

2.4.7 Quarry Blasting

Poorly designed or poorly controlled blasts may cause rocks to be projected long distances from the blast site (fly rock), which can be a serious hazard. Fly rock is not commonly a problem with carefully designed and executed blasting plans, but is a situation that deserves careful attention. Blast-induced vibrations and shock waves can cause buildings to crack or collapse, and walls can be altered by just one new crack. This situation can result in the death or displacement of communities (Vermeulen and Whitten, 1999).

According to Edwards and Northwood (1960), experimental studies of the effects of blasting on structures show that damage is correlated with size of charge and distance, and with displacement, velocity, acceleration, settlement, and strain measurements in the buildings. According to Northwood et al (1963), the threshold of damage is indicated by the lengthening of old cracks, formation of hairline plaster cracks, dislodging of loose mortar, concrete, brickwork or plaster. According to them minor damage, an extension of the threshold of damage, consists of superficial damage not likely to weaken the structure but may include new cracks in brickwork or concrete, or permanent opening of old cracks and the loosening or removal of mortar, plaster or concrete from previously sound walls. For a major damage, a degree more severe than minor damage, results in a serious weakening of the structure. This may include extensive cracking and permanent separations in walls, either caused directly by the vibration or indirectly because of settlement.

Alothough, the local surrounding geology and rock mechanics have great influence on vibrations as uncontrollable parameter, the charge weight per delay, delay period and geometric parameters of the blasts could be changed to solve the existing vibration problems in a quarry (Cengiz Kuzu and Hasan Ergin, Article Vol. 48 No. 2, July 2008).

Plate 15: Blasting causes cracks in buildings

2.4.8 Water Quality

Areas affected by the deterioration of water quality had severe, transitional and minor effects on resident aquatic organisms, fisheries and other water users at progressively greater distance from the discharge area (Mate, 1992). Run-off from quarry waste tips or quarry fines or stockpiles can cause erosion and contaminate local water courses. Suspended solids (and acid mine drainage) may harm freshwater ecosystems and impact on other water users. Waste may also create problems if dumped on flood plains where it may exacerbate flooding.

Transfer of dust from the air to surface waters can result in contamination. Impacts generally relate to the presence of suspended solids (in addition to those arising from water erosion). In rare cases, physical impacts may be aggravated by the presence of chemically active minerals in the dust (e.g. limestone contains alkaline calcium carbonate and acidic sulphides) that can alter water chemistry and suitability for the fauna and flora that it supports (Banez et al, 2010).

Silt can detrimentally affect fish spawning grounds, cause damage to fish gills and impact the invertebrate species resident in watercourse sediments. Suspended solids also reduce penetration by sunlight. Blanketing of benthic flora and changes in bottom morphology and characteristics may occur, particularly in areas where suspended solids tend to settle out, with associated impacts on flora and fauna. Exposure to suspended solids may result in the death of fish, biodiversity impacts and food chain disruption. Quarrying may intersect active ground-water conduits, or cause their blockage, with adverse consequences for aquatic communities. Ground-water withdrawal and diversion of surface water may cause above ground and underground hydrologic systems to dry up (Gale and Groat, 2001). Water bodies, which may be inhabited by small, site-endemic fish and snail species, will disappear and with the species.

In aggregate mining, the target limestone, if unsaturated, may also act as a protective cover for the underlying aquifer. If the protective soil cover or unsaturated rock is removed, the hole created by the mining may drain surface water to the ground-water system (Gale and Groat, 2001). Large amounts of silt and other effluents from quarries (waste, fuel, oil) may pollute rivers as well as underground water bodies within and far beyond the boundaries of the limestone.

Plate16: Fuel oil spills can rapidly contaminate aquifers

2.4.9 Land Degradation

Temporary or permanent land sterilization may result in the original landform permanently altered and the original vegetation cover destroyed. The visual impact of the quarries extends over larger areas as noticeable scars of high colour contrast, reducing the aesthetic appeal of the landscape and deteriorating the scenic quality of areas where tourism may be a major constituent of income (Mouflis et al, 2008). In other areas, arable lands are destroyed. Temporary or permanent loss of the associated fauna and flora are also likely, although this can be mitigated by appropriate restoration of the disposal areas.

Plate 17: Degraded land

2.4.10 Flooding

When quarries fail to make provision for adequate drains that will evacuate water from the quarry, large tracks of productive land might be lost to floods. These large tracks of water accumulating close to communities may serve as a potential source of water-vectored and water-based diseases.

Potential Health Effects

- **Water-vectored or related diseases**

A vector is an insect or other arthropod that actively transmits a pathogen from an infected reservoir host animal to another individual. Of all human diseases, vector borne diseases are the ones most closely tied to geologic materials and processes This is because the life-cycles of arthropods that transmit disease agents are directly influenced by soil type (which is determined by parent rock, climatic conditions, water availability, and other environmental factors) **(**Bunnell, Finkelman, Centeno and Selinus, 2007**) .**

As previously noted, malaria, one of the most well-known diseases, causes more cases of morbidity and mortality than any other tropical infectious disease around the world. Malaria is widely distributed in the tropics, and is a particularly serious health risk in developing countries. Human infection is caused by Plasmodium falciparum (most common and virulent), Plasmodium malariae, Plasmodium vivax, or Plasmodium ovale. It is a vector-borne or water-related disease, where an intermediate vector organism is needed to pass the infectious parasite between humans. Malaria infections are caused by the bite of an infected female Anopheles mosquito. At the beginning of this century it was estimated that about half the deaths of human beings were attributed directly or indirectly to malaria: it was by far the most lethal of all diseases (Ewer et al, 1978). Elephantiasis and yellow fever are also likely to infect inhabitants near the flooded plains.

Water plays a crucial role in transmission; mosquitoes require high humidity and standing water in which to breed. Thus, disease rates are largely determined by flooding or heavy rainfall. However, global environmental change is affecting the virulence of the parasite and the life cycle of the intermediate host. Climate is an important factor affecting the incidence of disease outbreak. As global temperatures rise, malaria may spread into new regions of the globe, for example North America or Europe.

- **Water-based diseases**

One of the most commonly known water-based diseases is Dracunculiasis or guinea worm disease. It is caused by the parasite Dracunculus medinensis. It is a water-borne disease which occurs in the rural areas where people get the water supply from sources such as lakes, ponds, and rivers (Ghana Association of Science Teachers, 1989). The disease is contracted by drinking water sources contaminated with the infected intermediate hosts of the parasite, called cyclops. Due to significant multi-lateral aid and research efforts, it is close to being eradicated, but remains a significant threat in Sub-Saharan Africa. Ensuring safe water supplies is key to controlling Dracunculiasis.

Bilharziasis or Schistosomiasis can also be contracted as one wades through the flood waters. Snails which act as intermediate host later release cecariae into the water which can penetrate the skin and migrate to the bladder resulting in blood in urine.

2.5 MITIGATION

2.5.1 Stages in Mitigation

Stage 1: Establish existing baseline conditions Existing ambient conditions should be identified over a period sufficient to identify seasonal variations in the range of existing conditions that naturally exist (ideally by a dust monitoring programme). According to Banez et al (2010), identification of the conditions should take into account the principal existing dust sources (other than the site) such as air pollution from urban and industrial areas, existing mineral operations, agricultural activities and construction activities, including:

i. identification of the location and nature of existing dust sources and establishment of their relative contributions to dust levels, their patterns of dispersion and rates of deposition.

ii. baseline monitoring of meteorological effects (especially prevailing wind direction and rainfall);

iii. establishment of background dust levels at nearby dust sensitive properties.

The location of residential areas, schools and other dust-sensitive land uses should be identified in relation to the site, and within-site dust emission sources. The assessment should explain how topography may affect the emission and dispersal of site dust, particularly the influence of areas of woodland, downwind or adjacent areas to the site boundary and valley or hill formations in altering wind patterns. The assessment should also explain how climate is likely to influence patterns of dispersal by analysing data from the Meteorological Office or other recognized agencies on wind conditions, local rainfall or ground moisture conditions.

Stage 2: Identify site activities that could lead to dust emission without mitigation. Potential dust sources should be identified and their potential to emit dust assessed with respect to the duration of the activity or the potential of dust to become airborne.

Stage 3: Identify site parameters which may increase potential impacts from dust.

This brings together information collected in stages 1 and 2 with information on sensitive land uses around the site in order to understand how these uses could be affected by dust or any quarry activity. Dust emission, dispersion patterns and impacts are difficult to predict due to the wide range of activities on site that may give rise to dust, and the lack of reliable emission factors for these activities together with the influence of local meteorology and topographic features.

Whilst the primary purpose of an approved monitoring scheme would be to establish whether or not the site was causing a dust nuisance, inclusion of a simple weather station and directional monitoring capability would allow the development of such a model. The advantage of this approach is that it would provide the operator with a better chance of rapidly identifying the source of any nuisance shown up by monitoring, and a better basis for implementing appropriate remedial controls.

2.6 MITIGATION MEASURES

An operator will normally use a mixture of approaches to deal with quarry wastes; the mix being determined by what is technically and economically feasible, taking into account the concerns of local communities and other stakeholders and planning obligations (Banez et al, 2010).

2.6.1 Supervisory Bodies

According to Banez et al (2010), Governments and Regulatory Authorities, Companies, Local Communities and Non-Governmental Organisations or Pressure Groups have the potential to minimize the impacts of quarrying on the environment. The roles that each sector can play are outlined as below:

Government or Regulatory Authorities:

- development of policies to protect, enhance and preserve air, water and land resources.
- enforcement of compliance with relevant regulations and laws.
- sustainable use of resources must be enforced
- protection of sensitive species

Companies:

- ☐ increased operating efficiency and reduced impacts.
- ☐ improved health and safety for workers and community.
- ☐ reduced risk of breaching consents and prosecution.
- ☐ reduced long-term liabilities.
- ☐ improved company image in the eyes of the shareholders, employees and the community.

Local communities:

- ☐ protection and preservation of the local environment.
- ☐ access to and use of, high quality local water- and land-based amenities.
- ☐ uncertainty and concern regarding exposure to contaminants.

Non- governmental organizations / pressure groups:

- ☐ monitoring compliance.
- ☐ focus on site-specific issues.

Measures to control dust should be specified and described in terms of their potential to reduce dust and consequent impacts.

2.6.2 Acoustic Screening

Once the working method and equipment for the site have been chosen, acoustic screening is the main method of noise control that can be implemented at the site. It can also result in visual intrusion. Some operations, such as processing of the mineral and maintenance operations, may be able to be carried out within buildings, but most of the operations on site can only be screened rather than enclosed. Consideration of acoustic screening does need to take place at the site planning stage. The primary method of screening operations is to use baffle mounds or noise fences. Baffle mounds use material such as soils and overburden that has to be removed to allow access to the mineral. They are generally located on the site boundary and are usually designed to provide screening for noise-sensitive properties.

Plate 18: Removed soil utilized as seeded baffle mounds (screening)

2.6.3 Creation of Habitats

During most operations a small percentage of the original landform/habitat is retained which helps by acting as a refuge. Such refuge areas will most likely require management to retain their features of interest (Banez et al, 2010). Safeguarding or creation of habitats must form part of the Local Biodiversity Action Plan and could be employed at the site. Features of the plan are:

- Maintain some space adjacent to woodland habitats especially where wildlife is known to feed.

- ☐ Leave margins around or along trees and hedges (e.g. 4m for hedges, 5m beyond the spread of trees for hedges with trees, 10m for trees and 15m for woodland).
- ☐ Leave margins for ditches.
- ☐ Ensure that at least part of a suitable habitat is always available for any rare species.
- ☐ Phase workings adjacent to woodlands and must progressively work and restore sites to give the ecosystem more chance to survive and recover naturally.

Plate 19: Creation of habitats (aquatic and terrestrial)

Although the creation of new habitats can readily be incorporated into the restoration design of a site, occasionally there may be opportunities for habitats and species populations to be enhanced during the operational life of the site. More often, new habitats can be created that are appropriate to the region in areas of the site which are not being excavated. These can include meadows, wetlands, ponds, etc. and of course are particularly important where they are replacing habitats which maybe destroyed by the excavation.

2.6.4 Restoration

Restoration of mined areas is an essential part of mineral sand or gravel mining and the companies have to post a financial bond to cover restoration before the state will grant a mining lease (Thomas, 1979). Restoration is a process that will enable work-out quarry or sand pit to be used for its original purpose (such as agriculture) or adapted for a new use (such an amenity). Restoration includes design, initial landscaping works, soil spreading, final landform construction and aftercare (Ireland Dept of the Envt, Heritage and Local Govt Guidelines, 2004). Waste tips should be located to minimize potential effects on the landscape and surface water flow and quality and take into consideration potential land-use conflicts with local communities and stakeholders.

According to the report by Banez et al (2010), quarry wastes can often be put to beneficial use around the site and have long been used to ameliorate the impact of workings on the landscape through the use of screening banks, backfilling, replication or simulation of natural landforms and to prepare ground for revegetation and restoration. Soil materials should be stored in a manner that protects their physical, chemical and biological characteristics until they are required for restoration.

Good practice should be implemented to prevent environmental and social impacts from wastes for which no beneficial uses exist. Quarry waste tips must be designed, constructed, operated and maintained to avoid instability or movement that might give rise to health and safety risks. Ideally, all waste should be kept out of sight within the workings to reduce visual impacts and the risk of dust dispersion. Where tips cannot be hidden their height and shape should be managed to reduce their visual impact and exposure to wind erosion. Amenity banks are an exception.

Waste tips should be revegetated as soon as possible to prevent wind and water erosion (and subsequent dust generation and contamination of surface waters with suspended solids). The revegetated areas can act as shelter belts which may reduce dust emission. Non-vegetated waste tips are liable to erosion and collapse. On closure, tips should be regraded where necessary to create a stable final landform and to prepare them for revegetation and integration with the surrounding landscape.

a

b


Plate 20: Restored quarry sites (a and b)

2.6.5: Dust Suppression

Water spray systems remain the most efficient and cost effective means of dust control for both process and fugitive dust emissions within industries like mining and quarrying as the dust remains with the product of origin while it is being disturbed (Australian MinEx Health and

Safety Council Guidelines, March 2008). Different methods of dust suppression are discussed as below:

- **The use of Filters and Scrubbers**

Very fine-grained materials may be removed from the air in dry processing plants by bag filters, cyclones, wet collectors (scrubbers) or electrostatic precipitators at dry processing plants. The choice of equipment will be dictated in part by the size range of dust requiring removal. Fabric filters and electrostatic separation are most suitable for fine and ultra-fine particulates, while cyclones and wet collectors are more useful for coarser dust.

- **The use of vacuum**

Engineering techniques, such as enclosing equipment and removing dust using vacuums, can mitigate impacts of noise and dust. Conveyor belts and crushing and screening equipment can be housed to provide acoustic screening.

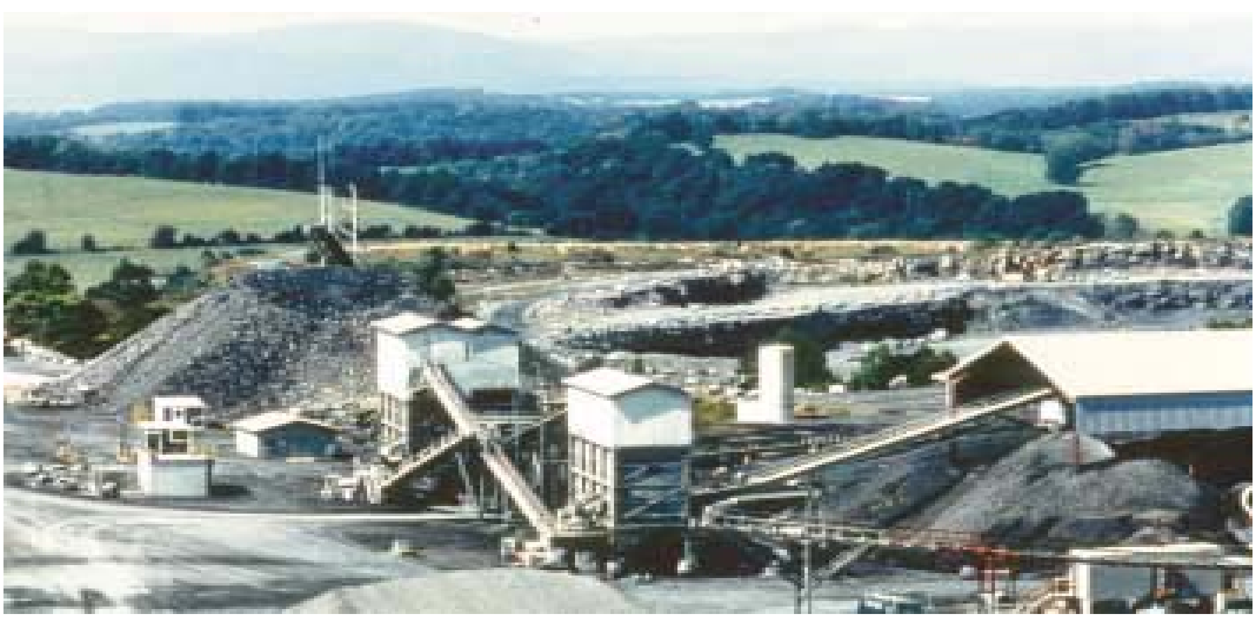

Plate 21: The use of vacuum to suppress dust

2.6.6 Spraying (Damping or Wetting)

- **Spraying before Blasting**

Spraying could be done before blasting. Dust extraction equipment, such as filters, should always be used on exhaust air emissions from drill rigs (Gale and Groat, 2001). It is important that this material is collected properly and not simply allowed to fall to the ground, where it can then be blown about. If it is possible to remove any dusty material which has collected on the blast areas prior to detonation then this should be done. Otherwise, in dry conditions it may be helpful to water the blast area first.

- **Spraying overburden or stockpiles**

Exposed material should be protected from the wind by keeping it within voids or protecting them by topographical features. Exposed surfaces should be sprayed regularly to maintain surface moisture unless the mound surface has formed a crust after rainfall or it has been grassed, which is often a very effective way of controlling fugitive dust. If necessary this can be done on steep broken slopes as well as flatter grounds such as haul roads. Where a dragline is in operation, a high pressure pump can be used to dampen the material as the bucket is being dragged through it. This is mainly to ensure the material is wet when it is cast from the bucket at what may be a considerable height above the surrounding ground. Stockpiles must also be watered at least every three hours during dry periods.

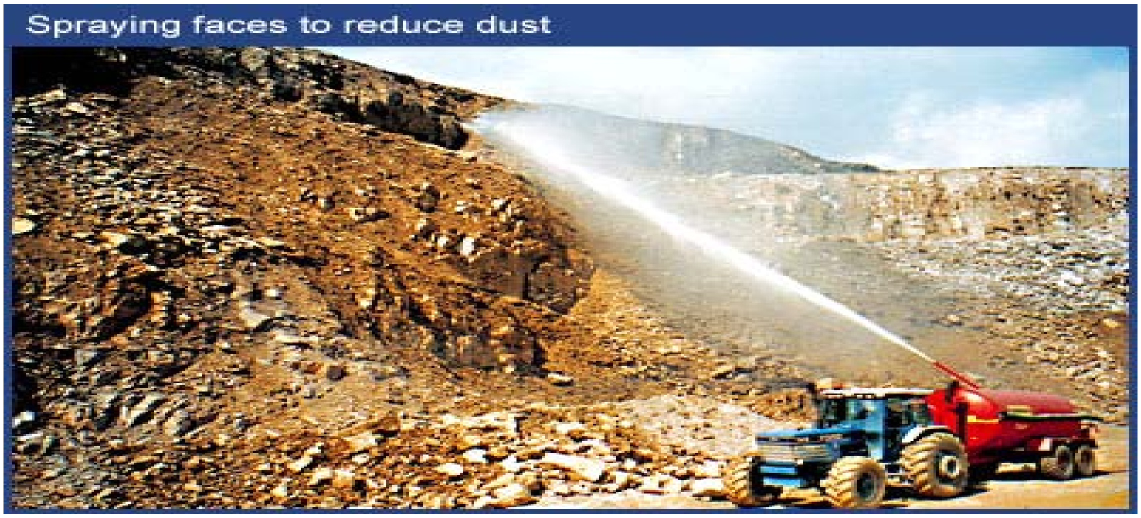

Plate 22: Spraying surfaces to reduce dust emission

- **Spraying unsurfaced (haul) road**

Unpaved or unsurfaced haul roads should be dampened when there is the danger of dust being generated. This can be done using water sprays from fixed pipes, water guns or by using a water tanker or bowser. Where surfaced or paved roads are used, they should be swept and washed regularly. In dry weather conditions active haul roads must be watered at least every three hours.

a  b 

Plate 23 Roadside dust suppression (a) Using pipes along road (b) Using a tanker

2.6.7 Reduction in Drop heights

Dust is most easily picked up in the wind when the material is falling through the air at points of transfer. It is therefore important to reduce the drop heights wherever practicable. A conveyor which has a sleeve attached to it can prevent the wind picking up dust as the material falls (Tanyaradzwa, 2010). In addition it may be necessary to protect the activities from wind by erecting a screen or using a natural barrier such as the high wall of a site. The solutions to any dust problem will vary depending on the type of equipment used but generally complete enclosure is best with use of air extraction and filter equipment as appropriate. Where conveyors are used, either as the major transfer system or simply as part of the processing, the transfer points should be sheltered from the wind. Indeed, it may be necessary to protect the entire conveyor by partially or completely enclosing it. Fig 24 shows gravel being stockpiled from a conveyor which has a sleeve attached to it to reduce drop height and prevent the wind picking up dust as the material falls.

