IMPACT OF DIMENSION STONE PRODUCTION ON THE ENVIRONMENT: A CASE STUDY AT GRANITES & MARBLES COMPANY LIMITED, GHANA.

by

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DECLARATION

I hereby declare that except for references to other peoples' work, which has been duly acknowledged, this thesis submitted to the Board of Postgraduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi, is the result of my own investigation and has not been presented for any other degree to the best of my knowledge.

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ABSTRACT

The study evaluated the impacts of dimension stone production on the environment at the Tongo Quarry and the Factory at Accra. The variables studied were the blasting noise, pollution of nearby water sources and pollution of effluent discharge from factory. The study described the standard procedures for collecting and processing samples for water and sediment, and field analyses of conductivity, pH, temperature, and dissolved oxygen. An experimental study was carried out on sediment and water samples in the laboratory to assess the level of heavy metal pollution. For this study, several composite samples were collected and analysed. The pH and turbidity values of the water samples were 6.3-7.45 pH and 0.15-118 NTU respectively. Curves were drawn that relate metal concentrations in Water and Soil Samples. With the exception of chromium concentration in samples, GM1s and FS1 which have very high values of 2.64 mg/l and 1.34 mg/l respectively, all the other samples were below the maximum permissible level of Environmental Protection Agency (EPA) of Ghana guidelines for discharge into natural water bodies. Quality assurance is maintained by strict collecting and processing procedures, replicate sampling, equipment blank samples, and a rigid cleaning procedure using detergent, hydrochloric acid and methanol. In this thesis, blasting operation and its possible environmental effects are defined. To achieve the study objectives, 24 blasts were carried out and 3 sets of recordings were taken for each distance of 4m, 210m, 416m, 622m 824m and 2000m. A measurement was recorded for each site for ambient noise levels. From this, experiment curves were drawn that relate average ambient and noise levels in decibels with distance from blasting point towards the community. The evaluation was performed if the noise level were within safe limits or not. The field experimental work conducted indicated that the highest blasting noise of 92.3 dB and 85.2 dB recorded at distances of 824m and 2000m respectively are within acceptable maximum permissible level of 115 dB with 5% allowable to 120 dB or less in an annual period.

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CHAPTER 1

1. INTRODUCTION

1.1 BACKGROUND

The country Ghana has rich and diverse natural resources. These resources are exploited to meet the growing demands of the populace. The uncontrolled manner of utilisation of these natural resources has resulted in reversible and irreversible changes within the environment.

Rock quarrying and stone crushing is a global phenomenon, and has been the cause of concern everywhere, including countries like Ghana, Singapore, Lebanon, United States, Pakistan and Israel. In Ghana, there are an estimated 40 quarries, which cater for the needs of railways, road construction and maintenance, housing and infrastructure building. Rock quarrying has seen tremendous growth in the last decade or so. This is mainly because of the growing urbanization, enormous demand for housing, and the abundant availability of rocky hills in the surroundings. Rock quarrying has enormous impact on the environment. Not surprisingly, the problems that arise relate to the use of explosive materials, physical hazards (e.g. slips, trips and falls, falling rocks, impact with moving machinery) as well as noise and dust pollution.

One form of stone quarrying is dimension stone production. Dimension stone can be defined as natural rock material quarried for the purposes of obtaining blocks and slabs that meet specifications as to size (width, length and thickness) and shape (Peggy and George, 1994). Colour, grain texture and pattern, and surface finish of the stone are normal requirements. Durability (essentially based on mineral composition and hardness and past performance), strength, and the ability of the stone to take a polish are other important selection criteria. Although a variety of igneous, metamorphic and sedimentary rocks can be used as dimension stones, the principal rock types are granite, limestone, marble, sandstone and slate. This is because these rock types meet the visual or aesthetic features (colour, grain size, textures) and technical features (petrography and mineralogy, brittle deformation, physic-mechanical properties).

Aggregate and dimension stone quarrying produces materials that are used in road construction (aggregate, base course, crushed rock, sand and gravel); building construction and landscaping (topsoil, fill dirt, rip rap, scoria, travertine, dimension stone); and other general construction uses.

The potential for interactions resulting from quarrying are also very important. The loss of ecology and/or archaeology due to soil/subsoil removal; vibration, dust and noise from site activities and blasting, visual impacts due to changes in topography, nuisances from wind swept dust, human dissatisfaction with quarrying activities. Therefore due to the nature of quarrying, the primary environmental impact from aggregate and dimension stone production could be listed as follows:

- total destruction of the vegetation of mined areas,
- impact on water,
- impact on air and
- "public nuisance" effect.

The quarrying activities at extraction sites often involve major topographical and land-cover changes to allow extraction activities, often including clearing of vegetation. Removal of soil and/or bedrock is unavoidable due to the nature of quarrying activity. Rock waste and removed topsoil (overburden) are the main inert wastes produced by quarrying activities. During processing of the rock into finished products, waste rock is also produced. Changes made to the topography as a result of the removal of materials from its original location and dumping of waste rock and overburden to a large extent constitutes visual impact. Few of these quarries have been formally reclaimed, although some have been naturally re-vegetated to some extent.

Acid drainage, also referred to as Acid Mine or Acid Rock Drainage (AMD or ARD), may occur when minerals containing sulphide and elemental sulphur are exposed to the atmospheric effects of oxygen and water when large quantities of rock are exposed. In particular, sulphide minerals in waste rock and tailings react to form sulphuric acid (H_2SO_4). The resulting acidic runoff can be devastating to the surrounding ecosystem. Treatment processes in the factory also introduce liquid wastes which may contain cyanide, kerosene, organic flotation agents and activated carbon. Runoff from quarries and factories may also have enhanced levels of metals such as arsenic, copper, lead, iron, cadmium, nickel etc.

Diamond-wire cutting activities and dimension stone quarrying activities typically involve significant use of water. De-watering of quarry sites to allow access to deeper levels of rock affects groundwater levels. Another major environmental impact from aggregate and stone quarries is groundwater use. Some quarries use water to control dust; they use millions of gallons of scarce water resource to perform these tasks. Although dust control is necessary at these quarries, the use of scarce potable water for dust suppression must be weighed against the increasing demands of domestic water use.

Dewatering of the quarrying pit, diamond-wire cutting, and surface water runoff can generate a wastewater discharge high in suspended solids. This could lead to sediment loading of streams. The effects of sediment loading include killing of fish and destruction of their eggs, reduction of oxygen in water and the increase in turbidity which tends to diminish the penetration of light required for photosynthesis.

The most obvious environmental impact from aggregate and stone quarrying is degraded air quality and its associated health effects resulting from fugitive dust. Fugitive dust is produced from quarrying operations (e.g. clearing, blasting), transportation (e.g. loading equipment, haul vehicles, conveyors), comminution (e.g. crushing and grinding), and waste management operations (i.e., waste rock dumping). Wind also entrains dust from dumps and spoils piles, roads, tailings, and other disturbed areas. Tailings and waste rock at quarries usually contain trace concentrations of heavy metals that may be released as fugitive dust to contaminate areas downwind as coarse particles settle out of suspension in the air. Dust blown from waste rock dumps and tailings dams may also include hazardous material that can stay suspended in the air for long periods and pose respiratory health hazards (Brodkum, 2000).

The final impact created by these quarries could be called the "public nuisance" effect. Some operations can emit dust that disturbs neighbours. Nearby homes can be covered with a thin layer of dust from the operations. These quarries sometimes operate at night and make enough noise to disturb neighbours as far as a mile away (Peterson and Northwood, 1981). The combination of bright lights to aid night operations, loud noises from drilling, blasting, vehicles, crushers and screen plants; and dust emissions creates a public nuisance for those people unfortunate enough to live near such operations.

In the past, smaller populations and lower levels of development made these impacts less noticeable. With larger populations and development that consistently outstrip the government's ability to regulate the environmental impacts, the cumulative effects of aggregate and stone mining, especially in urban areas, contributes to the overall degradation of the environment. In rural areas these impacts are also serious for affected local communities.

1.2 STATEMENT OF THE PROBLEM

The purpose of this study was to identify and catalogue the impact of dimension stone production on the environment as may occur in Ghana. Good environmental management in the dimension stone industry can result in good publicity and public relations, increase in foreign exchange earnings and the creation of jobs directly or indirectly.

Many human activities such as mining and quarrying can negatively impact on the environment. These environmental impacts could include topographical and land cover changes, degraded air quality from dust, noise and vibration etc.. Documentation of the relationship between dimension stone quarries and the environment in Ghana are either non-existent or very scare. There appears to be no in-depth studies of the environmental impact of dimension stone production in Ghana though the industry has existed for the last 30 years.

In the light of the above, the researcher has designed the study to answer the question "*What Impact will dimension stone production have on the environment and how can any negative impact be ameliorated?* The study was carried out in two locations, namely the Telensi-Nabdam District of the Upper East Region where a dimension stone quarry is sited, and in Accra where the processing equipment for Granites & Marbles Company Limited is located.

1.3 OBJECTIVES OF THE STUDY

The objectives of the study included:

- To identify the environmental impact of the production of dimension stone
- to ascertain pollution levels and
- propose mitigation measures where necessary.

1.4 ORGANISATION OF THE STUDY

The research work is organised into five chapters. Chapter one contains an introduction to the subject matter, statement of the problem and the set objectives. Chapter two involves review of related literature of subject matter. In chapter three research methodology is discussed. Some of the items in this chapter include location and access, climate and geology of the area, history of Environmental Impact Assessment (EIA) development in Ghana, an introduction to the production of dimension stone and potential environmental impact associated with dimension stone production. In chapter four, investigation, presentation, analysis and discussion of findings is done whilst Chapter five offers conclusions and recommendations.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 EVOLUTION OF ENVIRONMENTAL IMPACT ASSESSMENT IN GHANA

Ghana has a long history of an attempt to safeguard the environment from being abused by enacting in-appropriate legislation of environmental care. The best result from this entire attempt is the establishment of an organisation sorely responsible for the environment – Environmental Protection Agency (EPA).

Though Environmental Impact Assessment (EIA) was first introduced into the development paradigm of the country with the establishment of the then Environmental Protection Council (EPC) in 1974, it was unable to lead to the realisation of the objectives of Environmental Protection Council principally, because the then council literally lacked the power to enforce EIA. It was therefore not until after the promulgation of Act 490 (1994) which transformed the EPC to EPA with the latter having powers to enforce and ensure compliance with provision regarding EIA that, real meaning was given to EIA administration in Ghana. EIA enforcement in Ghana was given a further boost in 1999 when it was given complete legal status through the promulgation of the Environmental Assessment Regulation of Ghana, LI 1652. In a policy statement, Environmental Protection in Ghana was to be guided by the preventive approach so as to avoid the creation of environmental problems. This in practice is being done through the Environmental Assessment Administration Procedures. These procedures were derived from the main Environmental Legislation, Environmental Protection Agency Act, Act 490 and Environmental Assessment Regulation, LI 1652.