Plate 24: Sleeve on end of conveyor to reduce apparent drop height

2.6.8 Reduced speed and sheeting of vehicles

Vehicle speed should be restricted as there is a direct relationship between the speed and the amount of material that is thrown up in the air from wheel contact with the road, and the dust lost from bulk material being transported. All trucks leaving site should be properly sheeted to prevent dust escaping onto the public highways. However, it may also be advantageous to sheet vehicles being used for internal transfer of dusty materials. Material should be loaded and unloaded in areas protected from the wind and drop heights should be minimized.

Plate 25: A sheeted truck

2.6.9 Set Optimum Blasting Parameter

Blasting disturbs the environment in the form of dust emission, fly rocks, ground vibration and noise. Records of all blasting parameters must be maintained for better control and optimization. The parameters include:

- Proper spacing of blast holes depending on hole diameter

- Maintaining a safe drilling angle for the quarry face
- Calculating optimum quantity of explosives for charging
- Use of delay detonators for reducing ground vibrations
- Maintaining proper stemming depth to minimize fly rocks

2.6.10 Proper Material Storage

Where dusts are created and handled enclosures and equipment should be designed so that unwanted dust drift or spillage is either collected or totally avoided (New Zealand Dept. of Labour, 1980). A number of measures can be taken here. Material can be dampened, perhaps with a fine water spray. It can be screened to remove dusty fractions prior to external storage. It can be covered over in some way to protect it from the wind.

. Plate 26: Stockpiles stored under sheds to reduce fugitive dust emission

2.6.11 Reduction in vibration levels

There has been a trend for regulatory authorities, especially those concerned with the environment to impose low limit on blast vibration levels to community pressure, based on human perception and response to vibration (Gad et al, 2005). Low vibration levels will reduce the impact of blasting on residential structures.

2.7 NATIONAL AMBIENT AIR STANDARDS

The National Ambient Air Quality Standards (NAAQS) are standards established by the United States Environmental Protection Agency under authority of the Clean Air Act that apply to outdoor air throughout the country. Primary standards are designed to protect human health, with an adequate margin of safety, including sensitive populations such as children, the elderly, and individuals suffering from respiratory diseases. Secondary standards are designed to protect public welfare from any known or anticipated adverse effects of a pollutant.

The adverse health impacts of suspended particles have caused the United States to adopt National Ambient Air Quality Standards (NAAQS) for PM_{10} of 50µg/m^3 for an annual average and 150µg/m^3 for a 24-hour average (Federal Register, 1987a). Other standards include $PM_{2.5}$ Primary and secondary, 35µg/m^3 for a 24-hour average and 15µg/m^3 for an annual average. Time Weighted Average (TWA) for Ghana EPA Ambient Air Quality Guidelines (2006) is indicated below.

Substance	**Time Weighted Average (TWA)**		**Averaging Time**
TSP	230µg/m^3	Industrial	24hr
	150µg/m^3	Residential	24hr

	$75\mu g/m^3$	Industrial	1yr
	$60\mu g/m^3$	Residential	1yr
PM10	$70\mu g/m^3$		24hr

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 THE STUDY AREA

The study area is located in the Lower Manya-Krobo District in the Eastern region of Ghana. The target communities in the study area are Bueryonye, Odugblase and Klo-Begoro. A fourth site called Oterkpolu, located about three kilometres away from the quarries was used for comparative purposes. The district shares boundaries with the Yilo- Krobo District in the west, Upper Manya- Krobo and Asuogyaman Districts in the north, North Tongu District in the east and Akwapim North and Dangme West Districts in the south (Fig 3.1). Lower and Upper Manya- Krobo districts were created from the original Manya- Krobo District in 2008. The quarries are behind Yogwa mountain near the Odumase-Asesewa road.

Lower Manya Krobo District covers a land area of 71787.350 acres or 29053.hectres (CERGIS, UG –Legon). Manya- Krobo has a population of 254301 (Population and Housing Census, 2000). The population of Lower Manya Krobo which is captured only in the 2010 Population and Housing Census was not published during the thesis write up. The three communities in the study area had a total population of 696 (Bueryonye- 304, Odugblase--188, Klo-Begoro--204). The population includes 363 males and 233 females. The study area has 89 houses(Bueryonye: 32, Odugblase: 25, Klo-Begoro: 32) and 135 households(Bueryonye: 53, Odugblase:37, Klo-Begoro:45).

Three construction companies are located in the study area. These are A. J. FANJ, Kamsad and Love. The largest of the three, A.J. FANJ Company Limited, was contracted by Ghana Cement Manufacturing Company (GHACEM) to mine limestone on November 17, 2004. The inauguration of the beginning of limestone mining by GHACEM at Yogwase was by President John A. Kufuor. GHACEM was founded by the Government of Ghana in collaboration with Norcem A.S. of Norway, on August 30, 1967.

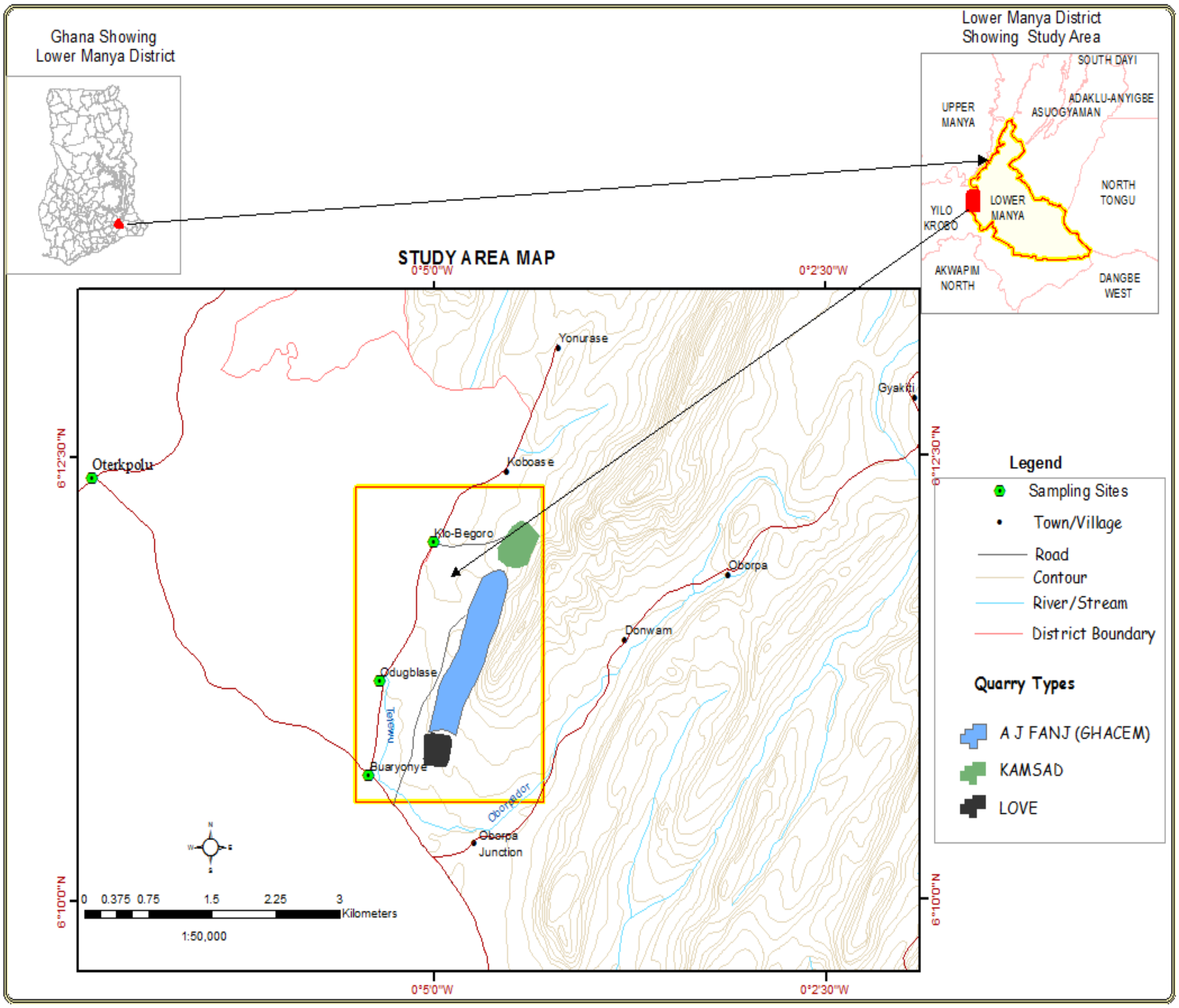

Fig3.1 Map showing the Study Area

(Source: CERGIS, UG Legon)

3.2 METHODOLOGY

This study was undertaken between January and October 2011 with focus on three communities (Bueryonye, Odugblase and Klo-Begoro) and the three quarries. The largest quarry, GHACEM, prepares monthly Environmental Impact Assessment (EIA) to the regional EPA office in Koforidua to reflect PM_{10} concentrations and other management practices that might reduce the impact of quarrying activities on the environment. The newly constructed haul road by GHACEM to link the quarry to Odumase-Asseswa road is one of the mitigation measures employed to reduce dust and noise impacts on the communities. Workers at the quarries use nose masks to reduce inhalation of dust and helmets to protect them from fly rocks enhance safety and good health. Haul trucks are also covered with sheets to prevent fugitive dust emission.

3.2.1 Sampling Framework

Data on the impact of quarrying activities on the communities was collected using two main methods (Fig. 3.2). These are primary and secondary data collection. In primary data collection actual sampling of dust in the study area was undertaken while secondary data was also obtained on health records in the clinics/hospital frequently patronized by the people.

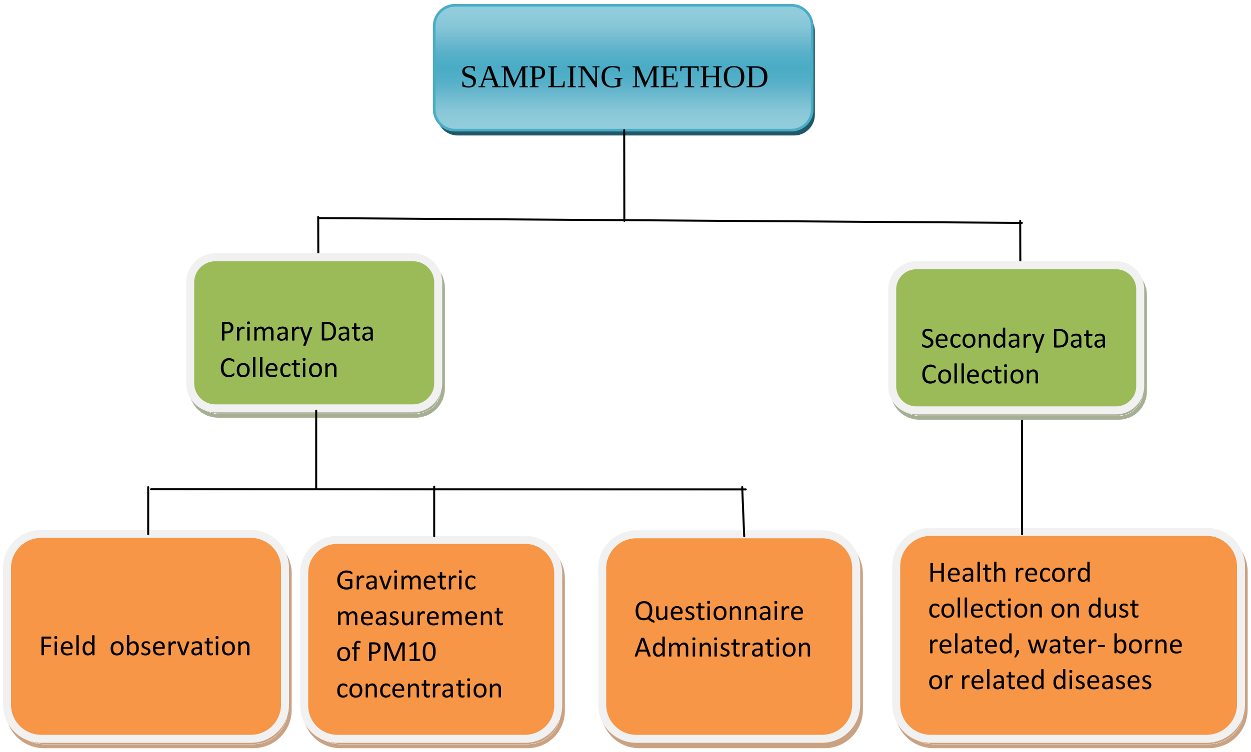

Fig 3.2 Sampling framework for data collection

3.2.2 Observation

A reconnaissance trip was first organized to the selected sites to interact with the chiefs, elders and assemblymen in order to have a fair knowledge of the issues related to quarrying activities. The three quarries were briefly visited. A detailed survey was then undertaken to visually identify (visual inspection) the effects of quarrying on the environment. The observation covered vibration effects on buildings resulting in cracks, flooded farmlands due to quarry run-offs, crops covered with dust, nature of crops grown close to quarries, visual concept about dust generated from the quarries and unpaved haul roads and other related environmental issues.

3.2.3 Questionnaire Administration for social data

This part of the data collection was done based on questionnaire administration. The questionnaires were used to collect data from a fraction of the population under investigation. The questionnaire was structured into four broad sections. These are background information, quarrying processes and implications, environmental issues and mitigation measures.

Houses and households where the target groups are resident were identified during the reconnaissance survey. The target persons in each household were people who experienced the two regimes of environment before quarrying activities (2000 – 2003) and an environment impacted by quarrying activities (2005 – 2010). A household as defined after the 2000 Ghana Population and Housing Census is "people who eat from the same pot".

A questionnaire (Appendix C) to solicit background information, processes involved in quarrying, effects of quarrying activities and mitigation information was designed. The rationale for the study was explained to respondents before the administration the questionnaires. The questionnaires were administered to a cluster of three, four or five respondents at a time due to large number of questions. The questions were read and explained to clients first and then guided to tick which ever response was appropriate using pens given to them. In cases where the respondents did not understand English very well, the researcher translated each question or statement into Dangme (local dialect) to facilitate response as shown in Plate 27. Twenty questionnaires were administered in each of the three sampling sites. In all, a total number of sixty (60) questionnaires were administered.

Plate 27: Researcher administering questionnaire to a cluster of indigenes of Bueryonye

3.2.4 Health data collection

Three health facilities mostly patronized by the indigenes in the study area were visited and the required data on out- patient morbidity was gathered. This data was collected to find out whether there has been an upsurge or emergence of quarry related diseases in the communities. The health facilities were Atua Government Hospital, Obenyemi Clinic and Oborpa Clinic. The two clinics are between one and one and half kilometres from the quarries where as Atua Government Hospital is about twenty kilometers away.

3.2.5 Gravimetric Measurement of Particulate Matter (PM_{10})

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Mini-Volume Portable Air Samplers (MiniVols) were used in sampling PM_{10}. For both accurate and precise measurements, the battery operated, lightweight MiniVol is ideal for sampling at a remote or areas without power. In addition, the low cost of the sampler allows a network of MiniVols to be deployed at a fraction of the cost for a similar reference network (Airmetrics, 2007). The MiniVol Portable Air Sampler is an ambient air sampler for particulate matter and non-reactive gases. The MiniVol features a 7-day programmable timer, a constant flow control system, an elapsed time totalizer, rechargeable battery packs, and all-weather PVC construction. The MiniVol Portable Air Sampler is designed to operate at 5 litres per minute (lpm) at ambient conditions. At the factory the sampler is calibrated at approximately 21°C at 754 mm Hg, and is adjusted to operate at 5 lpm at these conditions (Airmetrics, 2007).

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A single AA alkaline battery was used to power the programmable timer (Elapsed Time Totaliser). The programmable timer will automatically turn the pump off at the end of a sampling period. The Elapsed Time Totalizer linked in parallel with the pump records the total time in hours of pump operation (Airmetrics, 2007).

A standard flowmeter with a range of 1 to 10 lpm was used to indicate sampling flow rate. The uncalibrated accuracy of the flowmeter was ±4% of full scale (Airmetrics, 2007). To ensure a constant 5 lpm flow rate through the size separator at differing air temperatures and atmospheric pressures, the sampler was adjusted for each sampling project. The Flow Rate Adjustment knob varies the sampler's flow rate which is indicated by the level of the ball (read from the center of the ball) in the flowmeter.

Sampling of PM_{10}

PM_{10} (inhalable particles) was collected at three monitoring stations in January, April, June, August and October, 2011 in the study area. PM_{10} was sampled for a period of 24 hours using Mini Volume Portable Air Samplers to pump about 5 litres of air per minute. Flow rates of the systems were checked and recorded before and after sampling. The average flow rates were then determined. A Mini Volume Sampler each was mounted in the four communities for the 24- hour sampling period and the required data recorded. The samplers with exposed filters were retrieved immediately at the end of the sampling period. This is because the potential for filter damage or changes in sample mass due to particle loss, passive deposition, or volatilization increases if the filter is left in the sampler for extended periods. The samplers were obtained from EPA Head office, Accra and sampling was done with the assistance of a technician also from EPA, Accra.

Plate 28: Researcher being assisted by a technician to set the flowmeter and elapsed time totalizer

Plate 29: Mini Volume Sampler mounted at Bueryonye

Plate 30: Mini Volume Sampler mounted at Odugblase

Plate 31: a) Mini- Volume Portable Air Samplers used in sampling PM_{10} b) High Volume Air Sampler

Sampling sites

The four sampling sites were identified by codes (Table 1).

Table 1: Definition of codes for sampling sites

AREA CODE	SAMPLING SITE
N_1	Bueryonye
N_2	Odugblase
N_3	Klo-Begoro
N_4	Oterkpolu

Sampling Method

Filter papers of pore size less than 10 microns on which the particulates were collected and first stabilized in a desiccator for 24 hours. The filters were pre-weighed with an electronic balance (AG104 Mettler Toledo) of milligram sensitivity (M_1). The filters were then fitted into the PM_{10} samplers which draw air at a rate of 5.000 m^3 per minute and sent to the field. Plate 33 (a) shows the samplers used. Loaded filters with PM_{10} were removed and conditioned in a dessicator for 24 hours to ensure no moisture effect on the air particulate weight before re-weighing (M_2). The mass concentration of the sampled particulates was then calculated using the equation below (Baird, 1997).

$$PM_{10} \text{ mass concentration in } \mu g/m^3 = \frac{\textit{Sampled particulate matter (PM10) mass}}{\textit{Flow rate(l/min) x Elapsed time (min)}}$$

$$= \frac{(M_2 - M_1) \times 10^6}{FR \times T}$$

PM_{10} = Particles with aerodynamic diameter of 10 microns

M_1 = Weight of filter paper before sampling(g)

M_2 = Weight of filter paper after sampling(g)

FR = Average flow rate (l/min or m^3/min)

T = Sampling duration in minutes

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 OBSERVATION

A survey or visual inspection undertaken in the communities and the varoius quarries revealed worrying issues concerning the impact of quarrying on the environment. The issues relate to buildings, farmlands, crops, water systems, biodiversity, the surrounding atmosphere and others

Several buildings were observed to have developed different degrees of cracks. Some of the buildings were close to collapse. These cracks may be due to strong vibrations from rock blasting, the nature of building materials used, poor maintenance and the age of the structures.

Plate 32: Cracks in a 4-year old building at Odugblase about 300m from GHACEM quarry

Plate 33: An 85-year woman sitting near a cracked building at Bueryonye

Farmers in the communities have lost parts of their arable lands to flood waters. Water pumped from the quarry pits and run-offs have covered several farmlands as shown in Plate 36 below. A haul road constructed by Kamsad Quarry to link up with the main road at Klo – Begoro has blocked a channel that drains water into river Ponpon. This has resulted in the widespread of water to adjoining lands under cultivation during downpours and water pumped out of the quarry pits.

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Plate 34: Researcher observing a flooded farmland

Quarry run-offs may have deposited minerals and other sediments onto farmlands close to the quarries. A test on the structure of soils around the quarries using a cutlass has shown that the soils are compact and may, therefore,- be very difficult to cultivate. Villagers without any alternative farms are forced to cultivate these lands with declined yields.

Plate 35: (a) Crops about 100m from quarries (b) Crops on land about 700m from the quarries

Rivers and streams in the study area appear not to have fish in them because of the nature of water in them. A careful observation of these aquatic media seems not to show any existence of common fishes like mud fish and tilapia as fingerlings or fries cannot be easily seen. They may have lost their habitats to quarry materials and perhaps not to over extraction of fish as the inhabitants are predominantly farmers. Quality of water in the streams has deteriorated as can be seen by its colour (Plate 31). Acid mine drainage could be a contributory factor.

Plate 36: The yellowish colour of water in the River Tetewu

Dust was also seen on the leaves of crops and other plants. Dust may probably block the stomata in the leaves which is likely to reduce light entry and eventually affect photosynthesis. High concentrations of dust on the plants may result in low crop yield.

Plate 37: Dust on plant/crop leaves reduces photosynthesis

4.2 HEALTH DATA

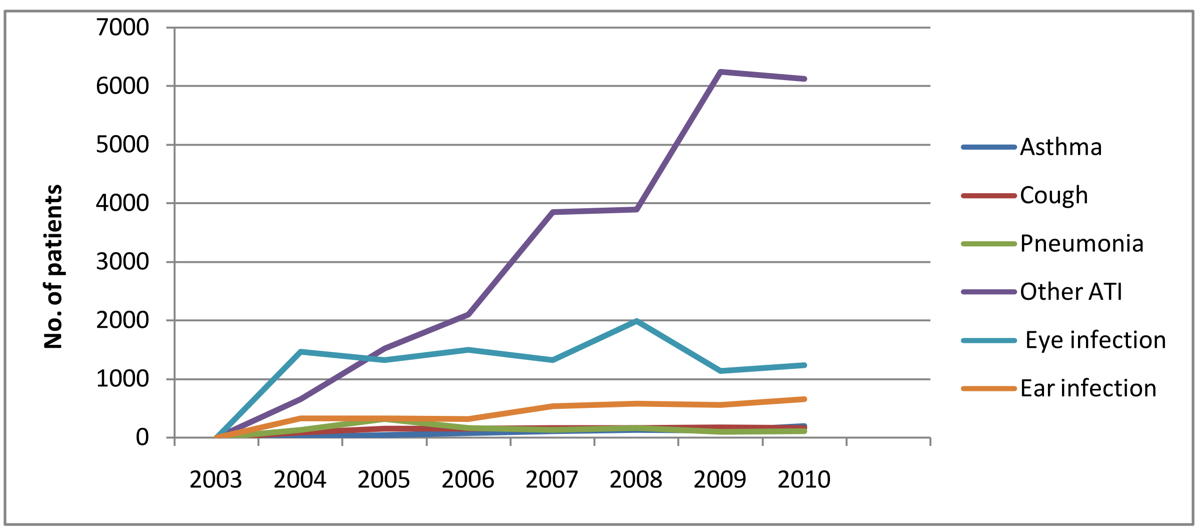


Fig 4.1 Atua Government Hospital Out-Patient Morbidity Returns (Dust related)

Source: Antua Government Hospital

In Fig 4.1, there is a sharp rise in infection of the diseases during the transition period between 2004 and 2005. This based on the fact that quarrying began late 2004 and became fully operational in 2005. Ear infection and acute respiratory tract infection (ATI) are still on the rise. Cough is also slightly on the increase. Ear and eye infections are quite impacting on the people. Pneumonia seems to be the least prevalent. Asthma also upsurged in 2005 and is on the rise.

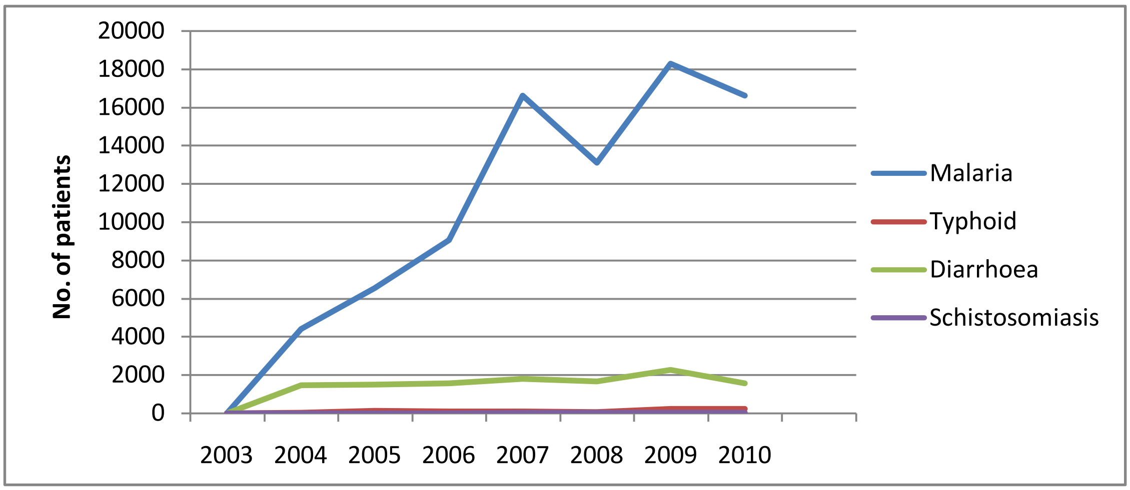


Fig 4.2: Atua Government Hospital Out-Patient Morbidity Returns (Water related/borne)

Source: Atua Government Hospital

In Fig 4.2, malaria infection rose significantly in 2005 onwards and diarrhoea also rose slightly. Schistosomiasis and typhoid infection were rather insignificant. The high malaria infection recorded at Atua Hospital may not necessarily be the result of mosquitoes generated from the flooded lands around the quarries but from several catchment areas in both Upper and Lower Manya Districts since it is a district hospital.

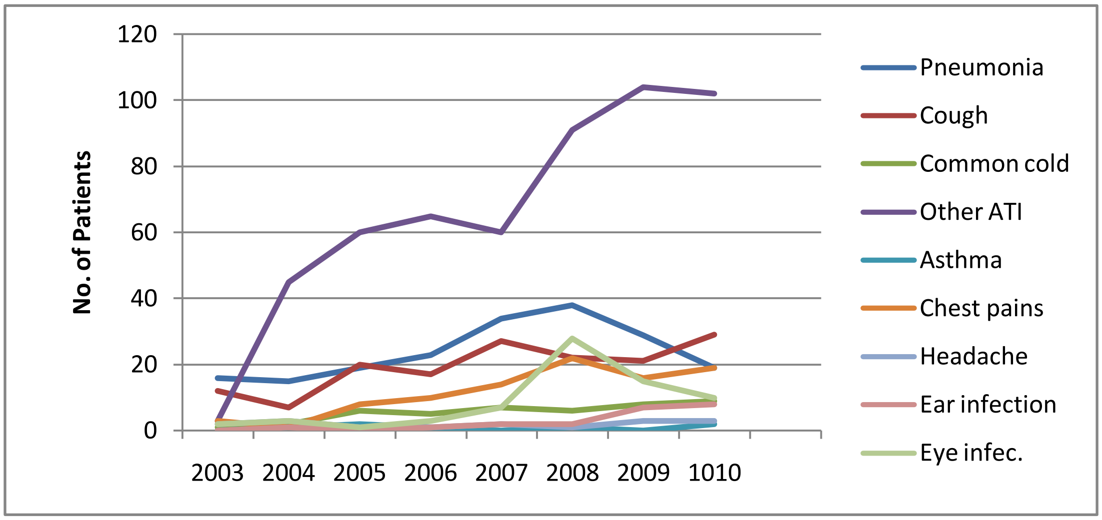


Fig. 4.3: Oborpa Clinic Out-Patient Morbidity Returns (Dust related diseases)

Source: Oborpa Clinic

At Oborpa clinic, there is a rise in cough, pneumonia, chest pains, common cold, eye problems with the other respiratory tract infections (ATI) like catarrh, sore throat recording the highest rise from 2005 to 2010. Headache, eye infection, ear infection and asthma have also increased significantly as portrayed in Fig 4.3. The increase in respiratory tract infection from 2005 is a clear indication that the patients might have inhaled quarry dust to an appreciable level likely to cause such related diseases. Additionally, Oborpa is about a kilometre from the quarries and villagers may want to visit the clinic for treatment

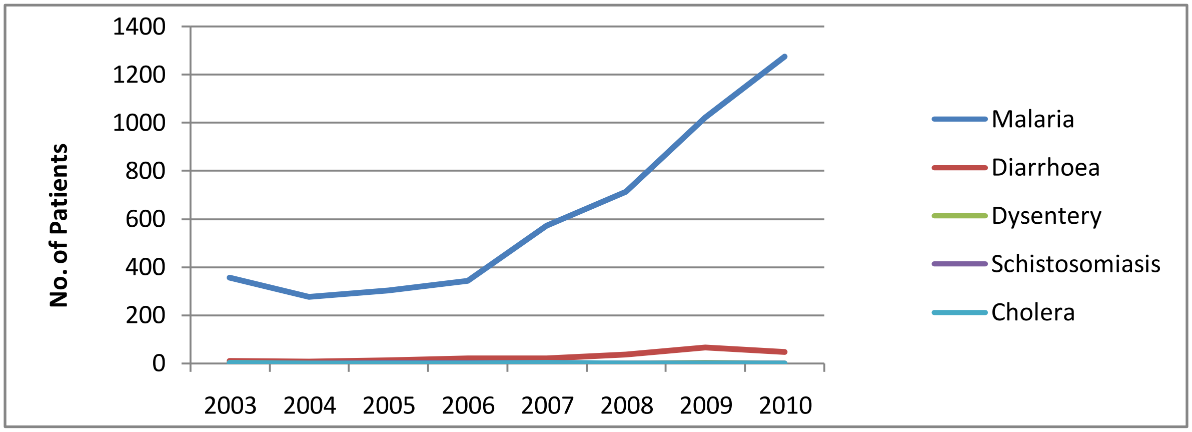


Fig 4.4: Oborpa Clinic Out-Patient Morbidity Returns (Water related)

Source: Oborpa Clinic

Records of patients with about five water-related or water-borne diseases obtained at Oborpa clinic are as shown in Fig 4.4. A decline of malaria from 2003 to 2004 rather saw an upsurge from 2005 to 2010. Diarrhoea also increased gradually since 2005. There, was no significant rise in cholera infection. According to Appendix A (Health data iv), dysentery recorded 1, 1, and 2 patients in 2003, 2007 and 2009, respectively, where as schistosomiasis registered 2, 1, and 1 in 2005, 2006 and 2006, respectively. Schistosomiasis and dysentery infection is, therefore, not prevalent among the people. The high malaria infection could be attributed to flooded lands which bred mosquitoes**.**

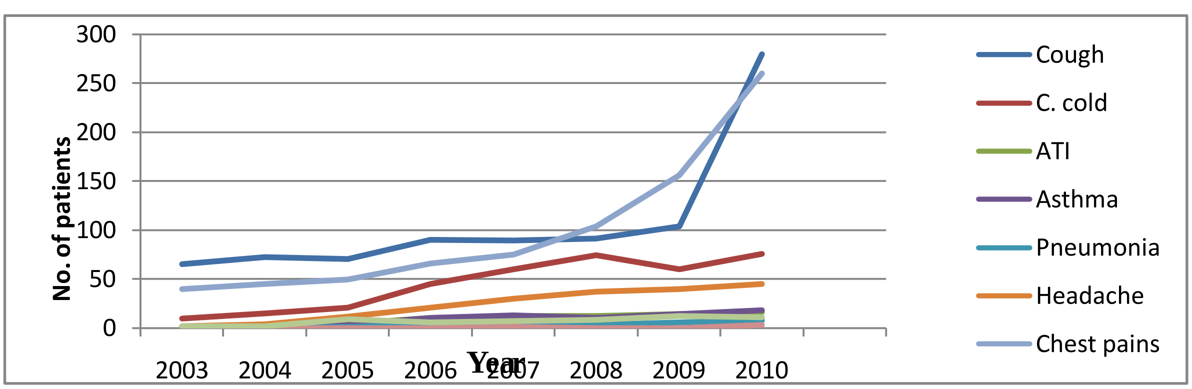


Fig 4.5: Obenyemi Clinic Out-Patient Morbidity Returns (Dust related)

In Fig 4.5, it is observed that all the diseases have risen sharply from 2005 onwards. The most observable diseases are cough, chest pains, common cold, headache, pneumonia, asthma, ATI and eye infection and these have also risen steadily from 2005 to date. The rise in ear infection may be due to the high levels of noise from machinery and trucks especially. The graph shows that dust related diseases are still affecting the people in the communities

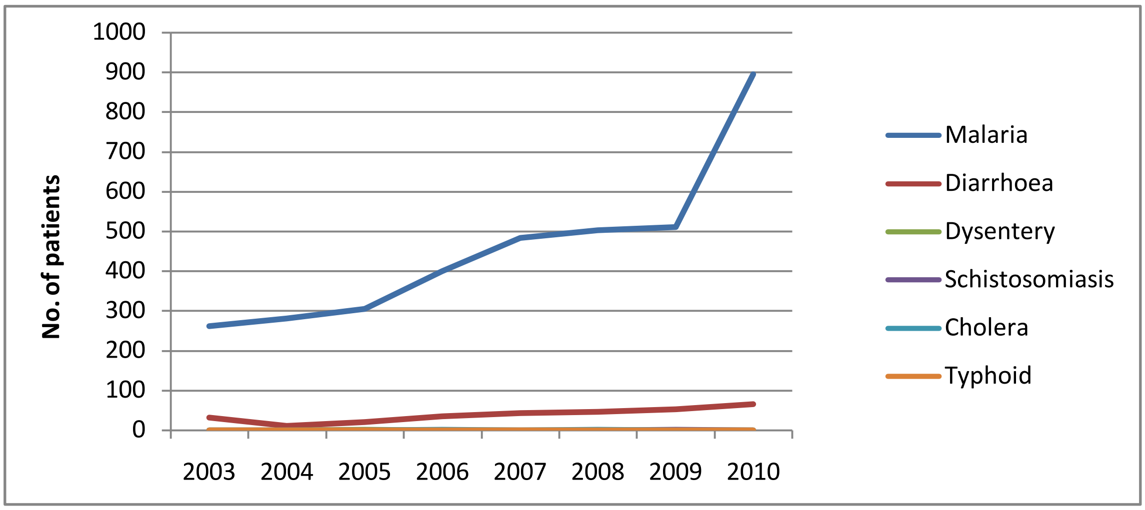


Fig 4.6 Obenyemi Clinic Out-Patient Morbidity Returns (Water related diseases)

Source: Obenyemi Clinic

From Fig. 4.6 above, it could be observed that there has been a steady rise in malaria and diarrhoea since 2005 to 2010. Typhoid is not among the water related or borne diseases prevalent during the extraction of limestone. The upsurge in malaria and diarrhoea infection could be attributed to flooding of lands. Floods generate mosquitoes and this might be the reason for the high rate of malaria infection.

4.3 QUESTIONNAIRE

In all 60 questionnaires were administered to the people of Bueryonye, Odugblase and Klo-Begoro. Since the questionnaires were administered in clusters a recovery rate of 100% was obtained.

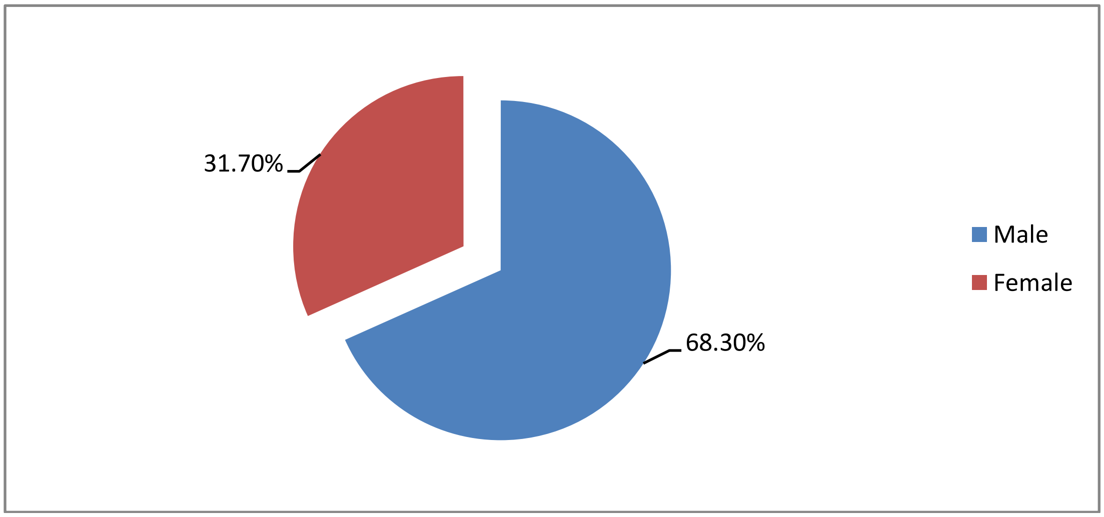


Fig 4.7: Sex of respondents

In Fig 4.7 68.3% of the respondents are males whilst 31.7% are female

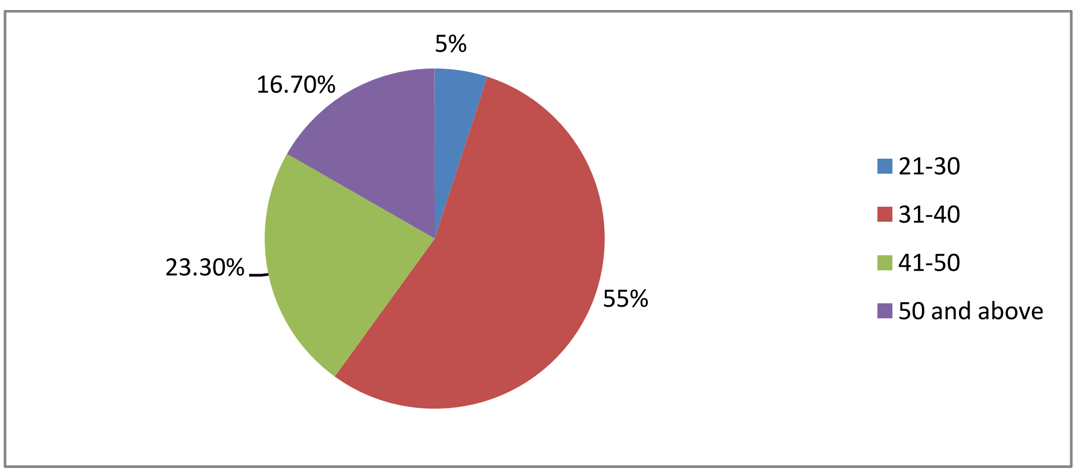


Fig 4.8: Age of respondents

Questionnaires were administered to indigenes that were between 21 and above 50 years old as can be seen in Fig. 4.8. Five percent (5%) of the respondents were in the range of 21-30 years, 55% between 31-40 years, 23.3% were in the range of 41-50 years and the rest which constitute 16.7% were 50 years and above. Respondents in the range of 31-40 years constitute the highest percentage.

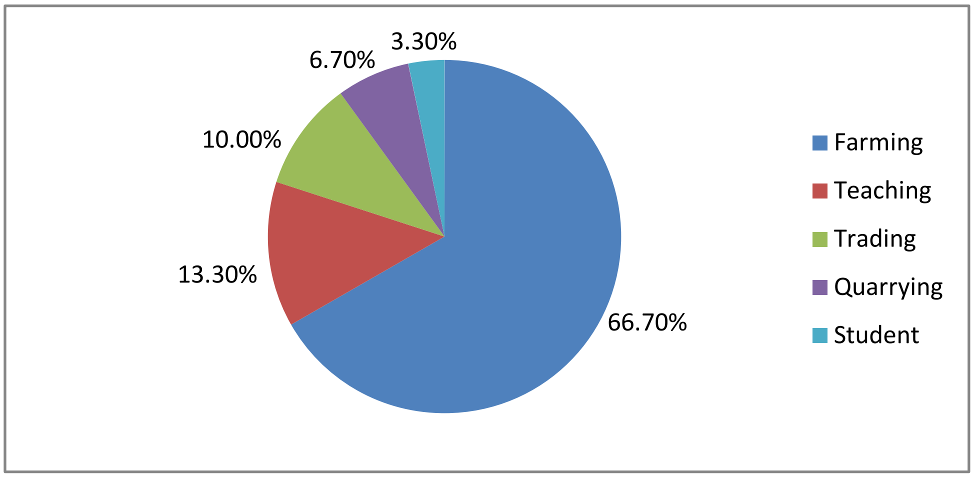


Fig 4.9: Occupation of respondents

Fig 4.9 shows the kind of occupation the villagers are engaged in. 66.7% of the respondents are engaged in farming, 13.3% in teaching, 10% in trading, 6.7% in quarrying and 3.3% are students. Most of the respondents are, therefore, farmers and this requires perfect health for better performance.