The procedures are as follows:

1. New developments are to register with the EPA, conduct an environmental assessment of their proposals and submit an environmental assessment report to the EPA for review. There are levels of assessment depending upon the type, scale and location of the activity. Environmental Permit is granted for the development to start when EPA is satisfied with the assessment conducted and the mitigation measures proposed for any environmental impact likely to be associated with the project.
2. Industries in existence before the legislation are to conduct an environmental assessment of their facility and propose ways and means of improving the level of performance of their set-ups. The Environmental Management Plans are then submitted to the EPA for review. The commitments made by the management of the set-ups are to be implemented and the goals achieved within three years, after which another plan must be submitted. The new industrial set-ups are also required to comply with this procedure after 18 months in operation.
3. Industries are also requested to submit monthly returns of their environmental parameters monitored to the EPA. Comments are also expected in cases where values exceed certain limits and what measures are in place to check the discrepancy.
4. Industries are also requested to submit Annual Environmental Report to the Agency, indicating how they have performed environmentally, what have been achieved, what went wrong and what needs to be done.

2.2 DIMENSION STONE TYPES

Scientific and commercial descriptions of various dimension stone types overlap. The scientific description of dimension stone types is focused primarily on the stone's locality and mineralogical composition, whereas the commercial description is focused primarily on the locality and colour of the stone. Stone producers in their bid to market their stone products effectively use various combinations of the scientific and commercial descriptions (Table 2.1).

Table 2.1: Classification of Commercial Granites by Percentage of Quartz

MINERALS	PLAGIOCLASE			
	0-35%	35-65%	65-90%	90-100%
QUARTZ 20-60%	GRANITE		GRANODIORITE	
QUARTZ 5-20%	QUARTZ SYENITE	QUARTZ MONZONITE		
QUARTZ 0-5%	SYENITE	MONZONITE		DIORITE ANORTHOSITE GABBRO

Source: Dunsworth, (2002)

2.2.1 Granite

According to Sherry Dunsworth, (2002), commercial granites include all feldspathic crystalline rocks of mainly interlocking texture and visible mineral grains. This category includes such rock types as anorthosite, granodiorite, monzonite, syenite, and all other intermediate rock types. Primary colours of granites are white, gray, pink, and red but with green and brown as secondary colours. Although black granites are also included in this category and range in colour from dark gray to black, they are not true granites mineralogically but rather mafic rocks such as diabases, diorites, gabbros, and similar rocks.

2.2.2 Limestone

Commercial limestones are rocks of sedimentary origin that primarily comprise calcium carbonate with or without magnesium. Included in this category are calcitic limestone, dolomite, dolomitic limestone, and travertine, which is a rock that is precipitated from hot springs (Dunsworth, 2002).

2.2.3 Marble

Commercial marble includes metamorphosed limestones and serpentine rocks, all of which are capable of taking a polish. An important member of this classification is serpentine marble, which is also known as verde antique, and comprises green-to-black serpentine, which is a hydrous magnesium silicate mineral that is crisscrossed by veins of lighter minerals, such as calcite or dolomite.

2.2.4 Sandstone

Commercial sandstone is a lithified sand that comprises chiefly quartz or quartz and feldspar with a fragmental (clastic) texture. Sandstone contains interstitial cementing materials, such as calcite, clay, iron oxides, or silica. Arkose (abundant feldspar grains), graywacke (abundant rock fragments), and conglomerates are included in this category. Other members of this category include bluestone, which is a dense, hard, fine-grained feldspathic sandstone, which splits easily along planes into thin, smooth slabs;

brownstone, which is feldspathic sandstone of brown to reddish-brown colour owing to abundant iron oxide; and flagstone, which is a sandstone or slate that splits into large, thin slabs (Dunsworth, 2002).

2.2.5 Slate

Commercial slate is a microgranular metamorphic rock formed by the recrystallization of clay sediments, such as claystone, shale, or siltstone. Characterized by excellent parallel cleavage planes slates may be easily split into relatively thin slabs (Dunsworth, 2002).

2.3 PROPERTIES AND USES OF DIMENSION STONE

(1) **Marbles** – Marble exhibits a low resistance to environmental attack and is used primarily for interior applications, except in favourable climates and in exterior restoration projects. Marble dominated dimension stone usage until the 1970's when granite gradually increased in usage until today where granite occupies ~50% of the market.

(2) **Granites** – Granites physical and chemical stability, strength and aesthetic appeal lend to durable exterior cladding applications as well as a growing interior usage for flooring and kitchen countertops.

(3) **Slates and Sandstones** – Physical and chemical stability and appearance lend their to exterior (roofing slate, landscaping, building block) and interior (flooring and wall cladding) applications.

2.4 DIMENSION STONE PRODUCTION

Dimension stone production consists of two main stages. These are dimension stone quarrying and dimension stone processing.

2.4.1 Dimension Stone Quarrying

Quarrying is the art of winning or obtaining from the earth's crust the various kinds of stone used in construction. The operation in most cases is conducted in open workings. The Ghanaian dimension stone industry produces materials which consist almost entirely of granite rocks. Production starts in the quarry. Despite the vast materials worldwide, most deposits are unsuitable for dimension stone production. They may be fractured, inaccessible, have unsuitable inclusions, lack consistency or are just not fashionable. They are rarely located in accessible areas. Quarrying for dimension stone requires a specialised method of extraction. Normal quarrying methods use large quantities of explosives to move huge volumes for breaking down into aggregate. This creates cracking throughout the stone which renders it unsuitable for use. Many dimension stone quarries have been rendered useless by the over use of explosives (Grimson, 2003).

Although some quarries use low powered or soft explosives to good effect, other techniques are typically used for successful dimension stone quarrying. Examples of such techniques include the use of channelling, chainsaw, stitch drilling, plug and feather, expanding clay, thermal lance, wire saw and high pressure water jet.

The purpose is to extract a block of regular dimensions and shape without affecting the structural integrity of the product, i.e. not to induce cracking. Block sizes may vary according to the deposit. Ideally a block of 20 tonnes of a size approximately 3.0m x 1.5m x 1.5m is preferred due to capacity of machine handling. However, necessity decrees that sometimes blocks as small as 6 tonnes are accepted, often 11 tonnes and anything up to the ideal. Twenty (20) tonnes is generally the largest due to transport requirements. However 50 tonnes blocks are not unusual in situations where the primary cutting units are located at the quarry (Grimson, 2003).

Extraction generally uses a combination of the methods mentioned. Channeling machines are utilized in the softer rocks such as sandstone or limestone since they would be liable to damage through blasting. The machine used for channelling is a large track mounted 3-metre diameter wheel with tungsten tips which traverses the terrain cutting a continuous channel approximately 200mm wide.

A chainsaw is literally a large track based saw with tungsten cutting teeth which can operate both vertically and horizontally. It is generally used in marble.

Stitch drilling is the method used in most quarries by itself or in conjunction with other methods. A series of 30mm diameter holes are drilled generally 150mm apart along the line required to be split. The stone is then broken along this line by one of three methods, namely plug and feather, expansive clay and soft explosives (Shadmon, 1996). Firstly, plugs and feathers which are wedges driven into metal guides by the use of heavy sledge hammers in the holes force split the block along the holes. Secondly, by filling the holes with a liquid clay (Fract.Ag) which expands as it dries forcing the block to split along the holes. Finally by charging the holes with 6 grammes strength of cordtex with water as stemming material and initiated with safety fuse which split the block along the holes (Grimson, 2003).

Thermal lance is a diesel-fuelled flame accelerated by compressed air which will cut a 200mm wide channel. It does induce cracking within the area of use. This often reduces the yield considerably.

Wire sawing is a long stranded wire or diamond tipped wire fed through a series of pulleys and assisted by abrasives. This is used for primary block extraction. Stranded wire has been used for many years in marble and sandstone, whilst an improvement in diamond technology has seen the recent introduction of wire sawing in granite quarries in this country. The yield from wire sawing is much higher and gives a semi finished surface which allows a close examination of the material before further working (Grimson, 2003).

The latest technology, water jet cutting, is still developing. It has not yet been introduced to Ghana. It cuts a channel similar to the thermal lance. The equipment is expensive but has the advantage of reduced waste and lower operating costs. The yield from stone quarries is relatively low. If dimension stone is the sole product, a yield as low as 30% is not uncommon (Toldyna et al., 2004).

The blocks from any of these methods are progressively fragmented into smaller blocks until they are of a size that can be handled by a front-end loader or crane.

2.6.2 Dimension Stone Processing

The quarry blocks are lifted by crane onto trucks and transported to a processing plant. At the plant they are cut into slabs or blocks of the required size by a circular diamond edged block saw (working on the same principle as the wire saw in quarries), or single or multibladed frame or gangsaws using either abrasive grit or diamond tipped blades.

Two methods of primary sawing are used. The first is gang sawing, by which a reciprocating frame, with up to 120 steel blades, works its way through the block. It can take up to one week to saw each block (Shadmon, 1996). The second method is diamond sawing. Although more costly, this is offset by the high capacity and better surface finish achieved. For tiles multi-bladed saws are used with blades of up to 1200mm in diameter. The 32-blade saw can produce 220 square metres per day in granite.

Blocks are cut in benches to a depth equal to the width of the required tile, generally 300mm. These strips, being the length of the block, are taken off individually using a horizontal blade. At this stage the strips have approximate width and thickness of a tile but not the length of the block due to machine limitation. The machine can traverse 2.8 metres generally for most machines. The actual tile line is a series of machines linked by belt or roller conveyors. The purpose is to process the raw strips into a precisely dimensioned tile. In most processing units the total line is 50 metres long.

Raw strips vary in thickness as the diamond segments on the block saws wear, so the first operation is to grind the material to the exact thickness required, but allowing for what is removed in the polishing process. This is achieved by using diamonds on a series of drum rollers (Shadmon, 1996).

Polishing is achieved by passing the strips under a series of high speed heads containing varying degrees of carburundum stones. Carburundum stone is a man-made material (silicon carbide, SiC) that is used as an abrasive for grinding, cutting-off and glazing of both natural or artificial stone or terrazzo. The first process is to start using 36-60 grit and finish at 1200 grit before the actual polishing heads. The polishing segments are similar but use different chemicals. A less slippery finish can be achieved by the use of grits up to 200 which is more likely to satisfy new standards for commercial flooring.

After polishing, the strips are docked to length using a multi-blade cross cut diamond saw. The method used allows for some degree of selection at this point. Natural stone comes with many imperfections - cracks, spots, discolouration etc. These can be cut out.

The tiles produced have a polish finished surface, accurate for thickness, cut oversize with raw edges. The final process is calibrating and chamfering. The oversize is reduced to the exact dimension by edge grinding with a diamond tool and the edges are finished by grinding a 45-degree angle to all sides. The completed tiles are dried, cleaned, inspected and packed.

Packing has recently changed from polystyrene to water resistant cardboard cartons for environmental reasons. Each carton contains approximately one square metre. These are packed on pallets and shrink wrapped in crates complete with shrink wrapping.

Grading of tiles eliminates unwanted features and poor processing. In fact on average one third of the raw strips are lost in processing. That is, out of 900 square metres strips produced only 600 square metres tiles end up as "finished tiles" (Shadmon, 1996).

2.6 POTENTIAL ENVIRONMENTAL IMPACT OF DIMENSION STONE PRODUCTION

Modern technology and scientific investigation methods have made it possible to reduce environmental impacts associated with the extraction of rocks and manage impacts at acceptable levels that do not cause significant harm to the environment. Nevertheless, rock resources cannot be obtained from the landscape without causing some environmental impacts.

An analysis of the environmental impact of quarrying could be activity-based or effect-based. The activity-based approach would attempt to consider all the effects that each activity involved in a method of production such as clearing, drilling, blasting, loading, haulage, processing and waste disposal has on the environment. In addition the physical hazards and risks that affect workers' health would be considered.