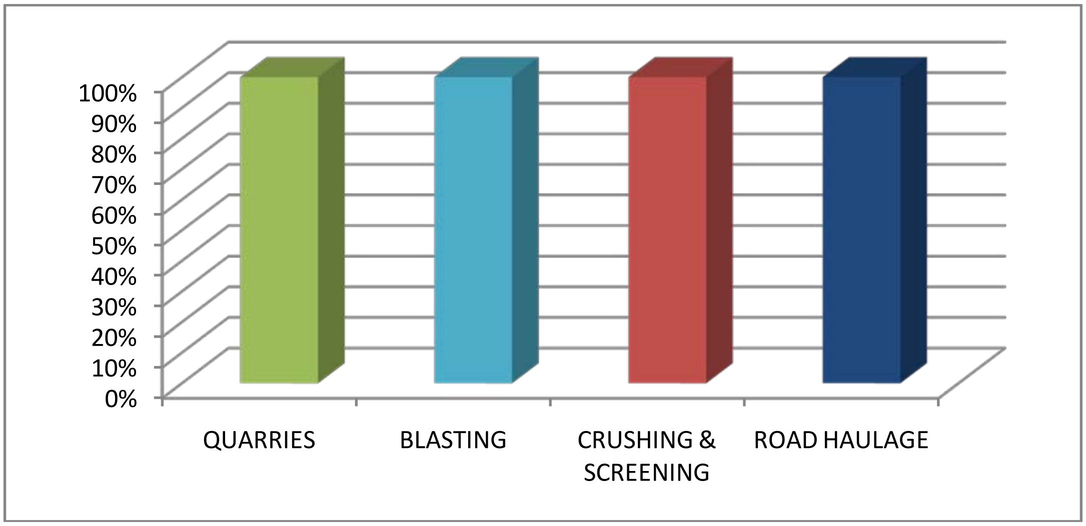


Fig 4.10: Sources of dust

All the respondents, 100%, agreed that the main source of dust is the quarries. Hundred percent (100%) of the respondents are of the view that blasting generates the highest quantity of dust. All the respondents hold the view that processing and transportation of rock materials also generate a lot of dust. The main sources of dust are, therefore, from blasting, processing and haulage of products to consuming centres.

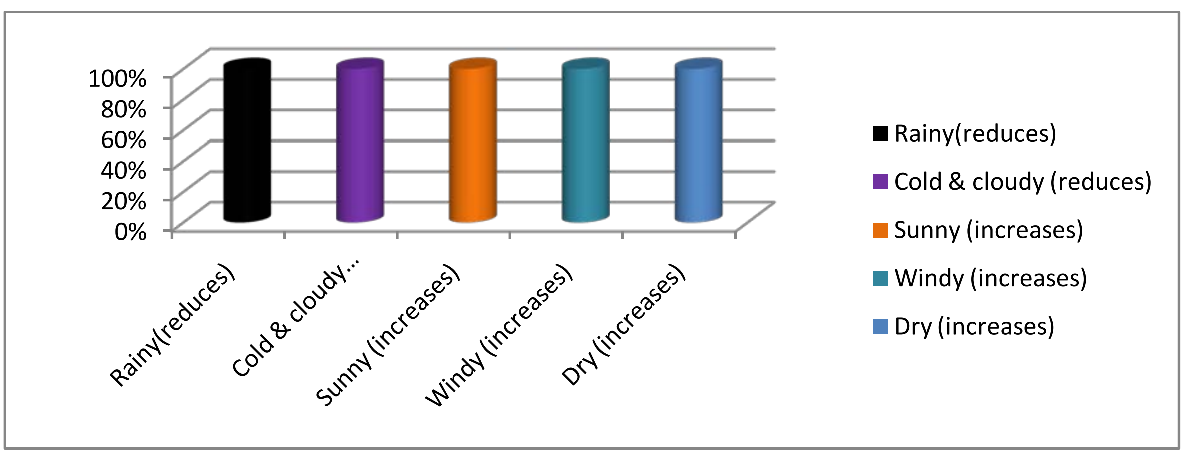


Fig 4.11: Effects of weather conditions on dust emission

Fig. 4.11 indicates that certain weather conditions facilitate or suppress dust emission and subsequently affect its concentration in air. Hundred percent (100%) of the respondents said that rainy weather condition reduces the amount of dust emitted whilst 80% agreed that cold and cloudy weather reduce the amount of dust in the air. All the respondents agreed that sunny, windy and dry weather promote dust emission and impact. Data obtained from the January PM_{10} sampling (Table 12) confirms the statement that dry weather promotes dust emission as all the communities had concentrations more than 100µg/m^3 in January.

In Fig 4.12, below, 100% of the respondents agreed that a lot of dust settles on their roofing. All the respondents also agreed that crops are coated with dust and therefore do not grow very well. High concentration of dust is therefore not acceptable as crop yield may be affected.

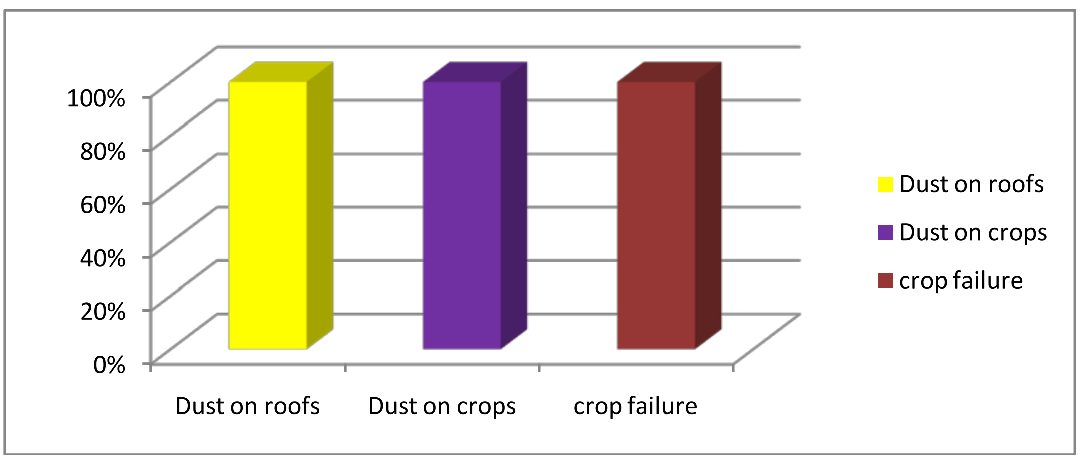


Fig. 4.12: Nuisance dust emission

In Fig. 4.12 above, 100% agreed that a lot of dust settles on their roofing, 100% said that crops are coated with dust, and 100% also accepted the fact that crops coated with much dust do not grow very well. Rain water harvested from the spouts of roofing sheets may contain mineral dust.

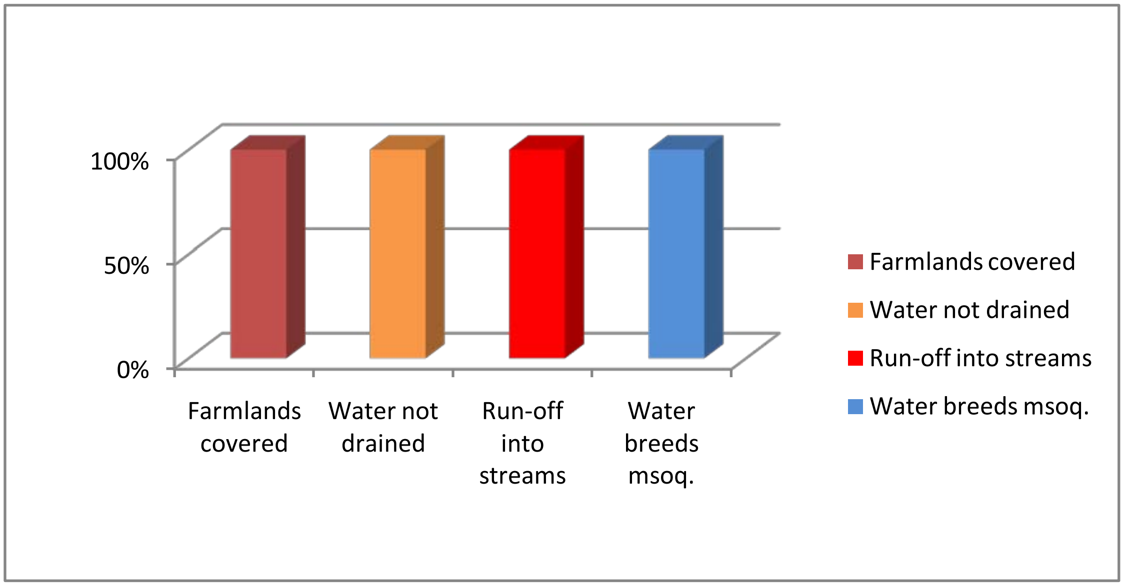


Fig 4.13 Quarrying run-off/flooding

Run-offs which cause flooding have affected farmlands, water bodies and humans. In Fig 4.13, all the respondents accepted the case of farmlands flooded with water, flood waters have never been drained, run-offs and water from quarry pits have found their way into nearby streams, and floods are breeding mosquitoes and perhaps other disease causing organisms. The rise in water-related or water-borne diseases since 2005 could be linked to the flooded farmlands.

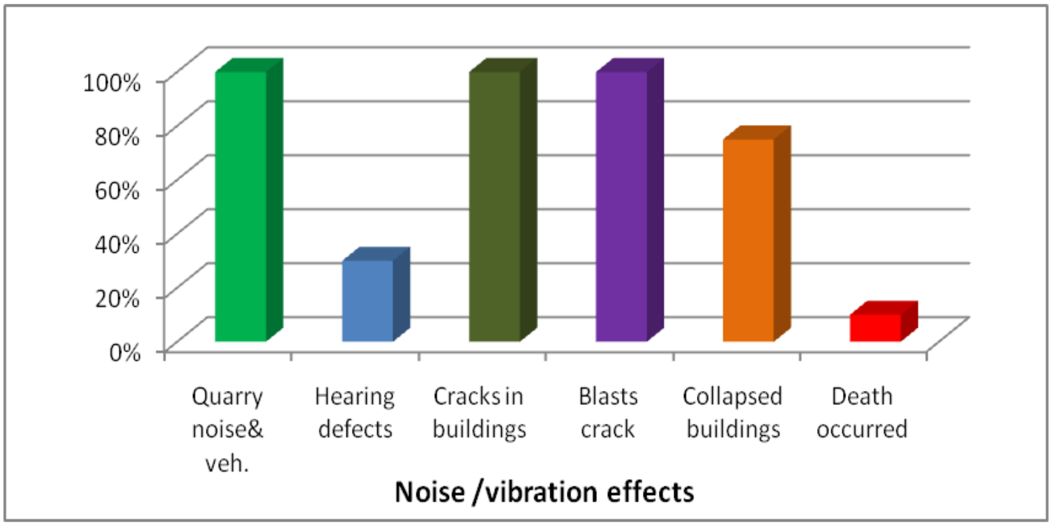


Fig. 4.14: Noise pollution/Vibration effects

In Fig 4.14, all the respondents agreed that the sources of noise are the quarry machinery, blasting, processing and haulage trucks; observed cracks in their buildings and attributed them to blasting vibrations. Thirty percent (30%) claimed that the noise level has affected their hearing, 75% claimed that some buildings have ever collapsed and 10% witnessed the death of a family member who was trapped under a collapsed building. The magnitude of the blasting vibrations may have contributed in several ways to the deep cracks in the buildings. Blasting must therefore be well controlled to minimize vibration intensity.

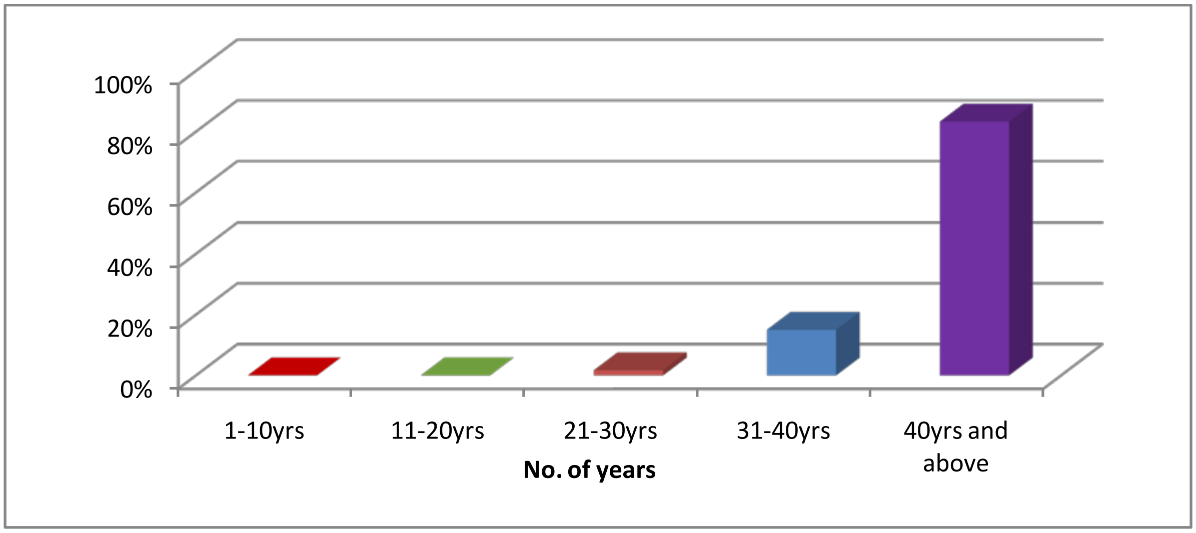
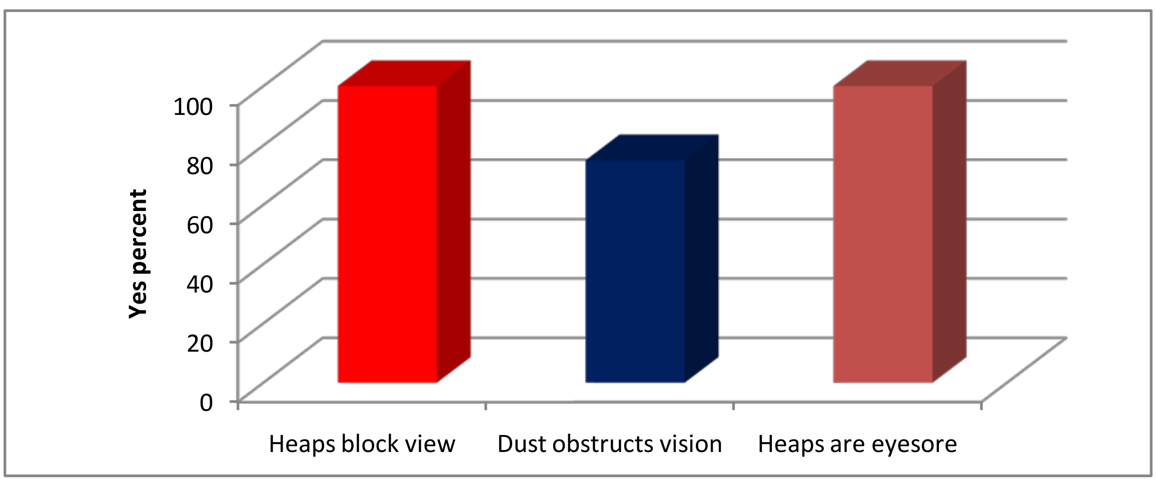


Fig 4.15 Life span of a well maintained mud building before cracking

In Fig 4.15, the life span of a well maintained mud building between 1-10 and 11-20 years before cracks are observed had 0% respondents, 21-30 years had 1.7%, 31-40 years had 15% and 40 years and above had 83.3%. A well maintained mud house can, therefore, stay for over forty years before cracks are observed. The cracks are forcing villagers to pull down houses and build new ones within some few years or are living in fear of being trapped under a collapsed building.



. Fig 4.16: Visual intrusion

Results about visual intrusion by stockpiles in Fig 4.16 show that 100% of the respondents agreed that quarry waste (stockpile) blocks their view as some of their farms are behind heaps, 75% said that dust from heaps obstructs their view some distance away and 100% claimed that these stockpiles might be considered an eyesore. These heaps are, therefore, a nuisance to the people until they are used in the restoration of degraded lands.

From Fig 4.17 below, 60% of the respondents agreed that excavation has destroyed many plants and animals, 100% hold the view that quarrying has displayed several living things from their habitats and 30% said that loss of biodiversity are not permanent. A large percentage of the respondents (70%) think that it will be very difficult to get back lost plant and animal species. When the quarry is closed down and the place is well restored, lost animals are most likely to come back from the Yogwa Forest Reserve some half a kilometre away from the quarries. Rare plants species are not likely to be restored.

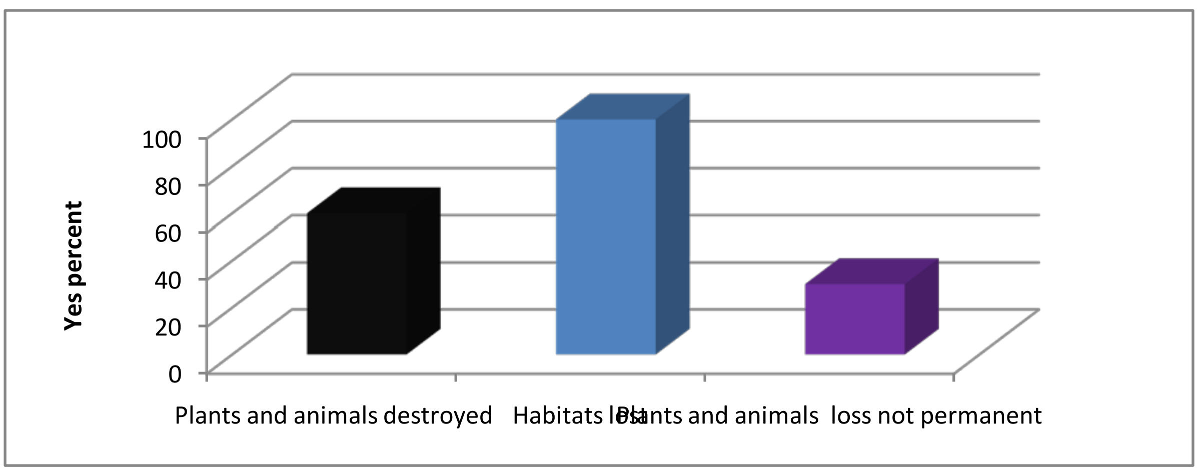


Fig 4.17 Biodiversity (plants and animals) loss

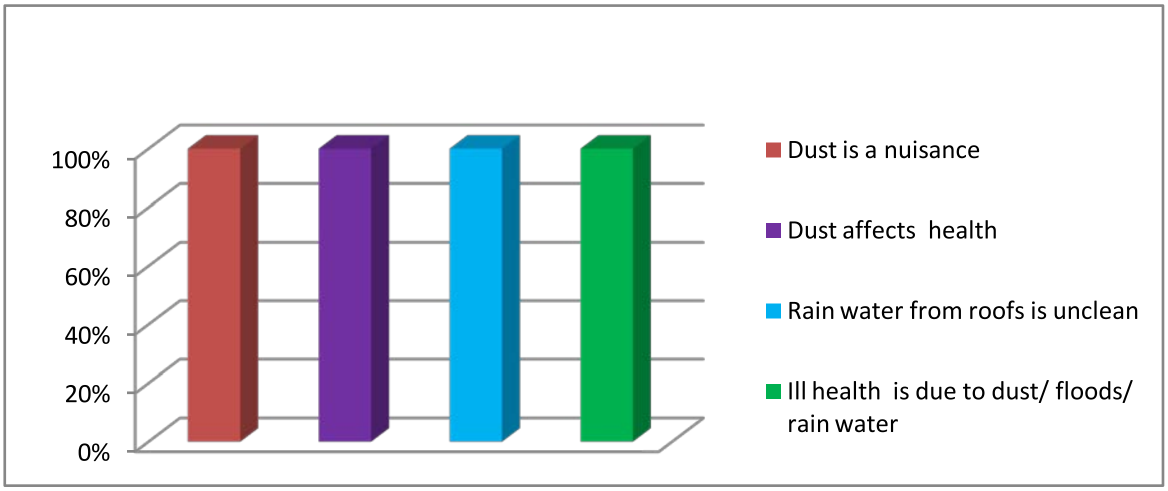


Fig 4.18: Influence of quarrying on Human Health

In Fig. 4.18, all the respondents (100%) claimed that dust is a great nuisance to them, dust affects their health, rain water harvested from roofs are always contaminated with dust. Also, all the respondents suggested that their frequent ill-health could be linked to dust and flood waters. From the responses in Fig 4.18, the high concentration of dust which is supported by data during the PM_{10} sampling and data about water related or water borne diseases are indications of the negative effects of quarrying on the villagers.

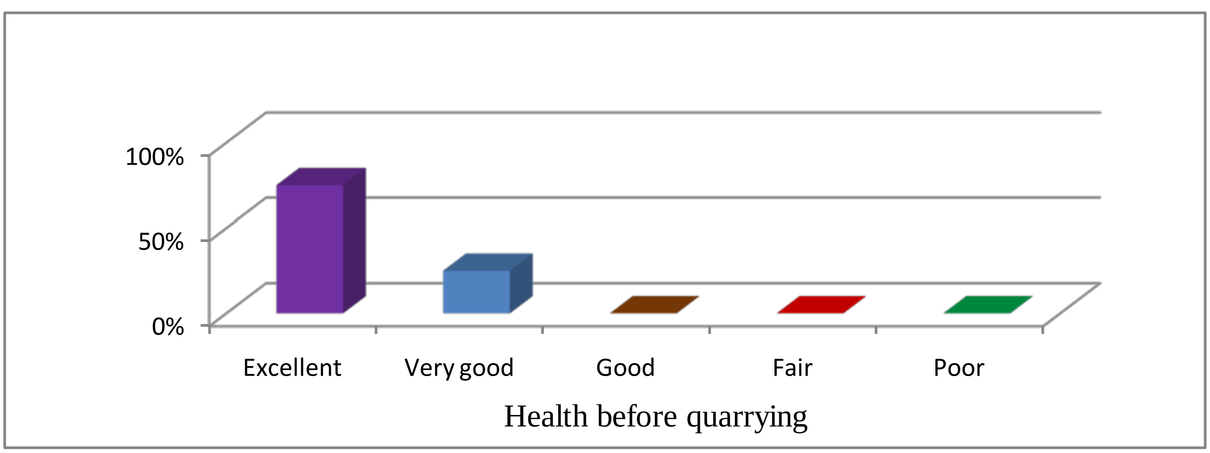


Fig 4.19: Health status before quarrying

From Fig. 4.19, 75% of the respondents had excellent health, 25% had a very good health status before quarrying began and 0% had good, fair or poor health condition. The health status of the people was excellent before the advent of quarrying..

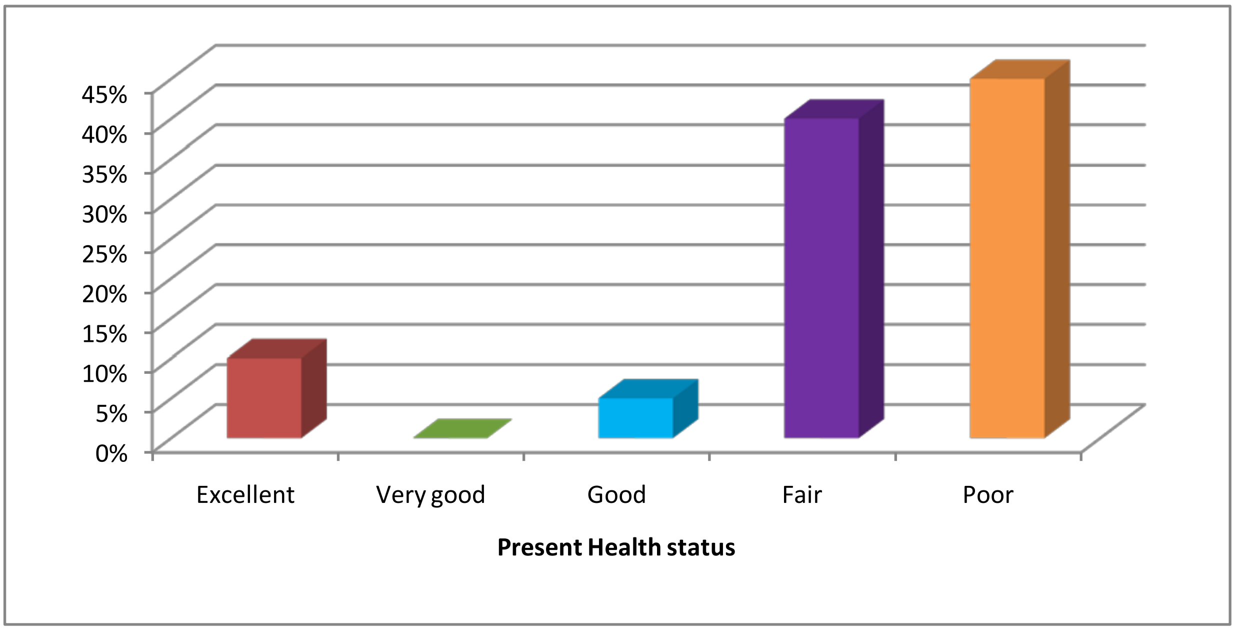


Fig 4.20: Present Health status

In Fig 4.20, only 10% of the respondents maintained their excellent health, no respondent (0%) had very good health and 5% had good health status. A large percentage of 40% and 45% had fair and poor health status respectively. The apparently poor health of the people could be attributed to the high concentration of particulate matter (dust) generated from the quarries, drinking unclean rain water and perhaps floods resulting in increase in disease causing organisms. The present general health status of the people is just fair.

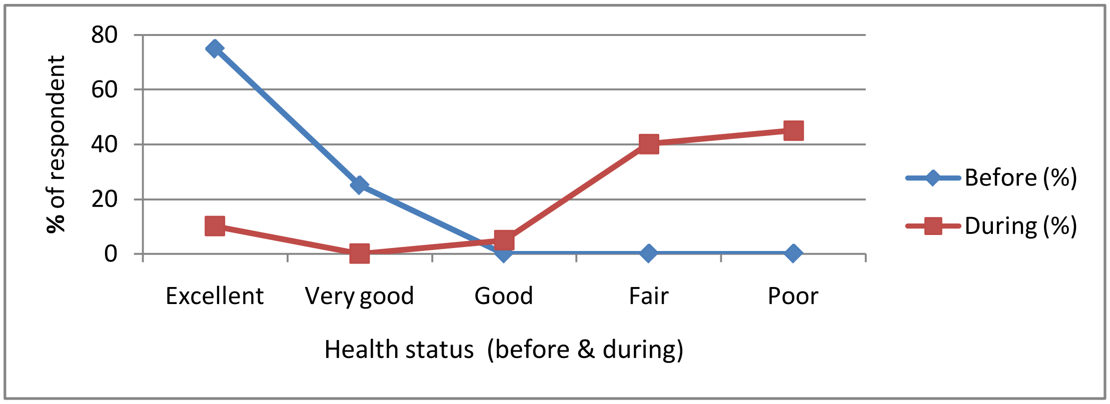


Fig 4.21: Comparative Health status (before and present)

In Fig 4.21, 75% and 25% of the respondents had excellent and very good health respectively before quarrying whilst 10% and 0% had excellent and very good health status respectively during quarrying. Also, no respondent had good, fair or poor health during quarrying. However, 5%, 40% and 45% of the respondents had good, fair and poor health respectively. The health status of the people, therefore, was quite excellent before quarrying as against their present fair health status. Limestone extraction and other factors may be impacting negatively on the health of the inhabitants.

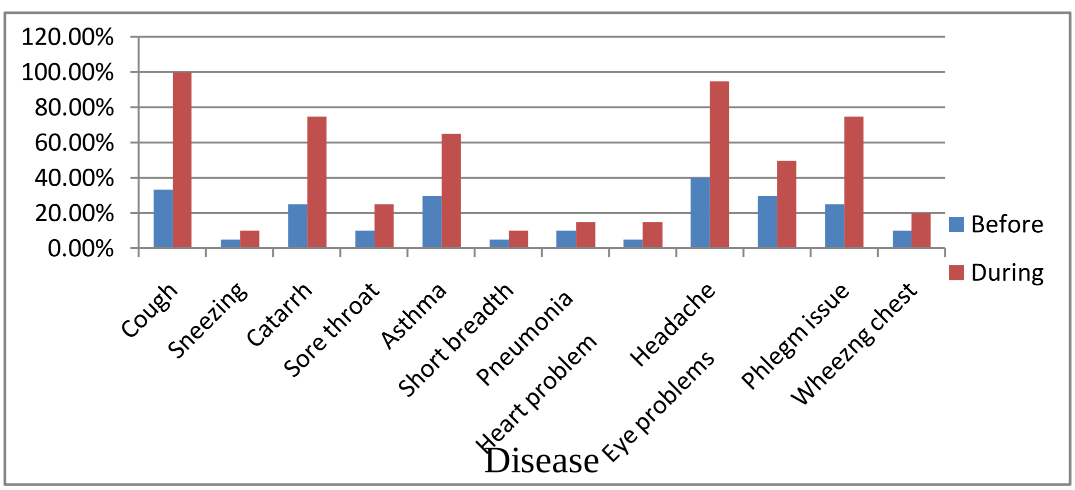


Fig 4.22: Dust related diseases suffered from before and during quarrying activity.

In Fig. 4.22, 33.3% of the respondents suffered from cough before quarrying while all of them (100%) suffered from the sickness since quarrying began, 5% were infected with sneezing before and 10% since quarry activity started, 25% suffered from catarrh before and 75% since quarry activity started, 10% contracted sore throat before and 25% since quarrying started. Also, 50% of the target group suffered from asthma before and 65% since quarry activity started, 5% suffered from short breadth before and 10% since quarry activity started, 10% had pneumonia before and 15% since quarry activity started, 5% had heart problems before and 15% since quarry activity started and 40% suffered from headache before and 95% since quarrying started. Thirty percent (30%) had eye problems before and 50% since quarry activity started, 25% suffered from frequent issue of phlegm before and increased to 75% during quarrying and 10% had wheezing chest or chest pains before and hiked to 20% during limestone mining. Several inhabitants have suffered from dust related diseases due to quarrying activity.

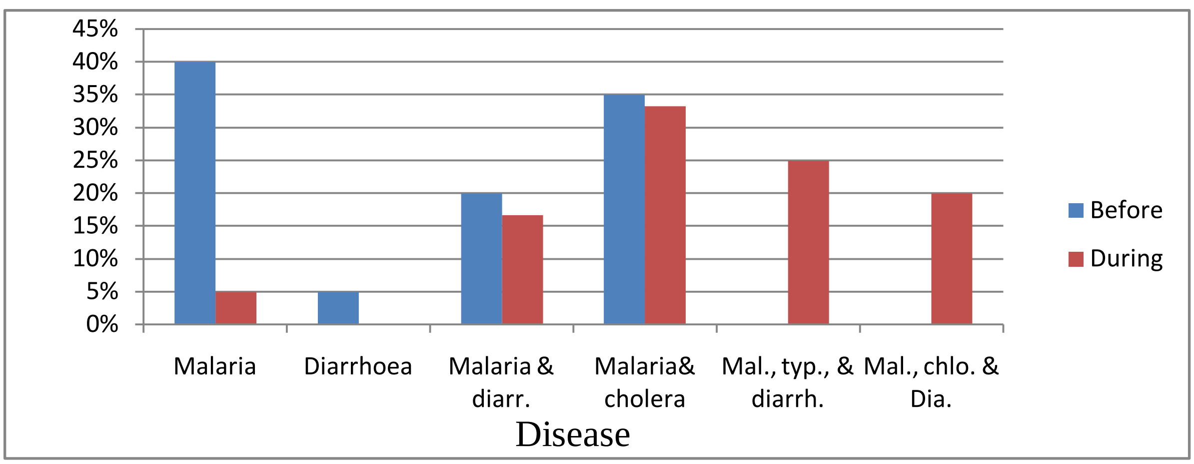


Fig: 4.23 Water related or borne diseases before and during quarrying

In Fig 4.23, 40% and 5% of the respondents suffered from malaria and diarrhoea only; 20% had malaria and cholera; 35% had malaria, typhoid and diarrhoea; nobody (0%) was infected with malaria, typhoid and diarrhea and then malaria, cholera and diarrhoea. During quarrying 3% and 0% suffered from only malaria and diarrhoea; 16.7% had malaria and diarrhoea; 33.3% had malaria and cholera, 25% had malaria, typhoid and diarrhoea. Twenty percent (20%) were infected with malaria, cholera and diarrhoea. Fig 4.23 also shows that 95% of the respondents suffered from malaria where as all of them (100%) suffered from the same disease during quarrying. The rise could be attributed to more mosquitoes due to the inundated farmlands.

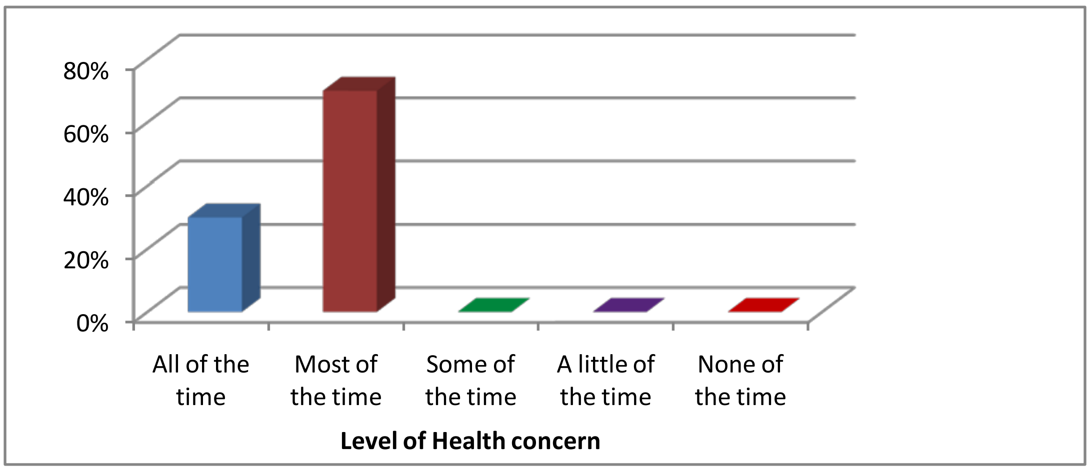


Fig 4.24 Health Concern of respondents

In Fig 4.24, 30% of the respondents were concerned about their health all the time, 70% were also anxious about their health most of the time. None of the respondents was concerned about his or her health some of the time, a little of the time and none of the time. This is an indication that all the respondents were much concerned about the decline in their health status most of the time since the mean is 1.7 and standard deviation is 0.46212 (Appendix B xxvii).

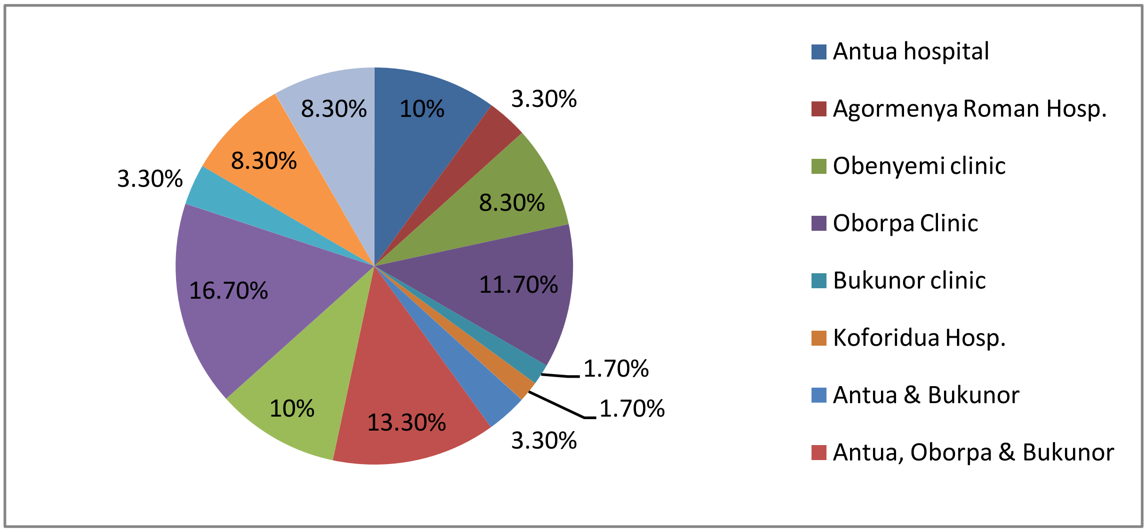


Fig 4.25: Hospitals/clinics visited

From Fig. 4.25, it could be seen clearly that the percentage of respondents that attended only Atua Government hospital, Agormenya Roman hospital, Obenyemi clinic, Oborpa clinic, Bukunor clinic and Koforidua Government hospital are 10%, 3.3%, 8.3%, 11.7%, 1.7% and 1.7%, respectively. Other respondents patronized two or three health facilities. Three percent (3%) visited Atua hospital and Bukunor clinic, 13.3% visited Atua hospital, Oborpa and Bukunor clinics, 10% also sought health care from Obenyemi clinic, Oborpa clinic and Koforidua Government hospital, 16.7% attended Obenyemi, Oborpa and Bukunor clinics, 3.3% went to Obenyemi clinic and Koforidua hospital, 8.3% visited Oborpa clinic and Atua hospital, and 8.3% attended Atua hospital, Oborpa and Obenyemi clinics. The most patronized health facilities are Atua Government hospital, Obenyemi and Oborpa clinics. Oborpa and Obenyemi clinics are the closest health facilities to the quarries that is probably why patronage is outstanding. From the Data on hospitals or clinics visited shows that 36.7% of the respondents attended only one health facility and 63.3% visited two or more health facilities.

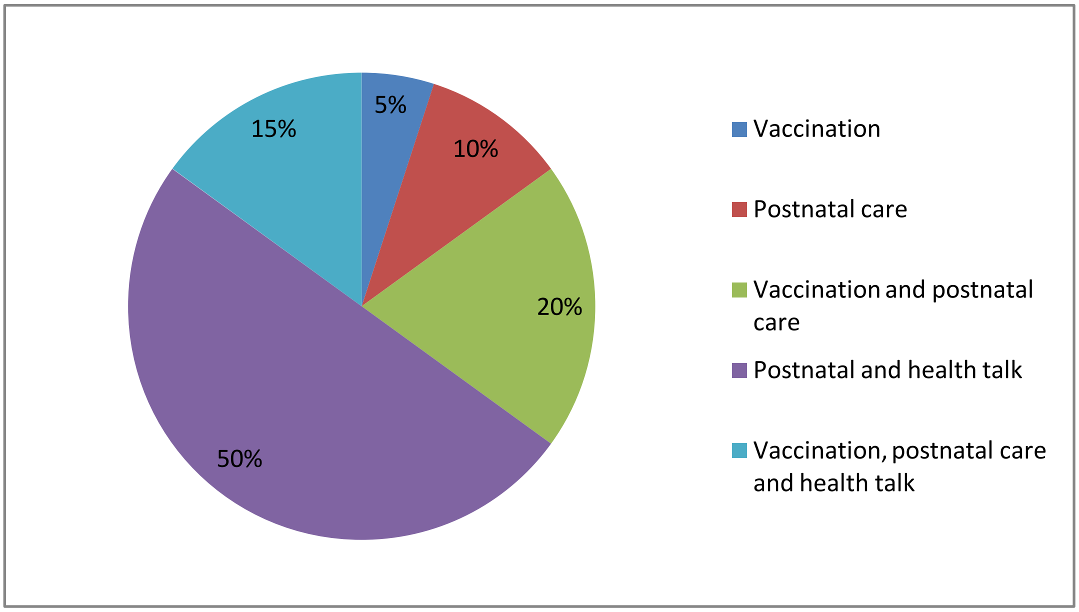


Fig 4.26 Health programmes

Health programmes organized in the communities are vaccination, postnatal care and health talk (Fig. 4.26). Three respondents representing 5% agreed that vaccination programmes have ever been organized in the community, 10% observed postnatal care programmes, 20% attest to vaccination and postnatal care, 50% witnessed both postnatal care and health talk, and 15% of the respondents also observed vaccination, postnatal and health talk activities in the study area. It is clear that there has not been any specific health screening exercise in any of the three communities in the study area. Blood screening, chest images and eye screening could help identify specific health requirements that would help militate negative impacts of quarrying activities.

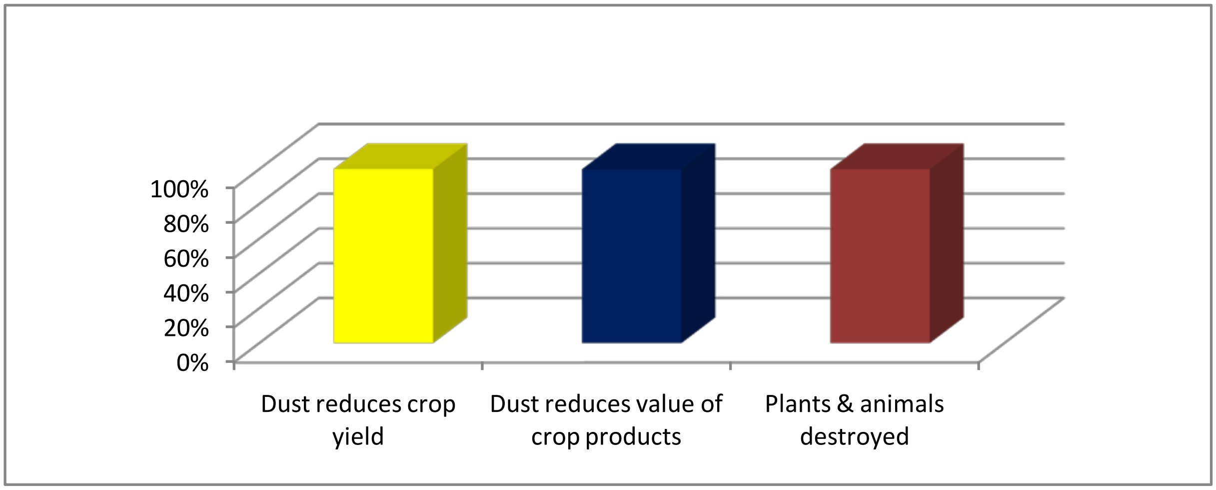


Fig 4.27 Influence of quarrying on fauna and flora

It is an undeniable fact that dust disturbs the proper growth of plants or crops. In Fig 4.27, hundred percent of the respondents agreed that the yield of crops reduces due to dust coating and the quality or price for the products such as tomatoes harvested also reduces. Also, hundred percent of the respondents agreed that dust and other quarrying activities have destroyed some valuable plants and animals. Dust blocks the stomata of leaves and thus reduces photosynthesis. This will certainly reduce crop yield especially during the dry season when weather conditions are not favourable for plant growth.