The variety of impacts on the environment depend on the characteristic of the rock, the type of technology and extraction methods used in quarrying and processing, and the sensitivity of the local environment (Munn, 1975). Apart from the physical impacts of extractive activities, contamination of air, land and water may also result. The following sources of potential impacts may be associated with dimension stone production.

The effect-based that dimension stone operations can have on the environment can be categorised as Land surface effects, Hydrologic effects, Ecological effects, Air quality effects, Social effects, Blasting effects and Subsidence effects.

2.6.1 Atmospheric Emissions

The majority of air emissions associated with quarrying industry includes dust generation and carbon monoxide from diesel engines. Dusts are solid particles generated by handling, drilling, crushing, grinding, etc. Any process that produces dust fine enough to remain in the air long enough to be inhaled or ingested should be regarded as hazardous until proven otherwise.

Gaseous emissions and particulates are known major air pollutants that have been emitted into the atmosphere due to the operations. Gaseous pollutants such as carbon dioxide and carbon monoxide are produced from combustible engines (Brodkum, 2000).

Quarrying without dust production is almost impossible. Dust is one of the most visible, invasive, and potentially irritating impacts associated with quarrying, and its visibility often raises concerns that are not directly proportional to its impact on human health and the environment. Dust may occur as fugitive dust from excavation, from haul roads, and from blasting, or can be from point sources, such as drilling (Langer, 2001). Site conditions that affect the impact of dust generated during extraction of dimension stone include rock properties, moisture, ambient air quality, air currents and prevailing winds, the size of the operation, proximity to population centers, and other nearby sources of dust. Dust concentrations, deposition rates, and potential impacts tend to decrease rapidly away from the source (John, 2001).

There are several dust particles that have a local action on the respiratory tract and cause disabling and incurable industrial pulmonary diseases. Silica dust, which is generated in the quarrying of granite rock, is one such dust. It produces a distinctive reaction in the lung that leads eventually to masses of fibrous tissue and distinctive nodules of thick fibrosis, which, damage the lung. The prolonged inhalation of silica results in silicosis, a disease of the lung (Anon., 1993).

Occupational Safety and Health Administration (OSHA) of U.S. Department of Labour established Permissible Exposure Limits (PELs) for many substances, including airborne crystalline silica. It is a time-weighted average amount that cannot be legally exceeded for an 8-hour shift during a 40 - hour week. The current OSHA PEL for respirable dust containing crystalline silica (quartz) for general industry is measured by the amount of silica dust in one cubic metre (mg/m^3) and is calculated using the following formula:

$$PEL = \frac{10\ mg/m^3}{(\%\ SiO_2 + 2)}$$

2.6.2 Solid Waste Generation

Inherent to quarrying and processing operations is the generation of solid wastes. These are mostly in the form of waste rocks and unwanted finished tiles, slabs etc. The solid wastes generated from the mining process are rocks. Improper management of discarded piles of rock can lead to accidents and become hiding places for reptiles and other dangerous creatures like scorpions. It is therefore important for the rock piles to be disposed of as quickly as possible from the site.

2.6.3 Vibrations and Noise Effects

Vibration effects are associated with quarry operations, especially drilling and blasting. Contact with mechanical vibrations in the range of 40-250Hz may cause constriction of blood vessels, secondary tissue changes and in some serious cases affect nerves and muscles (Peterson and Northwood, 1981). The condition may be associated with the use of tools driven by compressed air, percussive action drill or contact with vibrating machinery. The bottom bit works by a percussive action. Individual susceptibility varies and several pre-disposing factors may occur.

The primary source of noise from extraction of dimension stone is from earth-moving equipment, compressor and blasting. The impacts of noise are highly dependent on the sound source, the topography, land use, ground cover of the surrounding site, and climatic conditions (Langer, 2001).

Normal quarry blast and drill noise levels could exceed 100dB. It is recommended that a noise level of 90dB as the threshold exposure limit for a working lifetime of 8 hours per day is acceptable (Connell, 1972). The threshold limit is a time weighted average value, so that the higher the level of noise exposure, the shorter is the time that may be tolerated, without the risk of hearing impairment.

The effect of the noise generated from quarry operations includes the following:

- Hearing impairment, which may be temporary or permanent.
- Physiological effects such as stress, fatigue and sleeping interruptions.
- Headaches as well as other related health problems and also
- Interference with communications.

2.6.4 Water Quality

Quarry operations can affect surface run-off and ground water quality through contamination with dissolved and suspended materials. Surface water contaminants are by sediment or suspended solids.

Quarrying processes can result in the contamination of associated sediments in receiving streams when dissolved pollutants are discharged to surface waters in the stream. In addition, fine grained waste materials eroded from quarry sites can become sediments. Specifically, some toxic constituents (e.g., lead and mercury) associated with discharges from quarry operations may be found at elevated levels in sediments, while not being detected in the water column or being detected at much lower concentrations. Sediment contamination may affect human health through the consumption of fish and other biota. Finally, sediment contamination provides a long-term source of pollutants through potential re-dissolution in the water column (Kabata-Pendias, 1984).

Other likely contaminants are hydrocarbons from fuels and lubricants and sewerage from employees' ablutions.

2.6.5 Aesthetics

Some environmental disturbances created by quarrying is caused by extraction and processing of blocks. Quarrying has an associated, often dramatic, visual impact. The quarry site is commonly considered to be of high scenic value, thus compounding the effects of visual impacts of quarrying. The principal geomorphic impact of quarrying is the removal of rock, which results in the destruction of habitat including aesthetics values.

Splitting of boulders and the removal of rock from their original places tends to deface the natural beauty of the area, as split rock does not have the same colour as the weathered rock. The most obvious visual impact of quarrying is a change in geomorphology and conversion of land use.

There is no choice in where quarrying occurs as it depends on the location of the rock type. As a result, there is often competition to land use between quarrying and for example urbanization, agriculture and conservation. Quarrying operations are therefore required to comply with comprehensive measures to control their environmental impacts. One measure is the use of buffer zones where land around a quarry site is used for other purposes such as grazing (Shadmon, 1996).

CHAPTER 3

PROFILE OF STUDY AREA AND METHODOLOGY OF RESEARCH

This section of the study covered information on the profile of the area, the population of the study, research design, sampling techniques, data collection instrument and data analyses.

3.1 LOCATION AND ACCESSIBILITY

The Telensi-Nabdam District is one of the eight (8) districts in the Upper East Region. It was created in 2004, from the Bolga District. The Telensi-Nabdam District has its capital at Tongo. The concession of Tongo Quarry Limited is located at Wakii near Tongo in the Upper East Region of Ghana (Figure 3.1). The study area was approximately 15km south of Bolgatanga off the Bolgatanga –Tamale road at the Winkogo junction. Access to the property is 2km south of the newly created Telensi-Nandam District of the Upper East Region. The processing unit was located in Accra on the Spintex road where it shares boundary with Lion Aluminium Company.

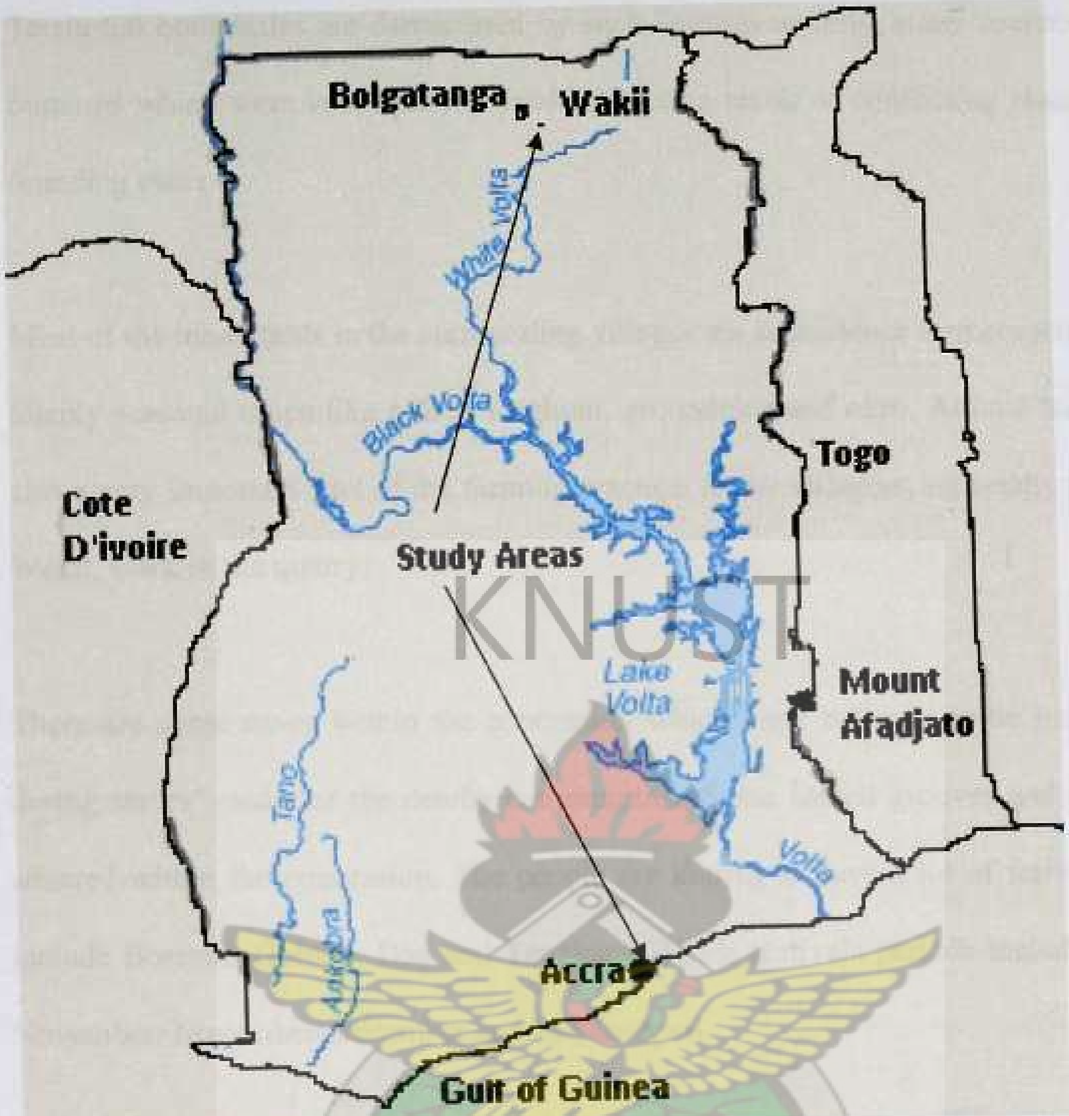

Figure 3.1: Map of Study Area

3.2 SOCIO-ECO CULTURAL AND ARCHAEOLOGICAL VALUES

The indigenous people are Talensis and speak Talen. They are patrilineal and sedentary peasant farmers and live in small compound houses with some space separating the compound units. Most of the buildings are made of mud blocks and roofed with grass or decked with earth.

Territorial boundaries are demarcated by such features as hills, water sources and rock outcrops which were subsequently established as a result of conflicting claims of rival founding clans.

Most of the inhabitants in the surrounding villages are subsistence farmers who cultivate mainly seasonal crops like millet, sorghum, groundnuts and okro. Animal husbandry is also a very important part of the farming practice. Some villagers, especially those from Wakii, work in the quarry.

There are some caves within the concession which were believed to be hiding places during slaves' raids for the nearby communities. Some sacred grooves and shrines are situated within the concession. The people are known to have a lot of festivals. These include Boaram, Golobo, Daa and Tengbana. These festivals periods include October-November, November-December and March-April.

3.3 CLIMATE AND VEGETATION

3.3.1 Climate

The Upper East Region's climate is the tropical continental type which is characterised by a single rainy season, a prolonged dry season, and high temperatures. The mean annual temperature ranges between 28°C and 31° C. Between November and March, the tropical Continental Airmass locally called harmattan, blows over the region from the Sahara Desert bringing in its trail a long dry season. The region's single rainy season is experienced between May and October when the moisture-laden Tropical Maritime

Airmass blows over the region from the South Atlantic Ocean. The average annual rainfall ranges between 90cm and 125cm (Dickson and Benneh, 2001).

3.3.2 Vegetation

The vegetation of the region is entirely the guinea savannah type. This type of vegetation is characterised by grassland and medium-size trees, common among which are the dawadawa (parkia filicoides) and shea (butyrospermium) trees.

There are also baobab trees but they are few and widely scattered. Plant life undergoes changes according to the different seasons. In the rainy season, the trees blossom and the grasses shoot up rapidly. However, during the dry season, the leaves change their colour from green to yellow/brown and shed their leaves. Because of the single rainy season, cultivation of the land is undertaken once a year instead of twice as is the case in the forest regions (Dickson and Benneh, 2001).

3.4 GEOLOGY

The region is built of three principal rock types namely: the Voltaian, the Granites and the Birimian. The Voltaian formation is the most extensive covering about 75% of the region including the entire eastern half and parts of the western sector. The formation consists principally of sandstones, shales, mudstones and limestones (Anon., 1994)

The granite rocks occur in parallel belts with the Birimian rocks. The Birimian formation which is the third rock formation occupies a corridor along the north-western part of the region. This geological formation is usually rich in minerals of high economic value.

The region's relief features consist largely of the Voltaian sandstone basin and the savanna high plains. The former occupies about three-fifths of the region. It is made up of gently dipping or flat bedded sandstones, shales and mudstones which are easily eroded. The basin forms an extensive flat plain which rises between 60 metres and 180 metres above sea level in most places with few exceptions like the Gambaga and Konkori scarps which stick out. The Gambaga escarpment is made up of horizontal layers of sandstone and marks the northern limit of the Voltaian sandstone basin. The average elevation does not exceed 450 metres above sea level (Anon., 1994).

3.5 QUARRY OPERATIONS OF GRANITES & MARBLES COMPANY

The main activities of the quarry are winning the granite blocks and transporting them to the factory site in Accra. Currently, the granite blocks are being extracted from the boulders scattered around the deposit. The quarrying process involves face preparation, drilling, blasting and dressing of blocks. The general purpose of quarrying work is to separate the rock material from its bed in masses of form and size adapted to the intended use.

3.5.1 Face Preparation

The practice of quarrying consists in uncovering a sufficient surface of the rock by removing the unwanted material and overburden which overlies it. There is the need to constantly prepare quarry face in order to gain access to the boulders scattered around.

The deposit is a boulder resource. A font-end loader (Cat 988F Payloader) is used to clear the quarry face. Explosives are used only when some boulders, which are unusable rock due to their size or fault lines, block the face preparation process.

3.5.2 Drilling

The drilling technique consists of drilling a series of 30 mm diameter-holes of 150mm spacing by means of hand held drills (jackhammers) vertically to the required depth. The production of blocks of dimension stone is effected ordinarily by drilling holes along the outlines of the block to be removed. Between four and six hand held drills are used for this purpose. A diesel compressor powers the drills. The rock is best quarried by the use of expansion mortar (Frac.Ag.) to ensure that the noise emitted is kept to a minimum.

3.5.3 Blasting

When blasting is necessary, some form of gunpowder and/or cordtex is generally used, rather than a violent explosive-like dynamite, in order to avoid shattering the rock. The type of blasting employed in the exploitation of the granite blocks is controlled blasting. This type of blasting ensures that the block is not shattered or weakened from within, since large rectangular blocks are required. The safe distance from the point of blasting in this type of operation is 10m.

Controlled blasting involves the use of high-speed cordtex and/or low speed gunpowder inserted into the drilled holes vertically and joined together. Sometimes the holes drilled are charged by putting a small charge of gunpowder at the bottom of the holes. The drill holes are filled with water as stemming material before any blasting. Detonation of cordtex and/or gunpowder in the holes exerts sufficient force to overcome the cohesion of the rock and split along the holes drilled. In the process the block moves or shifts forward for slipping a wire rope around it and pulling down with a payloader.

3.5.4 Dressing of Blocks

The blocks are shaped into rectangular blocks by Stitch drilling method used in conjunction with other methods. A series of 30mm diameter-holes are drilled generally 150mm apart along the line required to be split. The stone is then broken along this line by one of three methods. Firstly, plug and feather which is wedge driven into metal guides in the hole. These wedges driven into the holes exert pressure along the holes drilled forcing the block to split. Secondly, by filling a number of the holes with a liquid clay (Frac.Ag) which expands as it dries. As the clay expands in the holes a crack develops along the series of drilled holes which is the least line of resistance. The finally method is by the use of "soft" (gunpowder, cordtex) explosives.

3.5.5 Quarry Product

The main quarry products are granite blocks weighing up to 20 tonnes in rectangular shape. Other granite blocks smaller than the normal size of 2m x 1m x 0.8m are quarried for cobblestone production. A derrick crane at the loading bay of the quarry loads the blocks onto 40-ton articulated trucks, which transport the products to the factory site in Accra by road.

3.6 METHODOLOGY

This section provides information on the research design, population of the study, sampling technique, data collection technique and sources of data and method by which data were analysed.

3.6.1 Research Design

The research designs employed for the study were Survey Research, Observational and Experimental research.

The survey method was employed to obtain first hand information from some of the people around and within the operational area on the potential environmental hazards that were of concern to them. This became necessary and appropriate because the population of study is very large and therefore warrants sampling. Since a census study of the entire population will not be possible due to limited time and resources at the disposal of the researcher, a total of 17 respondents were chosen. The study employed qualitative approach through the use of structured close format and few open format (Appendix 5). This remained as open and adaptable as possible to the interviewees' nature and priorities and during the interview the interviewer "went with the flow". The qualitative approach was to organize comments into similar categories e.g. concerns, suggestions, indicators, etc.

The observation method was employed to corroborate the concerns of the environmental impacts from the survey research. The operations of the quarry starting from quarry face preparation, drilling, blasting, transportation and loading of final blocks into articulator trucks were observed. This afforded the researcher the opportunity to learn at first hand the activities associated with the production of finished goods. .Also the processes in the factory where blocks were loaded into either the gang saw or block cutter machines and polished into finished tiles or slabs were observed. This was to help in the selection of potential areas of pollution.

To further corroborate and correlate the responses elicited from survey and observational methods, the experimental method was employed to scientifically establish the different pollution levels of the environment. Project experimentation was carried out by the process of testing samples in the laboratory to ascertain the levels of environmental pollution. Experiments were conducted on the following environmental variables:

- Noise levels of blasting.
- Water quality of nearby water sources and
- The level of pollution of effluent discharge from factory.

The independent variable in the case of the variables was distance. The dependent variables are the noise levels, water quality and pollution of effluent discharge.

3.6.2 Population of the Study

The target study area was the Tongo Quarry in the Upper East Region where the Quarry was situated and in Accra (near the Spintex road) where the processing of the blocks takes place.

3.6.3 Sampling Technique

The subjects of the study were selected by purposive and simple random sampling technique. Five workers were selected using the simple random technique. This involved writing yes on five pieces of paper and no on fourteen pieces of paper. These pieces of paper were folded, mixed and thrown on the floor and workers were asked to pick. Those with yes on their pieces of paper were interviewed. The Quarry and Factory Managers (who control the operations) of the company and the Supervisors of the quarry and factory were selected using the purposive sampling technique because the attributes of the subjects of study were known to the researcher. In the case of inhabitants close to the operational area simple random sampling was used. Out of the 5 houses close to the quarrying site 3 were randomly selected and their landlords were interviewed. In all about 17 people were interviewed and their concerns categorized into noise, dust, water and land pollution. The responses gathered were analysed statistically with the aid of tables, frequencies, and percentages as presented in Appendix 6.

3.6.4 Data Collection Technique

The data collection techniques used were questionnaire and interview schedules, personal observation and use of laboratory test (experiments) of samples for the primary data. The result from exploratory experiments performed on the blasting noise, soil and water samples collected formed the primary data of the study.

From published books, papers, field reports, studies, journals dealing with impact of dimension stone production on the environment formed the literature review and as supporting evidence for the research.

3.6.5 Data Analysis

Data gathered were analysed using descriptive statistics and laboratory test or experiments. Summary tables were prepared to interpret data for parameters tested on the field and in the laboratory. The results from exploratory experiments performed on the blasting noise, soil and water samples were analysed using frequency distributions, mean, tables and simple percentages. The responses in respect of the interview were summarized, tabulated and interpreted in the form of tables and percentages. The responses served as a guide in selecting the type of test to be conducted. This was intended to simplify the results of the study for the researcher for easy discussion and recommendations. Overall summary tables and graphical depictions attempt to simplify detailed environmental study results into digestible interpretations and presentations.

CHAPTER 4

INVESTIGATION, PRESENTATION AND ANALYSIS OF STUDY FINDINGS

This chapter is devoted to field data acquisition of water, sediment and noise levels. The chapter describes the procedures for collecting water and sediment samples for processing for heavy metals and field analyses of conductivity, pH, alkalinity, temperature and dissolved oxygen. An assessment to find out the level of pollution of water and sediment samples was carried out through sample preparation, physical and chemical analysis in the laboratory.

4.1 HEAVY METAL MEASUREMENT IN WATER AND SEDIMENT

4.1.1 Introduction

Sediments are soils, sand, organic matter, or minerals that accumulate on the bottom of a water body. Sediment may contain toxic or hazardous materials that can adversely affect human health or the environment (Jaagumagi and Persaud, 1996). Finer-grained sediments (silts and clay) are more likely to contain contaminants than sand and gravel. This is the result of both chemical interaction between soil particles and the contaminants and the settling rate of different sized particles (Chapman, et al., 1992). Sediment quality testing is done to find out if there are unacceptable levels of pollution in the sediment and to provide a chemical data to compare with thresholds of concern. Thresholds of concern are the safety levels for sediment contamination set at many times less than scientists believe would really cause damage to fish and wildlife.

All water from natural sources contains dissolved substances. These substances are often called contaminants, especially when the amounts present are at possibly harmful or problematic levels. The substances in water can result from either natural processes or human activities. At low concentrations, many do not cause known harmful effects and may be beneficial. Research shows some substances may be harmful only when present at high enough concentrations. Analytical testing can determine what substances are present and their concentration levels.

4.1.2 Equipment

The equipment and materials used by the sampler for collecting water and sediment samples include syringe, a perforated container for draining off water from sediments collected, sample containers with lids and polythene bags, permanent marker for labelling containers and field sheets. A multiple purpose meter, Watech Multimeter, a 1995 model was used for measuring physical parameters of water samples collected.