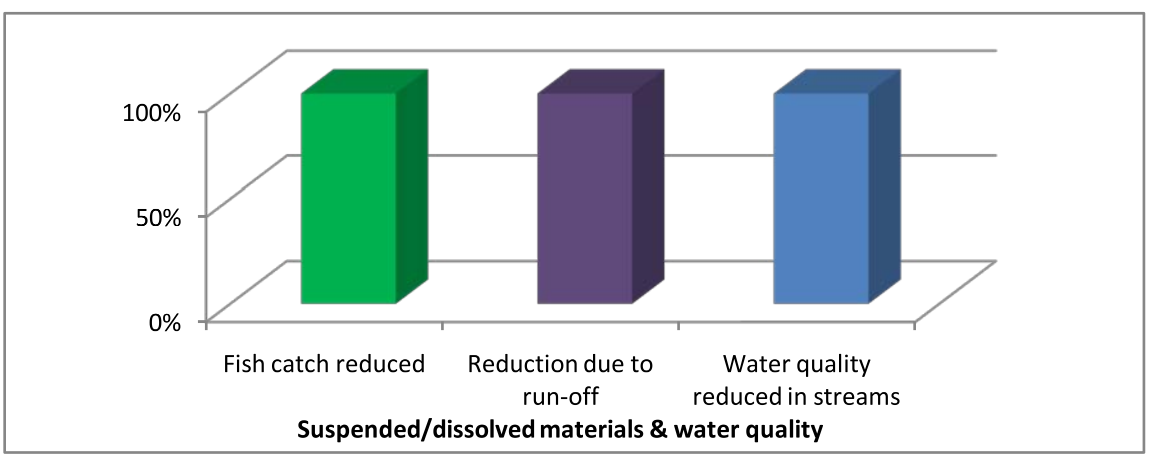


Fig 4.28; Suspended solids and water quality

Respondents have noticed the loss of water quality in the streams/rivers and the subsequent loss of aquatic life. Hundred percent ascertained the reduction in fish harvest in the past 6-7 years. All the respondents support the claim that the quality of water from the bodies has reduced in terms of domestic uses. Poor quality of water in the streams as a result of solids and minerals from the quarries has destroyed aquatic life. Fish harvest has, therefore, declined to the barest minimum.

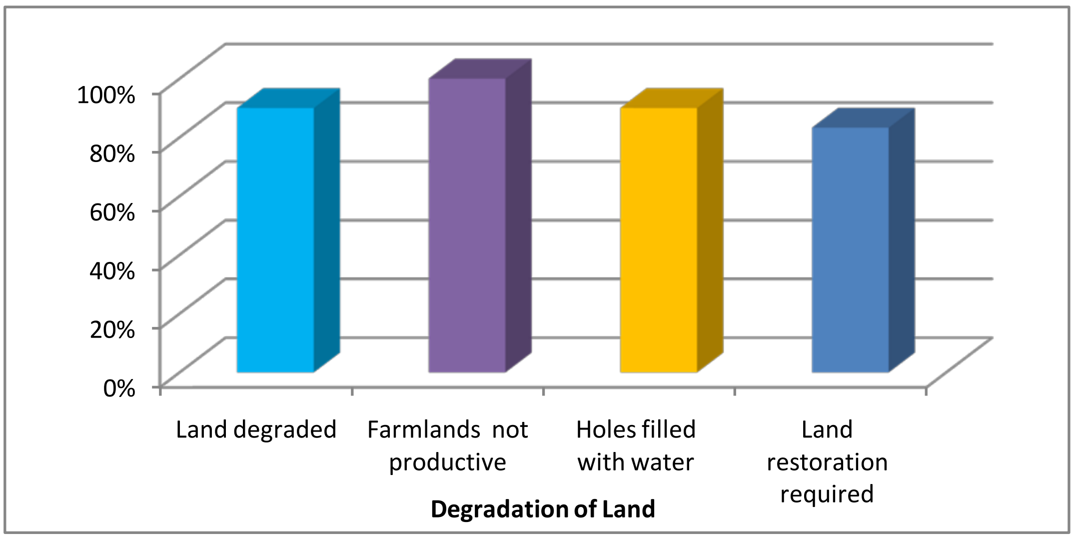


Fig. 4.29 Degradation of land by quarrying

Quarrying has a devastating effect on land. From Fig 4.29, it could be realized that 90% of the respondents have observed that land around the quarries have been degraded, 100% said that farmlands close to the quarries do not support proper plant (crop) growth, 90% agreed that cavities in and around the quarries are filled with water and 83.3% of the respondents requested for immediate programmes to restore degraded farmlands.

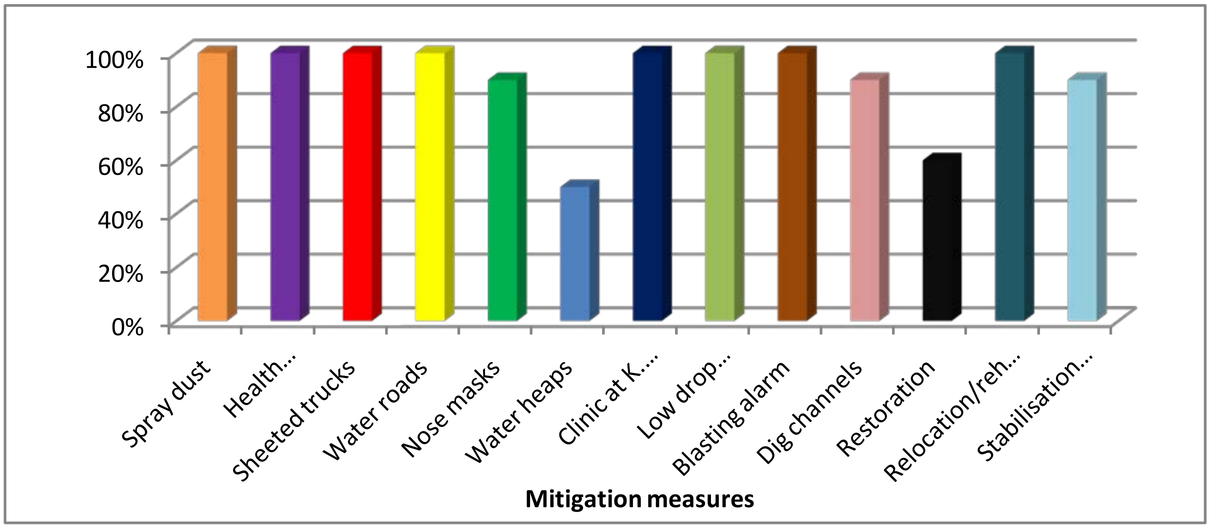


Fig. 4.30 Mitigation measures

As can be in Fig 4.30, all the respondents agreed that dust generated at all the processing points such as crushing and screening must be sprayed with water, health screening exercises should also be organized, haul trucks should be sheeted, dusty haul roads must be watered during dry and sunny days, a clinic must be built at Klo-Begoro because of the primary school there, quarry products should be dropped at low heights with the help of sleeves, alarm must be given prior to blasting and communities must either be relocated or rehabilitated. Ninety percent (90%) of respondents each agreed to the use of nose marks during blasting, construction of channels to drain water from pits and run-off and the creation of a stabilization pond to store water from the quarries. Sixty percent (60%) asserted that land restoration must be executed and 50% responded to the use of water to moisten surfaces of stockpiles, blasting surfaces, etc. The indication here is that these measures require immediate implementation to bring relief to the indigenes.

4.4 DETERMINATION OF PM_{10} CONCENTRATION

PM_{10} was sampled for a period of 24 hours using Mini Volume Portable Air Samplers to pump an average of 5 litres of air per minute. Sampling was determined from January to October to assess the concentration of PM10 for both the dry and rainy seasons. Oterkpolu which is not in the study area was used as a control town.

Table 2: Gravimetric concentration of PM10 in January, 2011

PARAMETER	COMMUNITIES			
	N_1	N_2	N_3	N_4
Initial Weight (W_1)	10.1989	10.2426	10.1990	10.2100
Final Weight (W_2)	10.1997	10.2434	10.1998	10.2104
Weight of PM10 picked up	0.0009	0.0008	0.0008	0.0004
Average flow rate (FR)	5.0000	4.7899	5.0842	5.2121
Pressure (mmHg)	726	726	726	726
Temperature (^{O}C)	32	32	32	32
Sampling duration (T)	24 hours (1440 mins)	24 hours (1440 mins)	24 hours (1440 mins)	24 hours (1440 mins)
PM_{10} (µg/m^3)	125.0	116.2	109.3	50.5

From Table 2, 125.0µg/m^3 was recorded at Bueryonye (N_1), 116.0µg/m^3 at Odugblase (N_2) and 109.3 µg/m^3 was recorded at Klo-Begoro (N_3). Oterkpolu (N_4) which is being used as a control community had 50.5µg/m_3. Fig 4.31 shows the graphical representation of the PM_{10} concentrations for the sites. The highest concentration was registered at Bueryonye. The second and third highest concentrations were recorded at Odugblase and Klo-Begoro, respectively, whilst the least level was observed at Oterkpolu. The concentration of PM_{10} for January in the study area is far above EPA's standard of 70µg/m^3 for ambient air for a residential environment but very low at the control site. Low atmospheric pressure, sunny and dry weather conditions were the major meteorological parameters for the high dust concentration and also the closeness of the communities to the quarries. Atmospheric pressure was 726mmHg whilst the temperature was 32^{o}C.

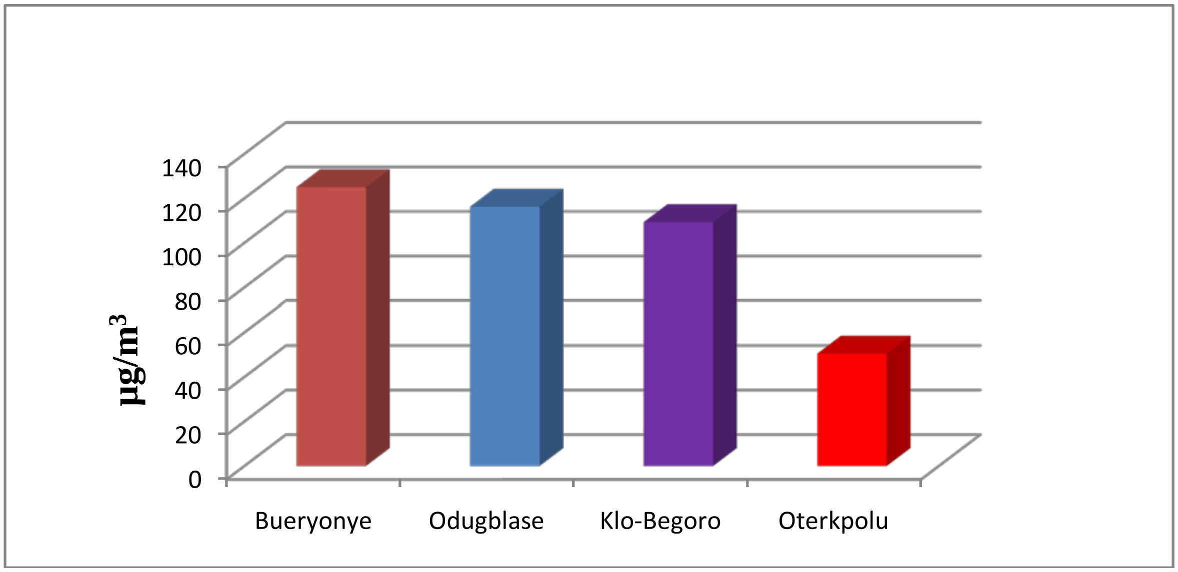


Fig. 4.31: Graphical representation of gravimetric concentration of PM_{10} in January, 2011

Table 3: Gravimetric concentration of PM10 in April, 2011

PARAMETERS	COMMUNITIES			
	N_1	N_2	N_3	N4
Initial Weight (W_1)	10.2404	10.1787	10.2307	10.2345
Final Weight (W_2)	10.2410	10.1795	10.2312	10.2348
Wgt of PM_{10} picked up	0.0006	0.0008	0.0005	0.0003
Average flow rate (FR)	5.0144	4.9135	4.6666	4.9122
Pressure (mmHg)	735	735	735	735
Temperature (^{O}C)	30	30	30	30
Sampling duration (T)	24 hrs (144 mins)	24hrs\ (1440 mins)	24 hrs (1440 mins)	24 hrs (1440 mins)
PM_{1O} (µg/m^3)	83.1	113.1	74.4	43.3

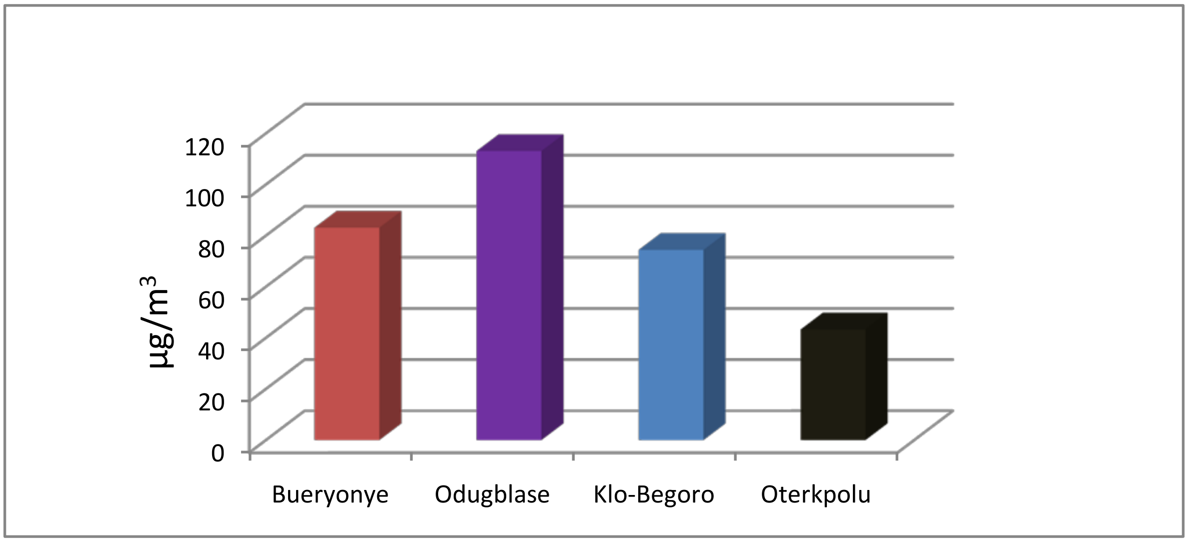


Fig 4.32: Graphical representation of Gravimetric concentration of PM_{10} in April, 2011

As can be seen in Table 3, Bueryonye (N_1) recorded 83.3µg/m^3, Odugblase (N_2) had a concentration of 113.1µg/m^3, Klo-Begoro recorded 74.4 µg/m^3 and the control town, Oterkpolu, had 43.3µg/m^3. The graphical representation of gravimetric concentration of PM_{10} shown in Fig. 4.32 indicates that Odugblase has the highest concentration and Oterkpolu the least. Odugblase had the highest PM_{10} concentration, followed by Bueryonye, Klo-Begoro and then Oterkpolu. All the concentrations are above EPA guidelines for ambient air except Oterkpolu which is far away from the quarries. Meteorological factors may have contributed to the high concentration of dust in April. Average temperature for the study area was 30^{o}C and atmospheric pressure was about 735mmHg. All the sites were characterized by sunny weather and quite a moderate humidity during the day.

Table 4: Gravimetric concentration of PM10 in June, 2011

PARAMETERS	COMMUNITIES			
	N_1	N_2	N_3	N_4
Initial Weight (W_1)	10.1787	10.1988	10.1849	10.1784
Final Weight (W_2)	10.1792	10.1994	10.1853	10.1786
Wgt of PM_{10} picked up	0.0005	0..0006	0.0004	0.0002
Average flow rate (FR)	5.0000	4.0135	5.0842	4.7889
Pressure (mmHg)	735	735	735	735
Temperature (^{O}C)	26	26	26	26
Sampling duration (T)	24hrs (1440mins)	24hrs (1440mins)	24hrs (1440mins)	24hrs (1440 mins)
PM_{10} (µ g/m3)	69.4	103.8	54.6	29.0

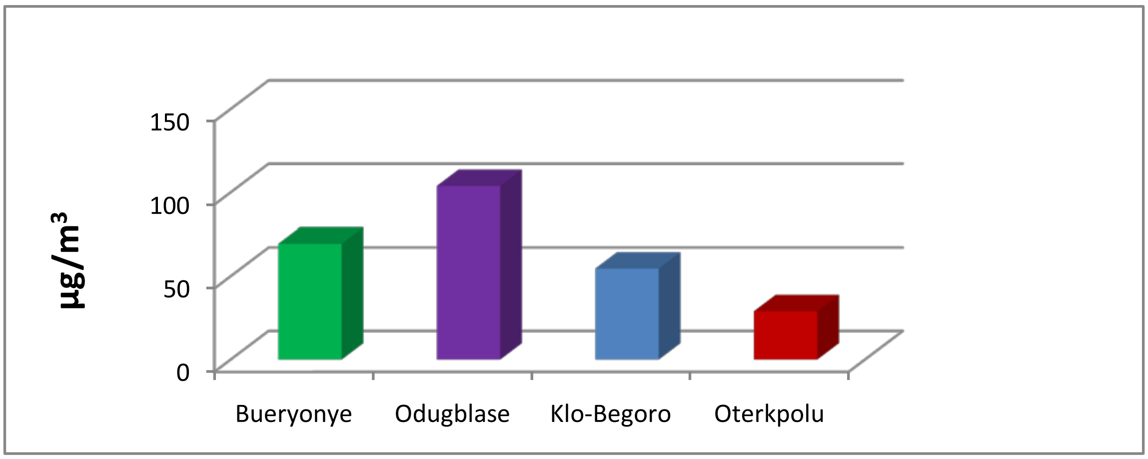


Fig 4.33: Graphical representation of Gravimetric concentration of PM_{10} for June, 2011

In Table 4, N_I had 69.4µgm^3, N_2 recorded 103.8µg/m^3 and N_3 had 54.6µg/m^3, N_1 recorded a concentration close to the 70 µg/m^3 standard set by EPA whilst N_2 had a figure above the standard mark. It was at N_1 and N_3 that the figures recorded fell below the standard concentration. At Oterkpolu (N_4) a very low value of 29.0µg/m^3 was recorded. The different concentrations are represented graphically in Fig. 4.33. Odugblase recorded the highest concentration where as Oterkpolu had the least concentration. The low level of PM_{10}

concentration at Oterkpolu could be attributed to its distance from the quarries and perhaps wind direction. This assertion is supported by literature and responses obtained from questionnaire. Meteorological parameters include sunny and rainy weather, high humidity, and average temperature of about 26°C and atmospheric pressure of 735mmHg. The reduction in the PM_{10} concentration in June was mainly due to the washout of particulate matter from the atmosphere by rain. The high particulate matter concentration at Odugblase may be attributed to wind direction, its central position and its closeness to the major quarry, GHACEM.