4.1.3 Sample Collection and Analysis

In order to determine the level of heavy metal pollution, sampling of the area based on purposive but random sampling was undertaken. Sediment and water samples were collected from quarry and factory sites. Three kilogrames (3kg) of sediment and 500ml of water samples each were taken. The sediment samples were numbered TQ1s, TQ2s, TQ3s, TQ4s, FS1 and GM1 whilst the water samples numbered TQ1w, TQ2w, TQ3w, TQ4w, SW1 and SW2. The TQs' represent sediment samples and TQws represent water samples from quarry site. FS1 is the tailings from the factory whilst GM1 is the expansive clay used in the quarry. Below is a sketch (not drawn to scale) of some sampling points.

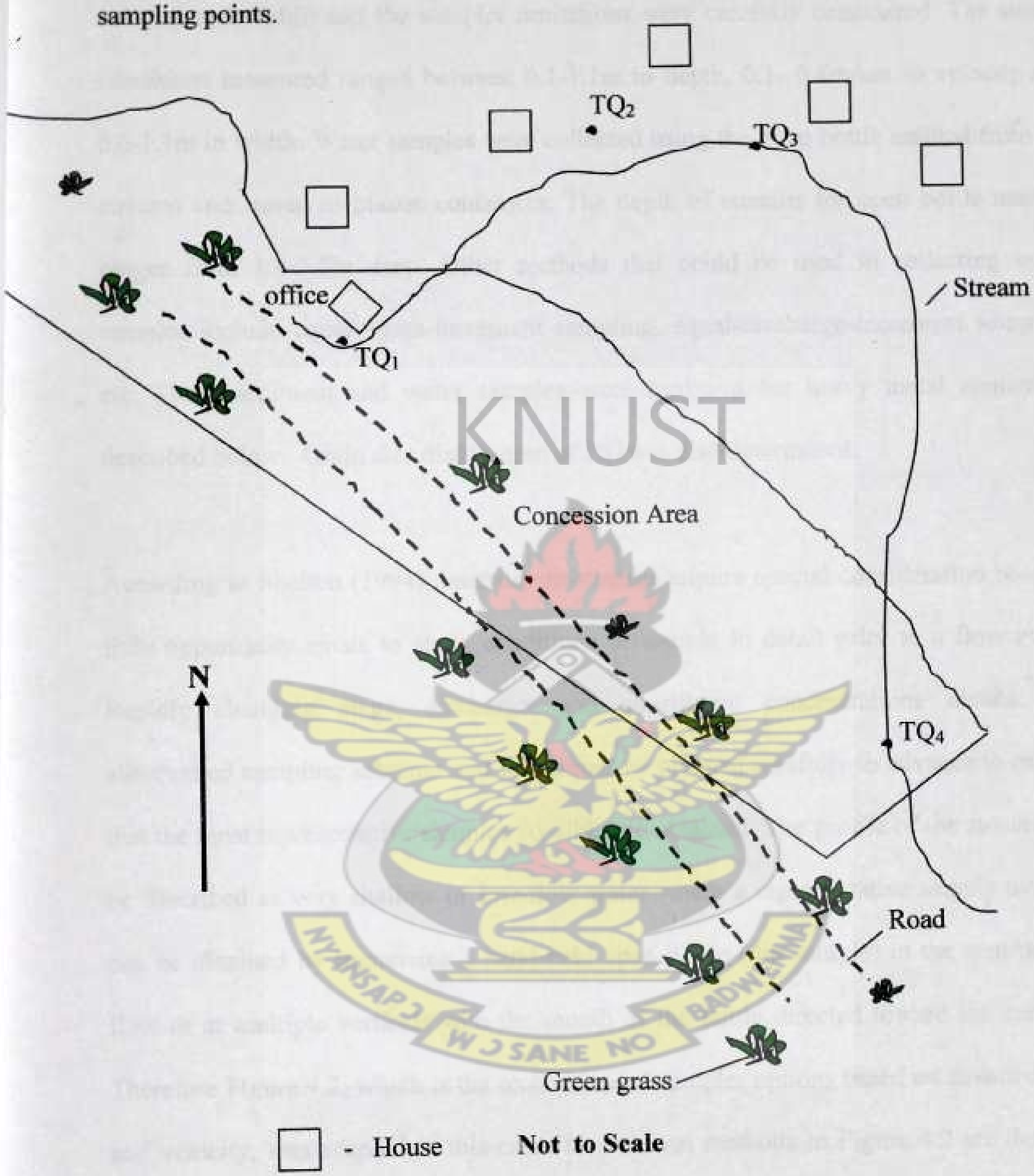

Figure 4.1: A Sketch of Some Sampling Points

To collect a representative sample of the stream chemistry, the stream conditions (depth, velocity and width) and the sampler limitations were carefully considered. The stream conditions measured ranged between 0.1-1.1m in depth, 0.1- 0.4m/sec in velocity and 0.6-1.1m in width. Water samples were collected using the open bottle method from the streams and stored in plastic containers. The depth of streams for open bottle method ranges from 1.8-2.7m deep. Other methods that could be used in collecting water samples include equal-width-increment sampling, equal-discharge-increment sampling etc. These sediment and water samples were analyzed for heavy metal content as described below. Grain size distribution of FS1was also determined.

According to Shelton (1994), intermittent streams require special consideration because little opportunity exists to study conditions or sample in detail prior to a flow event. Rapidly changing stage, discharge, and constituent concentrations dictate that abbreviated sampling schemes and techniques be planned carefully in advance to ensure that the most representative samples possible are obtained. The profile of the stream can be described as very shallow or low-flow water where a representative sample usually can be obtained by immersing a hand-held open bottle (dip sample) in the centroid of flow or at multiple verticals with the mouth of the bottle directed toward the current. Therefore Figure 4.2, which is the recommended sampler options based on stream depth and velocity, was adapted in this case. The various methods in Figure 4.2 are defined below.

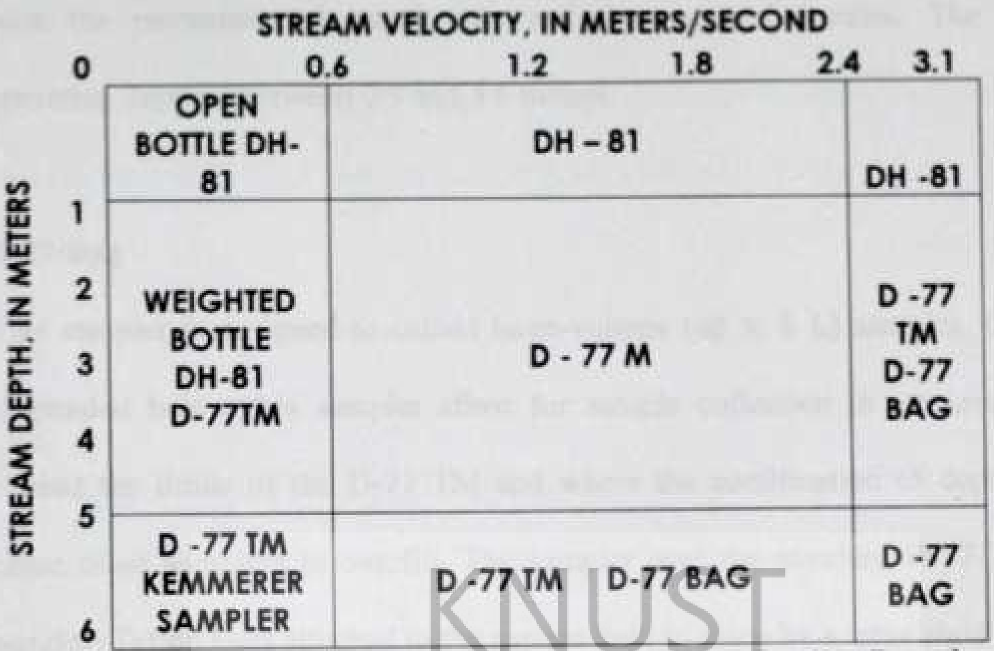

Figure 4.2: Modified Schematic of Suggested Water-Quality Samples for Various Stream Regimes (after Shelton, 1994)

DH-81

The DH-81 or an open-bottle sampler is used when stream flow conditions permit the stream to be waded. In natural streams the velocity should not be greater than 0.46m/s. The DH-81 sampler consists of a polypropylene collar screwed onto a plastic-coated wading rod.

D-77 TM

This 340kg sampler (epoxy coated to prevent trace-element contamination) collects large-volume (nearly 3 L) samples. This sampler is approved for flow velocities from 0.6 to 2.4 m/s, though some instability has been noted in turbulent flow velocities exceeding 1.8m/s. Depth limitations of the D-77 TM sampler are dependent on a combination of depth and velocity, preventing the sampler from overfilling when used with the recommended transit rate and the required nozzles. The recommended operating depth is between 0.9 and 4.6 meters.

D-77 Bag

This sampler is designed to collect large-volume (up to 8 L) samples. Counterweights suspended below this sampler allow for sample collection in streams where depths exceed the limits of the D-77 TM and where the combination of depth and velocity cause other samplers to overfill. The sampler uses the standard D-77 Teflon cap and nozzles. Teflon bags attached to the cap are held in place by a large rigid bottle, a frame, or both. The bag enables this sampler to collect larger volume samples. Its use is not recommended when velocities are less than 0.6m/s and should be used only when the D-77 TM is inappropriate.

Kemmerer

The Kemmerer which is a weighted bottle is a simple way to collect a water sample in slow moving streams with velocity less than 0.6m/s. A Kemmerer sampler is a 10.2cm-by 45.7cm. tube with end caps that close by means of a messenger and entrap a 4.2-L water sample inside. This sampler collects a point sample from a specific depth. Composite several point samples from one vertical for a depth-integrated sample.

Sediment samples were collected from the top 5 cm with perforated container measuring 16mm x 9mm (diameter) to drain off water from samples. Three different samples were taken at each location of 1m apart with the first sampling point being the reference point. These three samples for each location were then combined to form a single sample. The samples were then mixed thoroughly and sub-samples of sediment were collected into appropriate sample containers for analysis using the quartering system. The sub-samples of sediment were collected into appropriate sample containers (polythene bags) for analysis.

4.1.4 Quality Assurance and Control

Quality assurance and control was maintained by strict collecting and processing procedures, duplicate sampling, equipment blank samples, and a rigid cleaning procedure using detergent, hydrochloric acid and methanol. In order to obtain representative water samples and to avoid any contamination of the water samples,

- Plastic bottles were used for the sampling.
- The bottles were cleaned and rinsed at least twice with the water to be sampled.
- A few drops of nitric acid were added to prevent loss or breakdown of specific chemicals of water samples stored in plastic bottles.
- The bottles were completely filled and the cover replaced.
- Air bubbles were checked for by inverting the bottles.
- Samples were properly labeled with permanent ink.
- The containers were tightly closed and did not leak.

4.1.5 Preservation

Many of the ions normally present in natural waters change due to chemical and physical reactions, such as oxidation, reduction, precipitation, adsorption, and ion exchange, before analyses in a laboratory. Therefore, samples for many constituents must be stabilized by preservation. Some examples of preservative treatment are refrigeration to minimize chemical change caused by biologic activity and the addition of acid to prevent the precipitation of cations. A few drops of nitric acid, a preservative, were added to the water samples. Also the water samples were placed on ice in an ice-chest after collection and maintained until tests begun. With samples for mercury analysis, 0.5-1% of HNO_3 was added.

For preservation of sediment samples, the samples were placed on ice in an ice-chest as soon as collection and maintained on ice until tests begun. All sediments were packed into plastic sample containers so that no air space exists so as to avoid volatile organic chemicals to escape. This should reduce the chances of oxidation of the sediment.

4.1.6 Field analysis

Measurements of specific conductance, water temperature, dissolved oxygen, pH, and alkalinity could change dramatically within a few minutes or hours after sample collection. Immediate analysis in the field is required if results representative of in-stream conditions are to be obtained.

Therefore water temperature and dissolved oxygen were measured directly from the stream. Specific conductance and pH were measured directly from the stream so that these results will be from the same water matrix as the other chemical analyses. The single Watech Multimeter was used to measure specific conductance, water temperature, pH, turbidity and dissolved oxygen directly in the stream in the rainy season with different nozzles for each test. Each nozzle was placed in the centroid of the stream during measurement of each physical parameter and an average of three readings was taken. The nozzles were cleaned between discreet samples with distilled water, methanol, methylene chloride and finally sample water before usage. The results of physical parameters of water samples are shown in Table 4.1.

Table 4.1: Physical Parameters of Water

Parameter	WATER SAMPLES					
	SW1	SW2	TQ1w	TQ2w	TQ3w	TQ4w
Colour	Clear	Milky	Milky	Clear	Milky	Milky
Temperature °C	26.8	26.1	28.4	31.8	28.8	29.2
Conductivity µS/ cm	71	738	58	200	64	72
pH	6.3	7.2	6.5	6.71	7.45	7.4
Turbidity NTU	1.50	47.9	118	0.15	101	38.4
Dissolved oxygen	1.02	12.3	3.5	4.5	6.32	9.52
Coordinates N	05.63763	05.63770	10.69072	10.69226	10.68823	10.68823
E	00.12360	00.12357	00.80663	00.80539	00.80541	00.80305
Elevation	150m	88m	232m	230m	230m	219m

4.1.7 Laboratory Analysis of Sediment and Water Samples

Sediment characterization was done for sample FS1 (Appendix 7). The sample was analyzed for grain size using British Standard, BS 1377. The grain size was determined by drying about 3kg of sediment, breaking the loops up, and then quartering it up and sieving 50g of it through different-size meshes to establish percentages of gravel, sand, and silt+clay (BS 1377). The results are plotted in Figure 4.3.

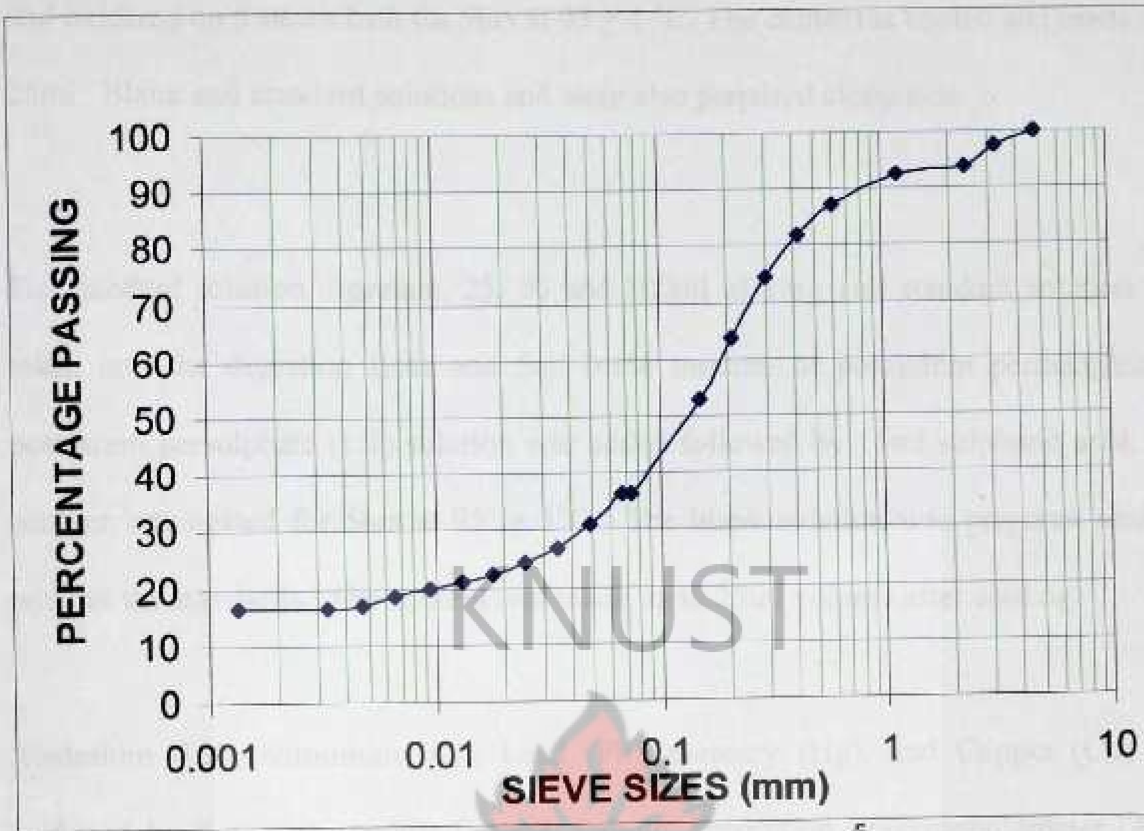

Figure 4.3: Particle-size Distribution (curve) of Sample FS1

For metal analysis, sediment samples were air-dried and ground into fine powder using pestle and mortar and passed through 1 mm sieve. Well-mixed samples of 1 g each were taken in 250 ml glass beakers and digested with 2 milliliters of nitric acid (HNO_3) and 6 milliliters of hydrochloride acid using Teflon bombs in a microwave digester until solution was clear. The resulting mineralized solution was boiled off to near dryness and restored to 50 milliliters in volumetric flask with distilled water. Digestion of sample was carried out to reduce interference by organic matter and to convert metals associated with particulates to form (usually the free metal) that can be determined by atomic absorption spectrophotometer. 100ml portion of each sample was accurately measured into 250ml Erlenmeyer flask. It is digested with 5ml 0.1% mixture of potassium permanganate – potassium persulphate (1:1) solution and 10ml sulphuric acid (conc.)

and oxidized on a steam bath for 5hrs at 95 ± 1 °C. The content is cooled and made up to 25ml. Blank and standard solutions and were also prepared along side.

For standard solution digestion, 25, 50 and 100ml of 1mg 1ml standard solution were taken into the digestion flask and 5ml 0.1% mixture of potassium permanganate – potassium persulphate (1:1) solution was added followed by 15ml sulphuric acid. The content was heated for 5hrs at 95° ± 1°C. The blank solution was prepared similarly without the standards. The content was made up to 25ml volume after cooling.

Cadmium (Cd), chromium (Cr), Lead (Pb), mercury (Hg), and Copper (Cu) were analyzed by flame or graphite-furnace Atomic Absorption Spectrophotometer (AAS), using PerkinElmer AAnalysis 100. The calibration curves were prepared separately for all the metals by running different concentrations of standard solutions. The instrument was set to zero by running the respective reagent blanks. Average values of three replicates were taken for each determination.

For mercury (Hg) analyses, the digests were analysed using the automatic mercury analyzer which uses the principle of Cold Vapour Atomic Absorption Spectrometry (CVAAS). This procedure is strictly used for the determination of mercury. Hg concentration in the sample is computed from standard graphs using the standard solutions and the blank. The results of these analyses are shown in Tables 4.2 and 4.3.

Table 4.2: Summary of Heavy Metals Concentration for Sediment Samples

Parameters	Cd mg/l	Cu mg/l	Zn mg/l	Cr mg/l	Pb mg/l	Hg mg/l
FS1	ND	0.27	0.47	1.34	1.03	0.42
GM1	ND	0.00	0.94	2.64	0.68	0.19
$TQ1_S$	ND	0.16	0.28	0.19	0.45	0.32
$TQ2_S$	ND	0.40	0.78	0.36	0.44	0.48
$TQ3_S$	ND	0.25	0.54	0.36	0.51	0.25
$TQ4_S$	ND	0.22	0.63	0.30	0.42	0.38

ND - NOT DETECTABLE mg - milligrams

Table 4.3: Summary of Heavy Metals Concentration for Water Samples

Parameters	Cd mg/l	Cu mg/l	Zn mg/l	Cr mg/l	Pb mg/l	Hg ng/l
SW1	ND	0.11	0.04	0.28	0.33	0.78
SW2	ND	0.12	0.09	0.24	0.35	0.85
TQ1w	ND	0.15	0.08	0.33	0.64	0.93
TQ2w	ND	0.15	0.13	0.31	0.39	0.42
TQ3w	ND	0.13	0.03	0.30	0.46	0.36
TQ4w	ND	0.14	0.00	0.35	0.37	0.84

ND - NOT DETECTABLE mg - milligrams ng - namograms

4.2 NOISE MEASUREMENT

4.2.1 Introduction

Noise measuring meter (Quest Technologies) with a sound level sensor was used to measure the intensity of the blasting noise. Measurements were taken during blasting at selected distant locations and at sometime period of the day to observe the changing levels of sound levels.

4.2.2 Scope

Blasting is an integral part of quarrying operations. The blasting process uses explosives (6gm cordtex) to fracture the rock, which enables mining to take place. The community may experience some impacts from blasting as a result of mining activities. There are two main impacts from blasting– overpressure and ground vibration. This research concentrates on only noise level pollution.

Noise pollution can be defined as sound or noise that is loud, annoying and harmful to the ear (Berghand B. et al, 1999). Loud sound can damage hearing, not only in humans, but also in animals (Anon., 1995). In general, sounds can be characterized by their frequencies (or pitch) and intensities (or loudness). The vibrations that produce sound are cyclical and are measured in hertz (Hz). One hertz (Hz) equals the number of cycles that occur per second. The sound pressure level is measured in decibels (dB).

4.2.3 Equipment

The materials and equipment used to measure noise pollution included Sound Level Sensor (Model 1900, Quest technologies, USA), a 30 meter measuring tape, a 5kg hammer, 30cm of ½' iron rod and an umbrella.

4.2.4 Experimental Procedure

Measurement of blasting noise was taken at selected location that is exposed to the direction of blasting towards the community. The first selected site for recording was at a distance of 4m from the point of blast and at a position between 1.2m and 1.5m above the ground. This position was maintained for all the other readings. The meter was initially calibrated at 1kHz, 114 db.

The range of noise for instrument was set between 60-120db. Twenty (20) ambient noise levels were performed at the various distances and their mean values were recorded at different distances from the blasting site. Twenty-four (24) experimental blasts were performed and 3 sets of blast-induced noise data were recorded at different distances from the blasting site.

The levels of noise associated with the blast were measured at various distances from the blasting site. The blast induced noise data provided were the average of three blasting results. These distances are 4m, 210m, 416m, 622m 828m and 2000m. The maximum explosive weight per blast was 1.65 kg.

4.2.5 Quality Assurance

The measurement and recording of airblast overpressure levels were undertaken by a person possessing both the qualifications and the experience appropriate to perform the exercise. No blasting measurement was taken when there was a temperature inversion or a heavy low cloud cover, since values of airblast overpressure will be higher than normal in surrounding areas. The blasting test was conducted generally between 10am and 1pm to minimise noise annoyance. Also blasting measurement was avoided at times when strong winds were blowing from the blasting site towards the community. The maximum instantaneous charge (MIC) in kg was the same through out the experiment.

4.2.6 Data Collection & Recording

Details of the distance/s from the blast site, ambient noise levels, airblast overpressure levels, time of recording and some meteorological conditions (temperature, relative humidity, temperature gradient, cloud cover, wind speed and direction) prevailing during measurements were recorded for this research (Table 4.4). The table contains results of the corrected ambient noise level and the average value of blasting noise.