Table 5: Gravimetric concentration of PM10 in August, 2011

PARAMETERS	**COMMUNITIES**			
	N_1	**N_2**	**N_3**	**N_4**
Initial Weight (W_1)	10.3412	10.2206	10.2482	10.2344
Final Weight (W_2)	10.3417	10.2213	10.2487	10.2346
Wgt of PM10 picked up	0.0005	0.0007	0.0005	0.0002
Average flow rate (FR)	4.7484	4.8981	4.8866	4.99122
Pressure (mmHg)	736	736	736	736
Temperature (^{O}C)	31	31	31	31
Sampling duration (T)	24hrs (1440 mins)	24 hrs (1440 mins)	24hrs (1440 mins)	24hrs (1440 mins)
PM_{10} ($\mu g/m^3$)	73.1	85.1	71.1	35.8

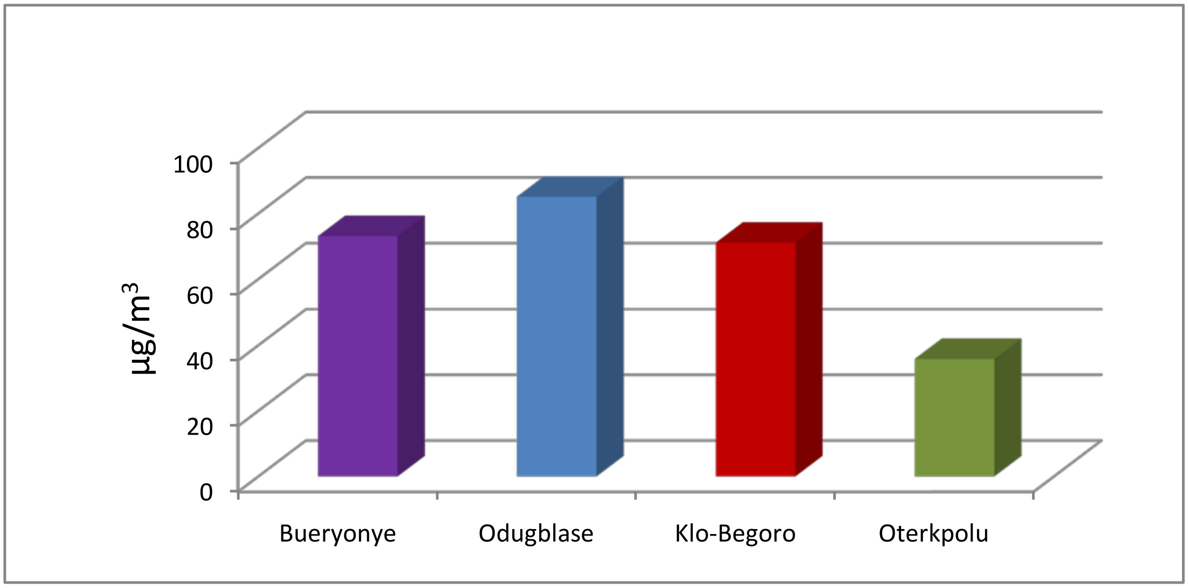


Fig 4.34: Graphical representation of gravimetric concentration of PM_{10} in August, 2011

In Table 5, it should be noticed that Bueryonye (N_1) recorded 73.1µg/m^3, Odugblase (N_2) had 85.1µg/m^3, Klo-Begoro (N_3) had 71.1µg/m^3 and Oterkpolu (N_4) recorded 35.8µg/m^3. Fig 4.35 shows the graphical representation of dust concentration at the four sampling sites. Odugblase had the highest concentration whilst Oterkpolu had the lowest concentration. The concentrations of PM_{10} in the study area are above EPA standards but are not very high because the weather was rainy and partly sunny. August is generally a month of coldness and rain showers which may remove most of the particulate matter form the atmosphere. Pressure and temperature for the period are 736 mmHg and 31^{O}C, respectively.

Table 6: Gravimetric concentration of PM10 in October, 2011

PARAMETERS	COMMUNITIES			
	N_1	N_2	N_3	N_4
Initial Weight (W_1)	10.1887	10.1988	10.1849	10.1859
Final Weight (W_2)	10.1892	10.1992	10.1854	10.1862
Wgt of PM_{10} picked up	0.0005	0.0006	0.0005	0.0003
Average flow rate (FR)	4.6607	5.1123	4.9112	5.1980
Pressure (mmHg)	736	736	736	736
Temperaqture (^{O}C)	25	25	25	25
Sampling duration (T)	24 hrs (1440 mins)	24hrs (1440 mins)	24hrs (1440 mins)	24hrs (1440 mins
PM10 (µg/m^3)	74.5	81.5	70.7	40.1

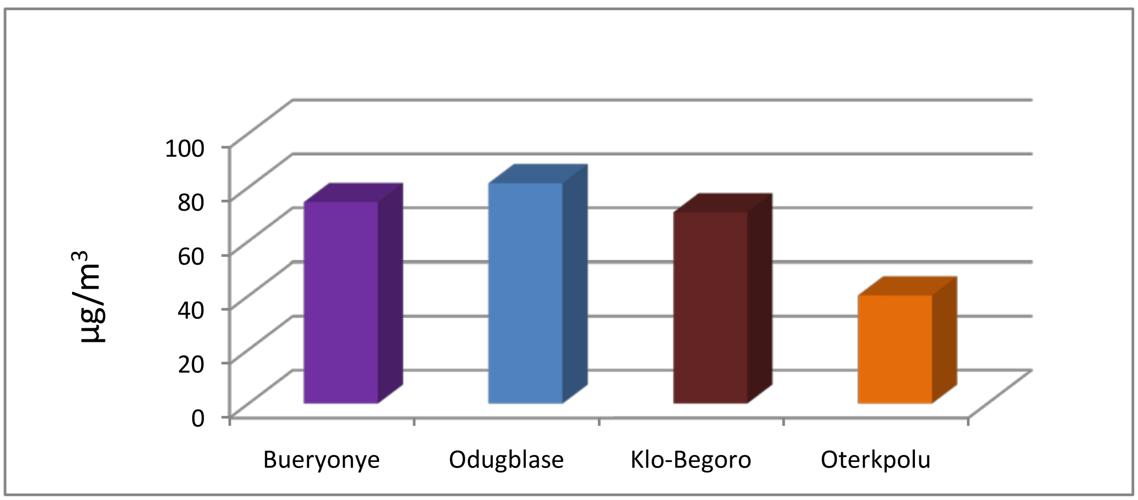


Fig. 4.35 Graphical representation of Gravimetric concentration of PM_{10} in October

In Table 6 above, 74.5µg/m^3 was recorded at Bueryonye, 81.1µg/m^3, 70.7µg/m^3 and 40.1µg/m^3 were also recorded at Odugblase, Klo-Begoro and Oterkpolu, respectively. The different gravimetric concentrations of PM_{10} are graphically represented in Fig. 4.35. In Fig 4.35, Odugblase recorded the highest concentration of dust, followed by Bueryonye, Klo-Begoro and

Oterkpolu in the descending order. Bueryonye and Odugblase, therefore, had concentrations above EPA's guidelines for ambient air. The sunny and slightly rainy weather, average temperature of 25°C and atmospheric pressure of 736mmHg may have contributed to the moderate PM_{10} concentrations. The concentrations are still quite hazardous to human health.

Table 7: Comparative Results of Gravimetric concentration of PM_{10} from January to October, 2011

	PM10 Concentration (μg/m³)			
DATE	**N_I**	**N_2**	**N_3**	**N_4**
18/01/2011	125.0	116.2	109.3	50.5
26/042011	83.1	113.1	74.4	43..3
22/06/2011	69.4	103.8	54.6	29.0
31/08/2011	73.1	85.1	71.1	35.8
6/10/2011	74.5	81.5	70.7	40.1
EPA's 24hr. guideline *for* PM_{10} = 70μg/m³				

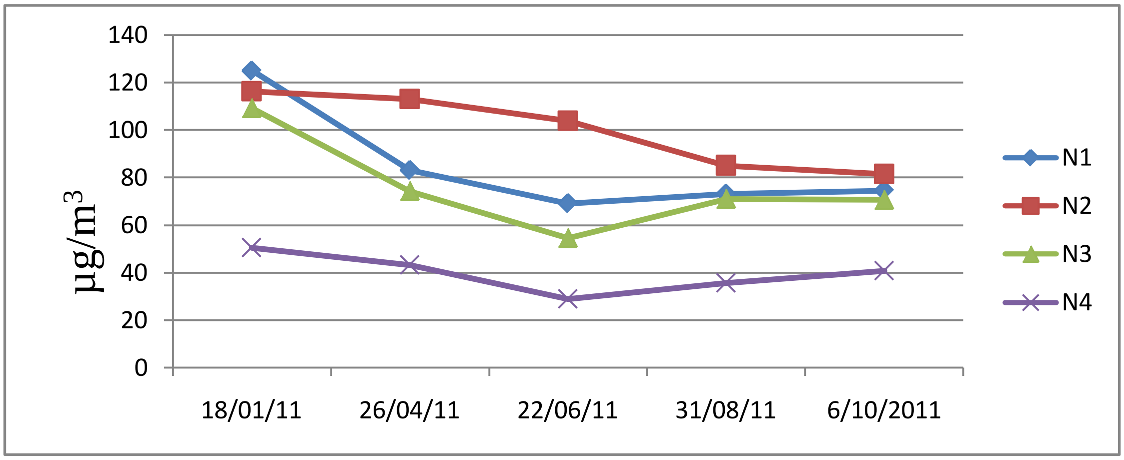


Fig 4.36: Graphical representation of comparative results of PM_{10} concentration from January to October, 2011

In Table 7, N_1 recorded 125.0µg/m_3 as the highest concentration and 69.4µg/m^3 as the lowest, N_2 had 116.2 µg/m^3 as the highest and 67.5µg/m^3 as the lowest and N_3 recorded 109.3µg/m^3 as the highest and 54.6µg/m^3 as the lowest. The highest concentration of 125.0µg/m^3 was recorded in January whilst the lowest value of 54.6µg/m^3 was recorded in June. Oterkpolu had 54.5 µg/m^3 as the highest in January and 29.0µg/m^3 as the lowest in June. In Fig. 4.36, higher levels of the curves are in January and decline to low levels in June. The concentrations then moved gradually upwards as the dry season is approached. The high concentration of dust in the dry season may be facilitated by additional dust from the Saharan desert during harmatan. Pre-quarry dust concentrations may not be different from those recorded at Oterkpolu since the values will reflect the normal dust levels in ambient air. The concentration of dust at Oterkpolu during the dry season is still higher due to the high concentration of dust during harmatan weathers.

The level of concentration of dust in air is highest during the dry season and lowest during the rainy season or weather. It is therefore prudent to say that the effects of dust are severer during the dry season than the wet or rainy seasons. Also, communities close to quarries are impacted with a greater intensity than those far away. This is clearly indicated in concentrations recorded at Oterkpolu which are below the permissible limit. Thus, suppression of dust must be effectively monitored during the dry season.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Limestone quarrying has brought about both benefits and costs to the Lower Manya Krobo District. The study has revealed that the communities have gained some benefits from quarrying. Some of the men in the area have been employed as quarry workers to reduce the unemployment canker among the people. Also, the surface of the road from Bueryonye to Klo-Begoro has been compacted with screenings by GHACEM quarry to allow easy movement of both haul and commercial vehicles and help reduce fugitive dust emission. The Lower Manya Krobo District Assembly agreed that tolls are collected from trucks that purchase aggregates to enhance their revenue generation.

The devastating effects of limestone extraction by the quarrying companies include creation of labour bottlenecks for peasant agriculture as agricultural lands have been encroached upon, destruction of buildings due to cracks, pollution of rivers, loss of biodiversity, destruction of crops and unclean rain water harvested from roofs. Inhalation of dust resulting in respiratory tract infections and habitat destruction also add to the list of the negative effects of limestone quarrying in the Lower Manya Krobo District.

With reference to Ghana EPA standard for $PM_{10,}$ the communities in the study area recorded daily concentrations that exceed the daily minimum level of 70µg/m^3 over a time-weighted average per 24 hours. Out of the fifteen PM_{10} concentration determined in the study area, 86.7%

were above the 70µg/m^3 set by EPA, Ghana. Dust related infections have doubled according to data recorded from questionnaires. Air pollution due to quarry dust is very high during the dry season as PM_{10} concentration was highest in January.

Data gathered from health facilities, PM_{10} sampling, observation and questionnaire administration really suggest that favourable conditions for infections due to dust emission, floods might be responsible for the persistence of diseases in the communities. This assertion is so because people in the study area in the Lower Manya Krobo District live at the risk of the diverse infections in performing their daily activities which include farming, quarrying, trading and performing of domestic chores. Health data has also supported the deadly effects of quarrying activities on the people in the three communities. There has been a sharp rise in dust and water related or borne diseases from 2005 when limestone mining started in the area. Malaria is the most contracted water related disease. Cough, catarrh, headache, asthma and frequent issue of phlegm are the major dust related ailments suffered by the people.

Quarrying companies appear not to comply with policy guidelines that promote good and safe environment. Mitigation of quarrying impacts requires that extraction companies should be monitored to enforce compliance with policy guidelines. Monitoring or regulatory bodies include Government agencies such as EPA, local communities and non-governmental organizations or pressure groups. Regulatory bodies should be well equipped to monitor compliance with laid down guidelines. Monitoring must concentrate on enforcement of relevant regulations and laws, protection and preservation of the environment (air, water and land resources), and improvement of health and safety for workers and communities. Monitoring is likely to minimize the impacts of quarrying on the environment.

5.2 RECOMMENDATIONS

The recommendations provided below will facilitate a gradual eradication or minimization of infections related to quarrying at Bueryonye, Odugblase and Klo-Begoro in the Lower Manya Krobo District. These are as follows:

- Quarrying companies and perhaps the Government should, as a matter of urgency, organize health screening exercises at least once or twice a year in the communities. This is because the concentrations of PM_{10} throughout the year are high enough to promote significant health effects such respiratory tract infection. A clinic could be built at Klo-Begoro which houses the only primary school in the area as a corporate social responsibility to provide better health care.

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

- Haul trucks from KAMSAD quarry should not be allowed to use the unpaved road which passes through the three communities. These trucks generate a lot of fugitive dust which disturb the inhabitants. KAMSAD should be urged to construct a road to link up with that of GHACEM to reduce impact of fugitive dust on the people.

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

- The drainage system in and around the quarries must be improved to reduce flooding of farmlands. Thus, a major channel should be dug through the lowland area of the potentially flooded farmlands so that farmers can cultivate crops even in the wet season. Also, a bridge should be constructed on the Klo-Begoro – Kamsad quarry road near Klo-Begoro to drain flood water.

- The potential effects of blasting must be declined by the companies. The use of alarm to alert inhabitants of blasting should be re-visited. It is a requirement by EPA guidelines that notice must be given to communities living close to the quarries prior to blasting. Blasting vibration is not only causing damage to buildings but also impacting negatively on other life activities. As the whole building vibrates objects from the roofing as well as particles from wall surfaces break away and fall off. Some of these particles are likely to fall into the food being taken during

- The three communities should either be relocated or rehabilitated. Dust concentration most of the time far exceeds the permissible limit and the vibrations from blasting have resulted in several cracks in several buildings. The inhabitants should be sent to different location or mining companies must supply the people with building materials for rehabilitation of their buildings. This recommendation is based on responses gathered from questionnaire and observation.

- The use of heavy machinery, such as graders, front-end loaders, and heavy trucks contributes to the rapid deterioration of roads. The Asesewa - Odumase portion of the road used by these heavy trucks has deteriorated and requires regular maintenance. The mining companies must collaborate with the District Assembly to rehabilitate regularly destroyed portions of the road. This will prolong the life span of smaller vehicles plying this segment of the road.

AREAS FOR FURTHER RESEARCH

Areas for further research include:

- assessment of the relationship between wind direction and dust impact.
- determination of levels of vibrations from blasting in terms of the quantity of explosives used.

REFERENCES

Airmetrics (2007). MiniVol Portable Air Sampler Operation Manual. 2095 Garden Ave. Suite 102 Eugene, OR 97403 U.S.A.

Akabzaa,z M. T. (2000). Boom and Dislocation - The environmental and social impacts of mining in the Wassa West District of Ghana. Third World Network. (TWN-Africa)

Banez, J., Ajon, S. M., et al (2010). Report on Quarrying and its environmental effects. U.N. Journal, Vol 10.

Bunnell, J.E., Finkelman, R.B., Centeno, J.A. and Selinus, O.(2007). Medical Geology. Geologica Acta, Vol .5, Nº 3, 273-281 www.geol*ogica-acta.com*

Baird, C. (1997). Environmental Chemistry

Cunningham, W.P. and Saigo, B. (1992). Environmental Science: A Global Concern.

Dept. of Labour (1980). Safety Guide for handling of loose materials. New Zealand (www.osh.dol.nz)

Dept of the Environment, Heritage and Local Govt. (April 2004). Quarries and Ancillary Activities: Draft Planning Guidelines Ireland p 17.

Edwards, A. T., Northwood, T. D. (1960). Experimental studies of the effects of blasting on structures. NRC Publication Archive.

Ewer, D.W., Hall, J.B., Lock, J.M. and Owen, J. (1978). Ecological Biology for A-level and Intermediate Students in Africa. Longman Group Ltd, 496.

Gad, E.F., Wilson, J.T., Moore, A.J., Richards, A.B. (2005). Effects of Mine Blasting and Residential Structures. Journal of Performance of constructed facilities

Gale, A, N. and Groat, C. G. (2001). Potential Environmental Impacts of Quarrying stone in Karst,. US Geoloogical Survey (http://pubs.usgs.gov/of/2001/ofr-01-0484/ofr-01).

Ghana Association of Science Teachers (1989). Integrated Science for Senior Secondary Schools. Macmillan Publishers Ltd and Unimax Publishers.

Ghana Environmental Protection Agency (2004). State of the environment (SOE).

Ghana Statistical Service (2000). Population and Housing Census (PHC).

Ghanaian Chronicles (2009). Good management of quarries. 29th May edition p7.

Health and Safety Guidelines (2008). Guidelines for the control of dust and associated hazards in surface mines and quarries. Australia, p3

Holgate, S,T.,Samet, J.M., Koren, H.S., M`aynard,R.L. (1999). Air Pollution and Health. Academic Press, New York

http://www.answers.com/topic/mining.

http://www.goodquarry.com/article.aspx?id=22&navid=2

http://www.goodquarry.com/article.aspx?id=24&navid=4 Ecology and Biodiversity: Good Quarry. Retrieved March 21, 2010)

http://www.hm-treasury-gov.ule/home.htm).

Kesler, S.E. (1994). Mineral Resources, Economics and the Environment. McMillan Publishers, New York.

Landscape and Urban Planning [Landscape Urban Plann.] (12th May 2008). Vol. 86, No.1, 92-102.

Mate, K. (1992). Environmental Impacts of mining in Ghana (Issues and answers). U.N. Journal on Natural Resources Forum, Vol 16 No. 1

Ministry of Health and Safety Council Guidelines (2008). Guidelines for the control of dust and associated harzards in surface mines and quarries, Australia p 3

Montgomery, C. W. (1992). Environmental Geology. Wm C. Brown Publishers, 3rd Ed.

Mouflis, G. D., Gitas, Z., Iliadou, S.; Mitri, G. H. (1984-2000). Assessment of the visual impact of marble quarry expansion on the landscape of Thasos Island, NE Greece.

National Academies Press, Washington, D.C. p44. http://www.nap.edu/catalog/11809.html

National Academy of Sciences (1980). Surface mining of non-coal minerals - Appendix I, Washington, D.C., 91.

National Research Council and Institute of Medicine (2007). Earth materials and health.

Northwood , T.D., Crawford, R. and Edwards, A.T. (1963). Blasting Vibrations and Building Damage. Research Paper No. 186 973-978

nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an...

Tanyaradzwa, C. (2010). An Assessment of the benefits and costs of Black Granite quarrying in Mutoko District, Zimbabwe: A socio-cultural Biophysical and economic Approach Journal of Sustainable Development in Africa (Volume 12, No.3)

Thomas L. J. (1979) An Introduction to Mining (revised edition), Robert Burton Printers Pty, Sydney p94

21st Century Universal Encyclopedia (1996). Quarry and Quarrying. Regency Publishing Group, Australia, 8th Ed. p. 30).

.