Table 4.4: Average Ambient and Blasting Noise Levels

Distance from blast point /m	Ambient Noise Level / dB	Blast Noise Level / dB	Time GMT	Temperature ^{0}C
4	59.57	114.4	1032	29.2
210	63.89	112.4	1110	28.6
412	56.52	92.0	1135	28.9
618	64.03	87.7	1205	29.8
824	82.78	92.3	1150	30.3
2000	77.96	85.2	1215	30.5

4.3 DISCUSSION AND ANALYSIS OF RESULTS

4.3.1 Physical Parameters of Water Samples in the Field

The results of the physical parameters of study for all the measured water samples were given in Table 4.1. The measured temperature values of samples ranged from 26.1-31.8°C and were below the ambient temperatures of 31° C – 36° C set by EPA's maximum permissible level for ambient temperature.

Conductance is the reciprocal of resistance and is a measure of the capacity of water or other substance to conduct an electrical current and is reported in microsiemens per centimeter (μS/ cm). For conductivity, the maximum value of 738 μS/ cm recorded for sample SW2 was due to the factory's flocculants prepared of lime, steel shots etc. used as a lubricant in the sawing process of the gang saw. The next high value of 200 μS/ cm of TQ2w is a borehole water could be due to the quantities of dissolved substances in the groundwater. Thus, conductance indicates the concentration of dissolved solids in water. The values for conductivity in Table 4.1 were below the maximum permissible level of 750 μS/ cm set by EPA of Ghana for natural water bodies.

Measurements of pH at stream sites in the quarry and factory were taken from a raw (unfiltered) sub-sample. About five direct in-stream measurements were made to determine a mean value. These mean values for the water samples are 6.3, 7.2, 6.5, 6.71, 7.45 and 7.4 pH. The quality guideline of maximum permissible level of EPA of Ghana is 6-9 pH for natural water bodies. Therefore the above mean values fall within these accepted range.

Dissolved-oxygen measurements made represent the mean dissolved-oxygen concentration at the time of the measurement. The highest value of 12.3 recorded by SW2 from the factory is due to the constant exposure of flocculants to air (aeration) by pumping from the pond to the gang saw.

The measurement for turbidity was done twice and the average concentration is computed as shown in the Table 4.1. It can be noted that turbidity in samples SW1 and TQ2w (control point) yield low values and these samples are borehole and pipe water respectively. The turbidity value of TQ1w in the Quarry site is relatively high compared to other sampling sites. This is the collection point of the stream from the hills and explains the high value obtained. There is a general decreasing trend of turbidity values from TQ1w – 118, TQ3w – 101 and TQ4w – 38.4 NTU of the stream. Consequently, the final water that leaves the Quarry site downstream is below the maximum permissible level of EPA of 75 NTU for natural water bodies. The WHO (WORLD HEALTH ORGANISATION) establishes that the turbidity of drinking water shouldn't be more than 5 NTU, and should ideally be below 1 NTU. The source of drinking water SW1w and TQ1w have values of 1.5 NTU and 0.15 NTU respectively which are within the international guidelines for drinking water quality given by the World Health Organization.

4.3.2 Particle-Size Distribution

From the results of the particle size distribution, the breakdown was as follows: Gravel – 6.1%, Sand – 71.7%, Silt – 5.7% and Clay – 16.5%. Sand component in the soil is about two-thirds of the sludge material from the factory. Also the sample (FS1) is rich in quartz and feldspar because it is a granite material, most of the feldspars will weather to form clays, and a clayey sandy soil may occur. According to International Soil Science Society (ISSS) the soil can thus be described as clayey sand. The clayey sand is usually fairly porous and permeable and allows fair water drainage. Clayey sand soils have low cohesion and may be subject to instability when slopes are over steepened or soils are saturated.

4.3.3 Heavy Metals Concentration

A major environmental variable that determines the mobility of most metals in water is pH. As pH drops below approximately pH 10 or 11, most metals increase their solubility in water exponentially. At high pH's and low solubilities, metals may either precipitate out of solution or bind to solid particles in a process called adsorption (Graham, 1990). Analysis of six (6) elements, namely Cd, Cu, Zn, Cr, Pb, and Hg were made from soil and water samples from quarry site and the effluent discharge from the factory. An Atomic Absorption Spectrophotometer (AAS) model machine was used for the analysis but could not detect Cadmium in the water and soil samples. The summary of results for the metal concentration in soil and water samples is shown in Tables 4.2 and 4.3 respectively.

The measurements were done twice and the average concentration is computed as shown in Tables 4.2 and 4.3. The concentration levels of the heavy metals in soil samples are relatively high compared to the water samples. It can be noted that chromium concentration in samples GM1s and FS1 have a very high value of 2.64 mg/l and 1.34 mg/l respectively. The sample GM1s is a sample from the expansive clay used in the splitting of blocks and FS1 is from the sludge from the cuttings of the gang saw. Sample locations of TQ1s-TQ4s give the lowest value of chromium concentration and are within the maximum permissible level set by Environmental Protection Agency (EPA) of Ghana (Appendix 3) of 0.5 mg/l for chromium. All the water samples are within the accepted level set by EPA for natural water bodies.

The summary of results using the AAS machine is shown in Figures 4.4 & 4.5. Figures 4.4 and 4.5 show the graphical representation of the metal concentrations of the various samples. It should be noted that the unit of the concentration of elements for the samples is in mg/l except mercury (Hg) whose unit is in ng/l. The results of the mercury analyses for all the measured sediment and water samples are given in Figures 4.4 and 4.5.

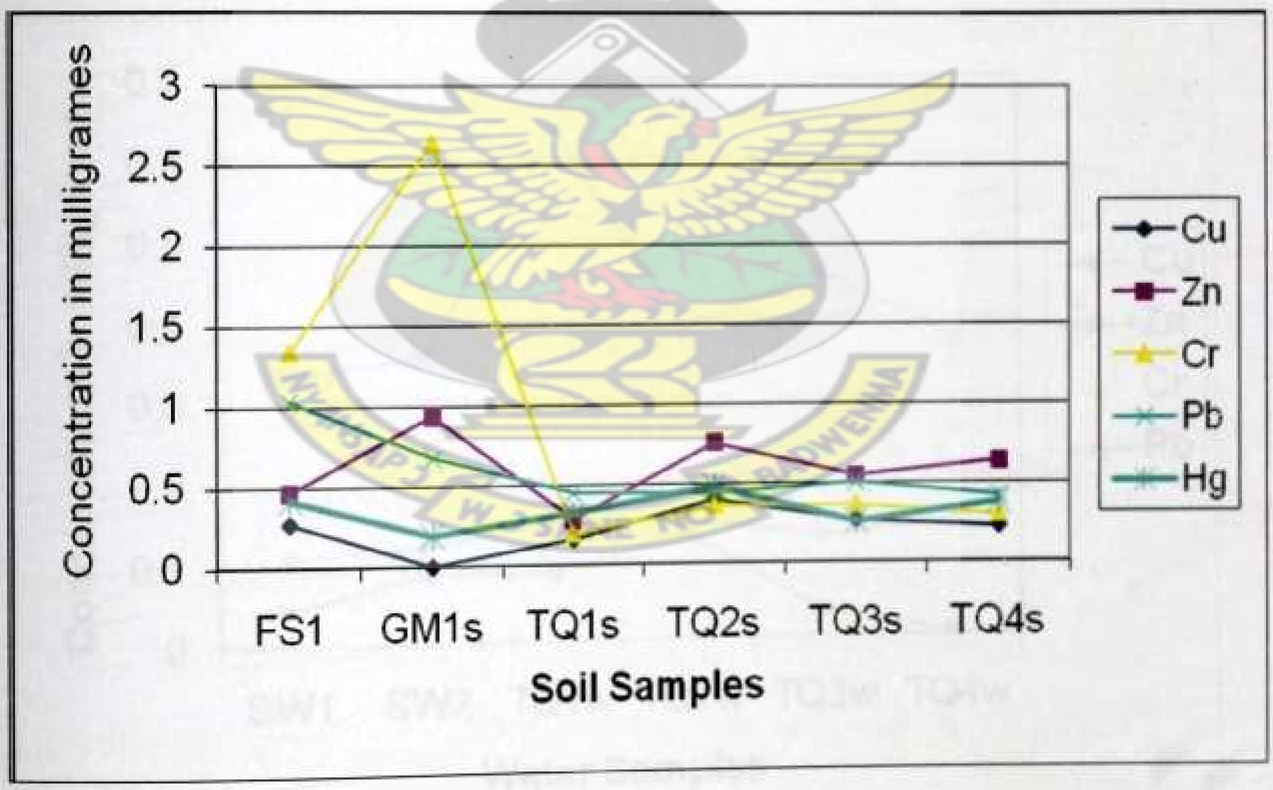

Figure 4.4: Metal Concentrations of Soil Samples

Lead concentration is highest in sample FS1 and decreases gradually from GM1s to TQ4s. Lead is considered as a good indicator of pollution by urban run-off (Teodinis et al., 2003). Its presence in higher concentration in sample TQ1w, as shown in the Figure 4.3, suggests that there is a route of lead discharge from the Quarry offices and the Village. It can also be noted that the lead concentration in soil samples is higher in value than in the water samples. This is partly due to soil and rocks containing 16ppm of lead (Alloway, 1995). Higher particulate lead concentration of sediment FS1 indicates the activities that occur at the processing of blocks into tiles. This is because the blocks that are being sawn contain 16ppm of lead on the average in rocks. The various metals products – steel shots, gangsaw blades etc. used in the factory also contains some amount of lead used in the manufacture of these products.