World Health Organisation (1997). The use of the Environment for Sustainable Development. U.N. Journal Vol 16

APPENDICES

APPENDIX A: Health Data

(i) Atua Government Hospital Out-Patient Morbidity Returns (Dust related)

YEAR	DISEASE					
	Asthma	Cough	Pneumonia	Other ATI	Eye infection	Ear infection
2003	-	-	-	-	-	-
2004	12	87	129	662	1460	321
2005	39	140	310	1520	1319	120
2006	74	150	162	2098	1493	316
2007	106	106	129	3857	1321	535
2008	133	120	157	3896	1989	578
2009	140	118	98	6248	1137	547
2010	196	153	103	6127	1230	649

(ii) Atua Government Hospital Out-Patient Morbidity Returns (Water related/borne)

YEAR	DISEASE			
	Malaria	Typhoid	Diarrhoea	Schistosomiasis
2003	-	-	-	-
2004	4417	22	1464	1
2005	6561	120	1258	5
2006	9066	105	1552	6
2007	16620	92	1779	10
2008	13103	69	1651	11
2009	18299	229	2248	12
2010	16633	223	1539	10

(iii) **Oborpa Clinic Out-Patient Morbidity Returns (Dust related)**

YEAR	DISEASE							
	Pneumonia	Cough	Common cold	Other ATI	Asthma	Chest pains	Headache	Ear infection	Eye infec.
2003	16	12	1	3	0	3	2	0	2
2004	15	7	2	45	1	1	3	1	3
2005	19	20	6	60	2	8	1	0	1
2006	23	17	5	65	1	10	1	1	3
2007	34	27	7	60	0	14	2	2	7
2008	38	22	6	91	1	22	1	2	28
2009	29	21	8	104	0	16	3	7	15
1010	19	29	9	102	2	19	3	8	10

(iv) Oborpa Clinic Out-Patient Morbidity Returns (Water related)

YEAR	DISEASE				
	Malaria	Diarrhoea	Dysentery	Schistosomiasis	Cholera
2003	355	10	1	0	1
2004	275	6	0	0	0
2005	301	11	0	2	0
2006	343	19	1	1	0
2007	571	20	0	1	1
2008	712	36	0	0	0
2009	1022	66	2	0	0
2010	1275	48	0	0	0

(v) Obenyemi Clinic Out-Patient Morbidity Returns (Dust related)

YEAR	DISEASE							
	Cough	C. cold	ATI	Asthma	Pneumonia	Headache	Chest pains	Ear infec.	Eye infec.
2003	65	10	1	0	0	2	40	0	2
2004	72	15	2	0	0	4	45	0	2
2005	70	21	4	3	1	12	50	0	9
2006	90	45	10	10	4	21	66	0	6
2007	89	60	12	13	5	30	75	1	7
2008	91	75	12	10	3	37	104	0	8
2009	104	60	14	14	6	40	156	0	12
2010	280	76	16	18	8	45	260	3	11

(vi) Obenyemi Clinic Out-Patient Morbidity Returns (Water related diseases)

YEAR	DISEASE					
	Malaria	Diarrhoea	Dysentery	Schistosomiasis	Cholera	Typhoid
2003	262	31	0	0	0	0
2004	281	10	0	0	0	0
2005	306	20	1	0	0	0
2006	400	35	0	0	1	0
2007	484	42	0	0	0	0
2008	503	45	0	0	1	0
2009	511	52	0	1	0	0
2010	895	65	0	0	0	0

APPENDIX B: Responses to Questionnaire Administration

(vii) Sex of Respondents

Sex	Frequency	Percent	Cumulative Percent
Male	41	68.3	68.33
Female	19	31.7	100.0
Total	60	100.0	

(viii) Age of Respondents

	Frequency	Percent	Cumulative Percent
21-30	3	5.0	5.0
31-40	33	55.0	60.0
41-50	14	23.3	83.3
51 and above	10	16.7	100.0
Total	60	100.0	

(ix) Occupation of Respondents

Occupation	Frequency	Percent	Cumulative Percent
Farming	40	66.7	66.7
Teaching	8	13.3	80.0
Trading	6	10.0	90.0
Quarrying	4	6.7	6.7
Student	2	3.3	100
Total	60	100.0	

(x) Sources of dust

Sources of dust	Frequency	Percent	Mean	Standard deviation
Main source of dust is from the quarries	60	100	1.00	.0000
Concentration of dust in the atmosphere is highest during blasting of rocks.	60	100	1.00	.0000
Crushing, conveying, ,transportation etc generate dust	60	100	1.00	.0000
Vehicles transporting quarry products also generate much dust.	60	100	1.00	.0000
Mean scale 1.0= Strongly agree(SA), 2.0=Agree(A), 3.0=Disagree(D), 4.0=Strongly disagree(SD)				

(xi) Effects of weather conditions on dust emission

	Frequency	Percent	Mean	Standard deviation
Rainy weather reduce the amount of dust in the air	60	100	1.00	.0000
Cold and cloudy weather reduce dust movement in the air	60	100 (80=SA,20=A)	1.20	.4034
Sunny weather promote distant movement of dust to our village	60	100	1.00	.0000
Windy weather facilitates emission of dust	60	100	1.00	.0000
Dry weather promotes dust emission	60	100	1.00	.0000
Mean scale 1.0= Strongly agree(SA), 2.0=Agree(A), 3.0=Disagree(D), 4.0=Strongly disagree(SD)				

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(xii) Nuisance dust emission

	Frequency		Percent or Yes	Mean	Standard deviation
	Yes	No			
Does dust settle on your roofing sheets or clothing/	60	0	100	1.00	.0000
Are your crops coated with dust?	60	0	100	1.00	.0000
Do crops/plants fail to grow well due to the dust?	60	0	100	1.00	.0000
Mean scale 1=Yes, 2=No					

(xiii) Data on quarry run-off/flooding

Quarry Run-off	Frequency		Percent of Yes	Mean	Standard deviation
	Yes	No			
Do you have any farmland covered with water?	60	0	100	1.00	.0000
If yes, has the flood waters ever been drained?	60	0	100	1.00	.0000
Does run-off from the quarry enter the river or stream in your area?	60	0	100	1.00	.0000
Stretch of water is likely to breed mosquitoes and other disease causing organisms	60	0	100	1.00	.0000
Mean scale 1=Yes, 2=No					

(xiv) Noise pollution/Vibration effects

	Frequency		Percent of Yes	Mean	Standard deviation
	Yes	No			
The main source(s) of noise at the quarries are from Excavation machinery, blasting of rocks, processing and haulage trucks	60	0	100	1.00	.0000
Has the noise level affected your hearing?	18	42	30	1.7000	.4621
Has any of your buildings developed cracks ?	60	0	100	1.00	.0000
The main cause of cracks in buildings in the village is vibration blasts	60	0	100	1.00	.0000
Has any of the cracked buildings collapsed ?	45	15	75	1.2500	.43667
Has any member of the community died in a collapsed building?	6	54	10	1.00	.30253
Mean scale 1=Yes, 2=No					

(xv) Life span of a well maintained mud house

	Frequency	Percent	Cumulative Percent
1-10 years	0	0	0
11-20 years	0	0	0
21-30 years	1	1.7	1.7
31-40 years	9	15.0	16.7
40 years and above	50	83.3	100.0
Total	60	100.0	

(xvi) Visual Intrusion

	Frequency		Percent of Yes	Mean	Standard deviation
	Yes	No			
Do heaps of quarry wastes or stockpiles block your view?	60	0	100	1.00	.0000
Does dust prevent you from seeing things a distance away?	45	15	75	1.25	.43667
Can these heaps of quarry waste be considered an eyesore?	60	0	100	1.00	.0000
Mean scale 1=Yes, 2=No					

(xvii) Biodiversity (Plants and Animals) loss

	Frequency		Percent of Yes	Mean	Standard deviation
	Yes	No			
Excavations have destroyed many plants and animals	36	24	60	1.40	.49403
Many living things have lost their homes(habitats) due to rock removal	60	0	100	1.00	.0000
The loss of plants and animals are not permanent	18	42	30	1.7	.46212
Mean scale 1=Yes, 2=No					

(xviii) Influence of quarrying on Human health

	Frequency		Percent of Yes	Mean	Standard deviation
	Yes	No			
Dust is a nuisance to you	60	0	100	1.00	.0000
Dust affects your health	60	0	100	1.00	.0000
Water harvested from roofing spouts is usually unclean(contains dust	60	0	100	1.00	.0000
Your frequent ill health may be associated with dust or flooded farmlands or rain water from roofs.	60	0	100	1.00	.0000
Mean scale 1=Yes, 2=No					

(xix) Health status before quarrying started

	Frequency	Percent	Mean	Standard deviation
Excellent	45	75	1.2500	.43667
Very good	15	25		
Good	0	0.00		
Fair	0	0.00		
Poor	0	0.00		
Mean scale 1=Excellent, 2=Very good, 3=Good, 4= Fair, 5=Poor				

(xx) Present Health status

	Frequency	Percent	Mean	Standard deviation
Excellent	6	10	4.1000	1.18893
Very good	0	0.00		
Good	3	5.0		
Fair	24	40		
Poor	27	45		
Mean scale 1=Excellent, 2=Very good, 3=Good, 4= Fair, 5=Poor				

(xxi) Comparative health status before and during quarrying

	Before (%)	During (%)
Excellent	75	10
Very good	25	0
Good	0	5
Fair	0	40
Poor	0	45

(xxii) **Data on dust related diseases suffered from before and during quarrying**

Disease	Freq. (Before)	Percent	Freq. (During)	Percent
Cough	20	33.3	60	100
Sneezing	3	5	6	10
Catarrh	15	25	45	75
Sore throat	6	10	15	25
Asthma	18	30	39	65
Short breadth	3	5	6	10
Pneumonia	6	10	9	15
Heart problem	3	5	9	15
Headache	24	40	57	95
Eye problems	18	30	30	50
Frequent bringing out of phlegm	15	25	45	75
Wheezing or whistling of chest	6	10	12	20

(xxiii) Water related or waterborne disease suffered before and during quarrying

	Freq.(Before)	Percent	Freq.(During)	Percent
Malaria	24	40.0	3	5
Diarrhoea	3	5.0	0	0
Malaria and Diarrhoea	12	20.0	10	16.7
Malaria and cholera	21	35.0	15	33.3
Malaria,,typhoid,diarrh.	0	0	20	25
Malaria, cholera, diarrh.	0	0	12	20
Total	60	100.0	60	100

(xxiv) Fear about your health as a result of quarrying activities

	Frequency	Percent	Mean	Standard deviation
All of the time	18	30.0	1.7000	.46212
Most of the time	42	70.0		
Some of the time	0	0.00		
A little of the time	0	0.00		
None of the time	0	0.00		
Mean scale 1=All the time, 2=Most of the time, 3=Some of the time, 4= A little of the time, 5=None of the time				

(xxv) Data on Hospital/clinics visited

	Frequency	Percent	Valid Percent	Cumulative Percent
Antua hospital	6	10.0	10.0	10.0
Agomenya Roman hospital	2	3.3	3.3	13.3
Obenyemi clinic	5	8.3	8.3	21.6
Oborpa Clinic	7	11.7	11.7	33.3
Bukunor clinic	1	1.7	1.7	35.0
Koforidua gov't hospital	1	1.7	1.7	36.7
Antua hospital and Bukunor clinic	2	3.3	3.3	40.0
Antua hospital, Oborpa Clinic and Bukunor clinic	8	13.3	13.3	53.3
Obenyemi clinic, Oborpa Clinic and Koforidua gov't hospital	6	10.0	10.0	63.3
Obenyemi clinic, Oborpa Clinic and Bukunor clinic	10	16.7	16.7	80.0
Obenyemi clinic and Koforidua gov't hospital	2	3.3	3.3	83.3
Oborpa Clinic and Antua gov't hospital	5	8.3	8.3	91.7
Antua hospital ,Oborpa Clinic and Obenyemi clinic	5	8.3	8.3	100.0
Total	60	100.0	100.0	

(xxvi) **Data on Health programmes**

	Frequency	Percent	Cumulative Percent
Vaccination	3	5.0	5.0
Postnatal care	6	10.0	15.0
Vaccination and postnatal care	12	20.0	35.0
Postnatal and health talk	30	50.0	85.0
Vaccination, postnatal care and health talk	9	15.0	100.0
Total	60	100.0	

(xxvii) Data on the Influence of quarrying on Fauna and Flora

	Frequency	Percent
Coating of crop reduces yield	60	100
Coating of crops reduces value of products	60	100
Some valuable plants and animals have been lost	60	100

(xxviii) Data on Suspended/dissolved solids and water quality

	Frequency	Percent
Has fish catch from the stream/ river reduced within the past 5 years?	60	100
Could the reduction in fish catch be due to the run-offs into the river?	60	100
Has the quality of the water become poor in terms of domestic uses?	60	100

(xxix) Data on degradation of land

	Frequency	Percent
Land in and around quarries degraded	54	90
Farmlands close to quarries are not very productive	60	100
Cavities(holes) at quarries are filled with water	54	90
Land restoration must start immediately	50	83.3

(xxx) Data on mitigation measures

	Frequency	Percent	Mean	Standard deviation
Dust must be sprayed with water during processing to reduce its levels in air.	60	100	1.00	0.0000
Health screening should be organized every 1 or 2 years.	60	100	1.00	0.0000
Haulage trucks must be covered with sheets.	60	100	1.00	0.0000
Dusty haul roads must be watered regularly using water tankers	60	100	1.00	0.0000
Nose masks must be worn especially when rocks are blasted	60	100 (SA=90,A=10)	1.10	0.3025
Exposed surfaces(stockpiles) must be watered regularly	60	100 (SA=50,A=50)	1.50	0.5042
A clinic must be sited at Klo- Begoro.	60	100	1.00	0.0000
Reduce drop heights from conveyor belts using sleeves	60	100	1.00	0.0000
Alarm should be given before blasting	60	100	1.00	0.0000
Channels must be provided to drain quarry run-offs	60	100 (SA=90,A=10)	1.10	0.3025
Quarry waste must be used to restore degraded land.	60	100 (SA=60, A=40)	1.4	0.4940
Communities must either be relocated or buildings rehabilitated	60	100	1.00	0.0000
Creating a stabilization pond/reservoir to store water from pit/run-off	60	100 (SA=90, A=10)	1.1	0.3025

APPENDIX C : Sample Questionnaire

QUESTIONNAIRE ON ASSESSMENT OF THE EFFECTS OF QUARRYING ACTIVITIES ON SOME SELECTED COMMUNITIES

SECTION A: BACKGROUND INFORMATION

Please fill in the following or tick as applicable

1. Date……............/............./. 2011...............................
2. Village/Town………………………………..
3. Sex: ▢ Female ▢ Male
4. Age.. ▢ 21-30 ▢ 31-40 ▢ 41- 50 ▢ 51 and above
5. Occupation: ▢ Farming ▢ Trading ▢ Quarrying ▢ Teaching ▢ other
   Specify other……………………………………………………………………….

SECTION B: QUARRYING ACTIVITIES (IMPLICATIONS)

I. AIR POLLUTION

How do you agree on the following statements?

{ Strongly agree(**SA**), Agree(**A**), Disagree(**D**), Strongly disagree (**SD**)}

	SA	A	D	SD
6. The main source of dust in your village is quarrying by GHACEM, Kamsad and Love Construction Ltd.	▢	▢	▢	▢
7. Concentration of dust in the atmosphere is highest during blasting of rocks.	▢	▢	▢	▢
8. Crushing, conveying, sieving, and haulage of gravel produce a lot of dust.	▢	▢	▢	▢
9. Vehicles transporting quarry products on the unsurfaced roads	▢	▢	▢	▢

also generate much dust.

10. Rainy and Cold weather reduce the amount of dust in the air. ▢ ▢ ▢ ▢
11. Cold and cloudy weather reduce dust movement in the air. ▢ ▢ ▢ ▢
12. Sunny weather promotes distant movement of dust. ▢ ▢ ▢ ▢
13. Windy weather facilitates emission of dust. ▢ ▢ ▢ ▢
14. Dry weather promotes dust emission. ▢ ▢ ▢ ▢

II. NUISANCE DUST EMISSIONS (Tick as applicable)

15. Does dust settle on your roofing sheets or clothing? ▢ Yes ▢ No
16. Are the leaves of your crops or plants in the area covered with dust? ▢ Yes ▢ No
17. Do crops (plants) grow well when dust coats leaves? ▢ Yes ▢ No

III. QUARRY RUN-OFFAND FLOODING (Tick as applicable)

18. Do you have any farmland covered with water? ▢ Yes ▢ No
19. If yes, have the flood waters ever been drained? ▢ Yes ▢ No
20. Does run-off from the quarry enter the river or stream in your area? ▢ Yes ▢ No
21. Stretch of water is likely to breed mosquitoes and other disease causing organisms. ▢ Yes ▢ No

IV. NOISE POLLUTION / VIBRATION EFFECTS

22. The main source(s) of noise at the quarries are from Excavation machinery, blasting of rocks, processing and haulage trucks. ▢ Yes ▢ No
23. Has the noise level affected your hearing? ▢ Yes ▢ No
24. Has any of your buildings developed cracks due to blasting vibrations? ▢ Yes ▢ No
25. The main cause of cracks in buildings in the village is vibration blasts. ▢ Yes ▢ No
26. Has any of the cracked buildings collapsed ? ▢ Yes ▢ No
27. Has any member of the community died in a collapsed building? ▢ Yes ▢ No
28. What is the life span of a well maintained mud house in the village

before cracking? ▢ 1-10yrs ▢ 11-20yrs ▢ 21-30 yrs ▢ 31-40yrs ▢ 41 & above

V. VISUAL INTRUSION

29. Do heaps of quarry wastes or stockpiles block your view?

(ie you can't see behind the heaps)? ▢ Yes ▢ No

30. Does dust prevent you from seeing things a distance away ? ▢ Yes ▢ No

31. Can these heaps of quarry waste be considered an eyesore? ▢ Yes ▢ No

VI. BIODIVERSITY(PLANTS AND ANIMALS) LOSS (Tick as applicable)

32. Excavations have destroyed many plants and animals. ▢ Yes ▢ No

33. Many living things have lost their homes (habitats) due to rock removal, noise and dust deposition. ▢ Yes ▢ No

34, The loss of plants and animals are not permanent. ▢ Yes ▢ No

SECTION C: ENVIRONMENTAL ISSUES

I. HUMAN HEALTH ISSUES

Respond to the following statements by ticking "Yes or No" or the applicable one.

	YES	NO
35. Dust is a nuisance to you.	▢	▢
36. Dust affects your health	▢	▢
37. Water harvested from roofing spouts is usually unclean (contains dust).	▢	▢
38. Your frequent ill health may be associated with dust, flooded farmland or rain water from roofs.	▢	▢

39. How was your health status before quarrying started?

▢ Excellent ▢ Very good ▢ Good ▢ Fair ▢ Poor

40. In general, what would you say about your health since quarrying started?

☐ Excellent ☐ Very good ☐ Good ☐ Fair ☐ Poor

41. Which dust related disease do you usually suffer from? **(You may tick more than one).**

☐ Cough ☐ Sneezing ☐ Catarrh ☐ Sore throat ☐ Asthma

☐ Short breadth ☐ Pneumonia ☐ Heart problem ☐ Headache ☐ Eye problems

☐ Frequent bringing out of phlegm ☐ Wheezing or whistling of chest

42. Which of the following water- related or water-borne diseases have you ever suffered from before quarrying started? (**You may tick more than one**)

☐ Malaria ☐ Guinea worm ☐ Cholera ☐ Typhoid ☐ Elephantiasis

☐ Diarrhoea ☐ Bilharziasis (Schistomiasis) Any other…………………………….

43.. Which of the following water- related or water-borne diseases did you ever suffer from during quarrying? (**You may tick more than one**)

☐ Malaria ☐ Guinea worm ☐ Cholera ☐ Typhoid ☐ Elephantiasis

☐ Diarrhoea ☐ Bilharziasis (Schistomiasis) Any other…………………………….

44. Was the disease suffered from before quarrying as severe or frequent as it was during the period of the quarry activities? ☐ Yes ☐ No

45. How fearful are you about your future health?

☐ All of the time ☐ Most of the time ☐ Some of the time

☐ A little of the time ☐ None of the time

46. Which hospital(s) do you normally visit when you are sick? **(You may tick more than one)**

☐ Antua Hospital ☐ Agomenya Roman Hospital ☐ Oterkpolu clinic

☐ Obenyemi clinic ☐ Oborpa clinic ☐ Bukunor clinic

☐ Koforidua Government Hospital

47. Which health programmes have you seen organized during since quarrying started? **(You may tick more than one)**

☐ Vaccination ☐ Screening ☐ Postnatal care (weighing) ☐ Health talk

Specify any other……………………………………………………………………

II. FAUNA AND FLORA

48. Coating of crop leaves with dust has resulted in reduced yield. ☐ Yes ☐ No
49. Coating of crops has reduced the value of agricultural products. ☐ Yes ☐ No
50. Some valuable plants(eg, medicinal) and animals(eg. game) have been lost due to dust and land degradation in the area. ☐ Yes ☐ No

III. SUSPENDED SOLIDS AND WATER QUALITY

51. Has fish catch from the stream/ river reduced within the past 5 years? ☐ Yes ☐ No
52. Could the reduction in fish catch be due to the run-offs into the river? ☐ Yes ☐ No
53. Has the quality of the water become poor in terms of domestic use. ☐ Yes ☐ No

IV. LAND DEGRADATION

54. Have lands in and around the concession been destroyed? ☐ Yes ☐ No
55. Are heaps of quarry waste and holes filled with water found around the sites? ☐ Yes ☐ No
56. Is it true that farmlands near the concession cannot be used to grow crops? ☐ Yes ☐ No
57. Restoration of degraded land must start immediately. ☐ Yes ☐ No

SECTION D MITIGATION MEASURES

Show how you agree on the following statements using the following responses by ticking the appropriate one.

Strongly agree (**SA**), Agree (**A**), Disagree (**D**) , Strongly disagree (**SD**)

	SA	A	D	SD
58. Dust must be sprayed with water during processing				

to reduce its levels in air. ☐ ☐ ☐ ☐

59. Health screening should be organized every 1 or 2 years. ☐ ☐ ☐ ☐

60. Haulage trucks must be covered with sheets. ☐ ☐ ☐ ☐

61. Dusty haul roads must be watered regularly using water tankers. ☐ ☐ ☐ ☐

62. Nose masks must be worn especially when rocks are blasted. ☐ ☐ ☐ ☐

63. Exposed surfaces(stockpiles) must be watered regularly ☐ ☐ ☐ ☐

64. A clinic must be sited at Klo- Begoro. ☐ ☐ ☐ ☐

65. Reduce drop heights from conveyor belts using sleeves. ☐ ☐ ☐ ☐

66. Alarm should be given before blasting. ☐ ☐ ☐ ☐

67. Channels must be provided to drain quarry run-offs. ☐ ☐ ☐ ☐

68. Quarry waste must be used to restore degraded land. ☐ ☐ ☐ ☐

69. A stabilization pond or reservoir must be created. to store run-off and water pumped out of the pits. ☐ ☐ ☐ ☐

70. Communities must either be relocated or buildings rehabilitated. ☐ ☐ ☐ ☐

71. Specify any other……………………………………………………………………................

……………………………………………………………………………...........................