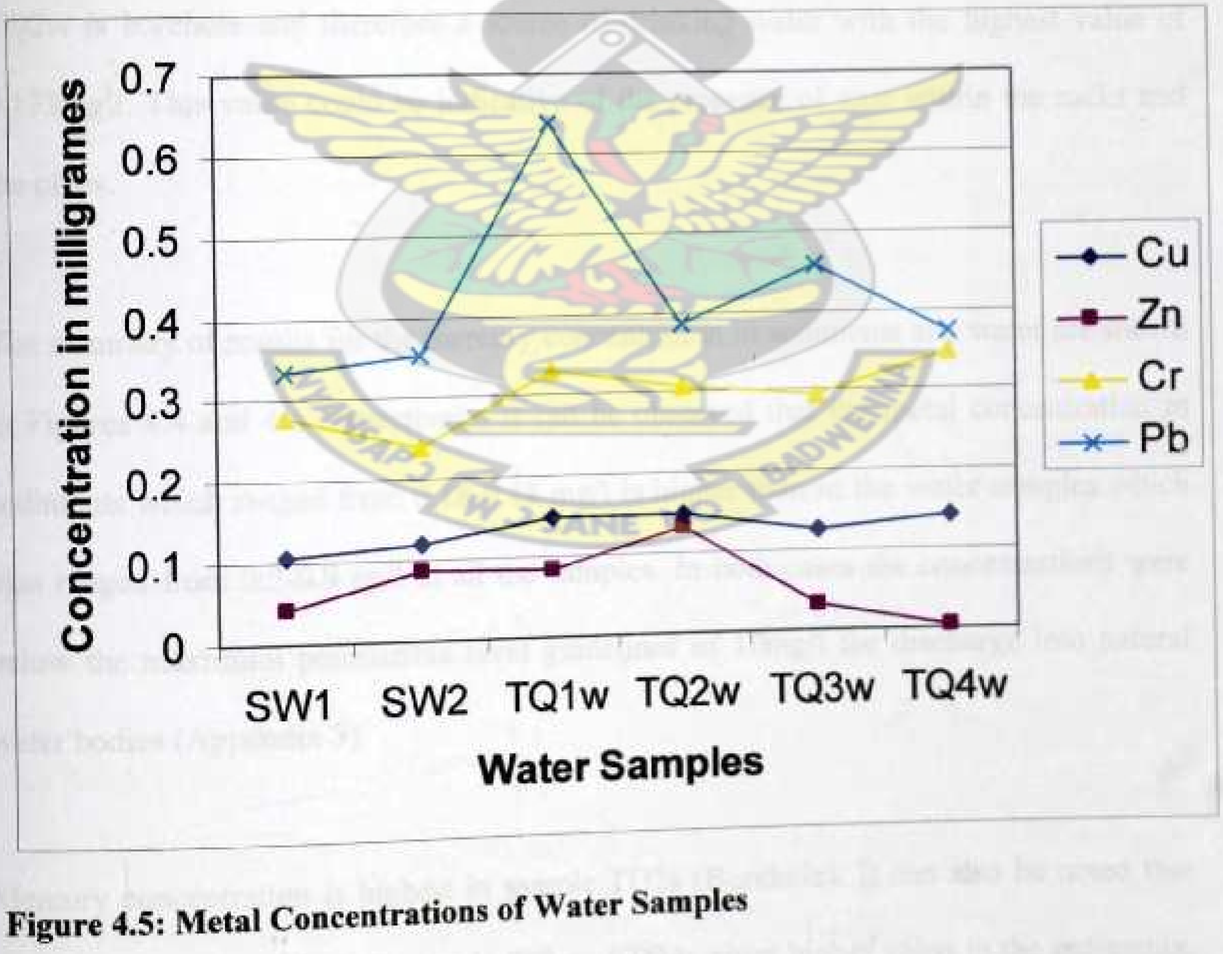

Figure 4.5: Metal Concentrations of Water Samples

Generally the copper concentration of soils samples is high compared with water samples. The concentration of cupper in soil samples ranges between 0-0.4 mg/l and that of water samples range between 0-0.15 mg/l. No presence of Cu is observed in sample GM1s. Sample TQ1w and TQ2w have the highest value of Cu quantified. TQ2w which is a reference point is water sample from borehole which contains copper pipes, fittings or solder joints and that explains its high value.

It can be observed that GM1s sample from the expansive clay has almost 1mg/l of zinc and this represented the highest value. The concentration levels of zinc analysed were generally between 0.3 – 1mg\l. The reference points of TQ2s and TQ2w had values of 0.8mg\l and 0.15mg\l respectively. No presence of zinc was observed in sample TQ4w. TQ2w is borehole and therefore a source of drinking water with the highest value of 0.133mg\l. This value could be indicative of the presence of zinc within the rocks and the pipes.

The summary of results for the mercury concentration in sediments and water are shown in Figures 4.4 and 4.6 respectively. It can be observed that the metal concentration in sediments which ranged from 0.18-0.48 mg/l is higher than in the water samples which also ranged from 0.3-0.9 ng/l in all the samples. In both cases the concentrations were below the maximum permissible level guidelines of 10mg/l for discharge into natural water bodies (Appendix 3).

Mercury concentration is highest in sample TQ2s (Borehole). It can also be noted that the mercury concentration in sample FS1 and TQ4s gives higher value in the sediments.

The higher particulate mercury concentration of TQ2s sample indicates the mercury used to amalgamate gold close to the borehole by some of the inhabitants who are galamsey operators.

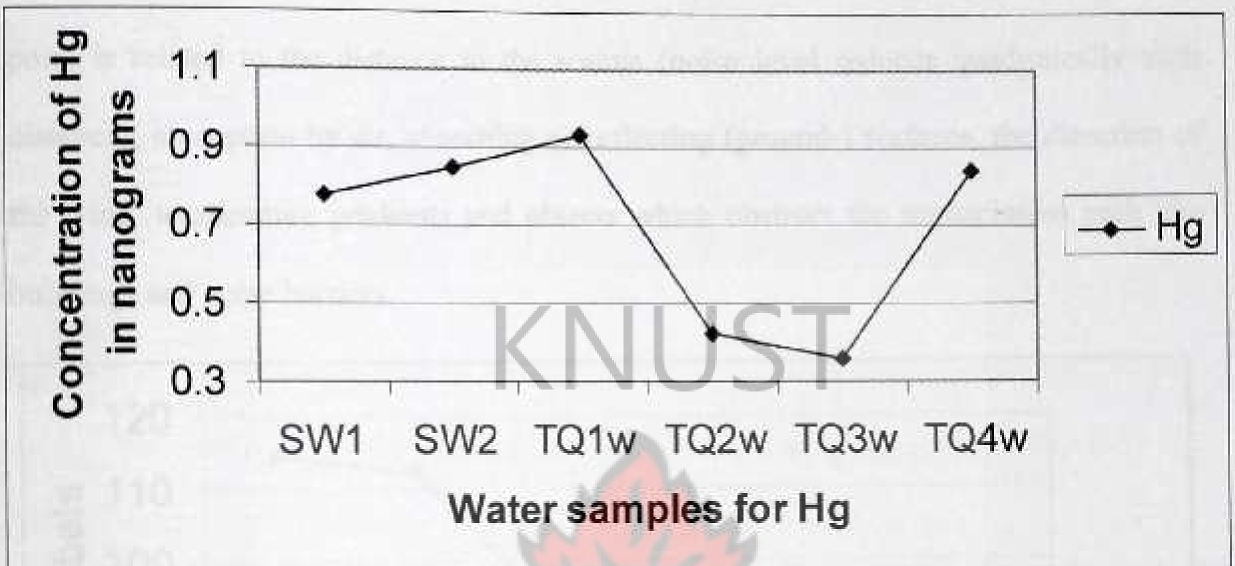

Figure 4.6: Hg Concentrations in Water Samples

Figure 4.6 shows the graphical representation of the mercury concentration of water samples. Level of mercury in the water samples was found to be much higher in TQ1w than the other samples. However, the concentration of mercury in samples SW1 and TQ2w which are sources of drinking water are below the Ghanaian guidelines of EPA for drinking water quality (< 0.5 μg/l) and several times below than the international guidelines for drinking water quality given by the World Health Organization (WHO) which is 0.006 mg/l (Anon., 2006).

4.3.4 Noise Pollution

The various factors affecting generation of noise/air overpressure include blast design parameters; topographical and meteorological conditions, such as direction and speed of wind, temperature, cloud cover, and humidity; use of detonating cord; weight of explosive charge per delay; total quantity of explosive used in a round of blast; etc.

According to Stoter, (1999), the noise transmission and the noise level at an observation point is related to the distance to the source (noise level reduces quadratically with distance), absorption by air, absorbing or reflecting (ground-) surfaces, the direction of the wind, temperature gradients and objects which obstruct the transmission path like buildings and noise barriers.

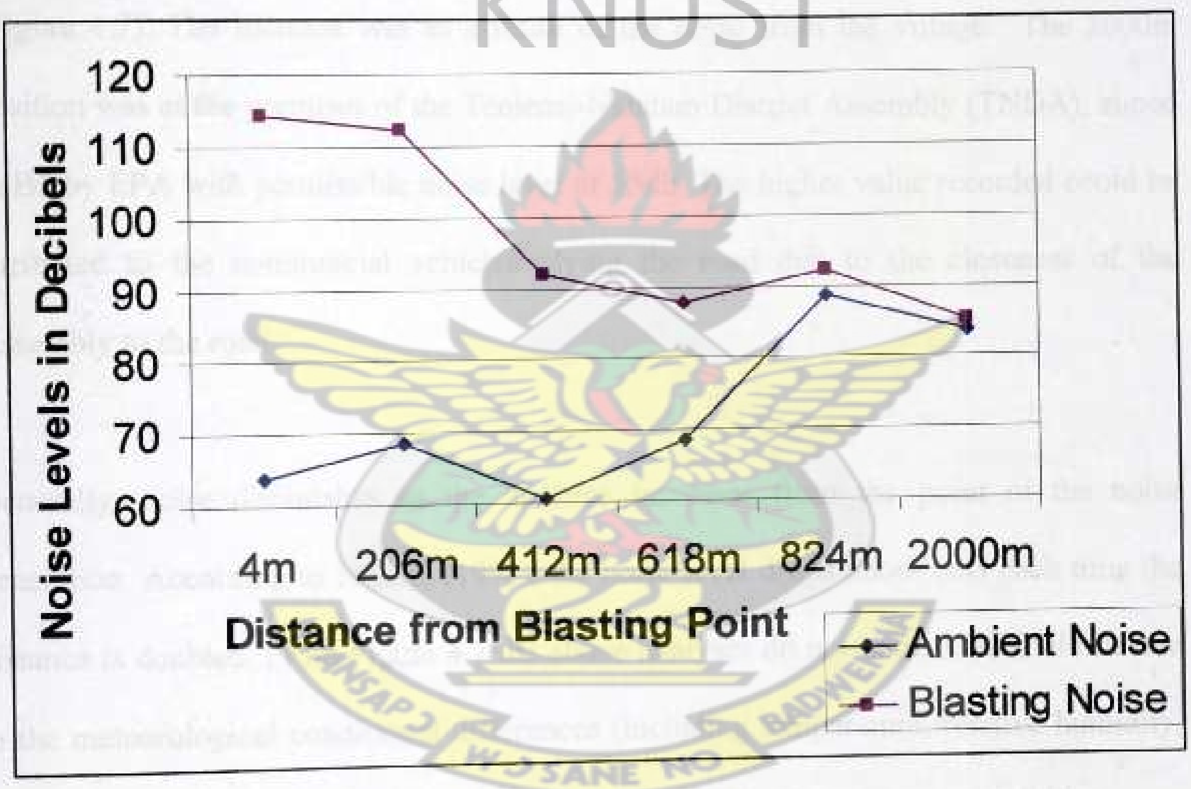

Figure 4.7: Average Ambient and Noise Levels in Decibels

Ambient noise generally is an accumulation of noises and does not have a single, identifiable source. The ambient noise level is lowest at the position 4m and highest at 824m position located within the village. The value of 59.57db measured at the quarry site was low because there was no activity taking place except the presence of the workers. The inhabitants in the village were carrying out daily routine of farming, rearing of animals, fetching of water, firewood etc. They farm around their houses and thus this as well as conversation and singing resulted in the high value. The EPA standard of ambient noise for areas with some commercial or light industry is 60dB (Appendix 4). Therefore 82.78dB far exceeds the maximum permissible level.

There was an increase of ambient noise levels from the quarry site towards the village (Figure 4.7). The increase was as a result of the noise from the village. The 2000m position was at the premises of the Tenlensi-Nabdam District Assembly (TNDA), zoned as B1 by EPA with permissible noise level of 55db. The higher value recorded could be attributed to the commercial vehicles plying the road due to the closeness of the Assembly to the road.

Generally, noise diminishes as the distance increases from the point of the noise generation. According to Nunez, (1998), the noise level drops about 6dB each time the distance is doubled. From Figure 4.7 the above analyses do not hold. This could be due to the meteorological conditional differences (including temperature, relative humidity, temperature gradient, cloud cover, wind speed and direction); and human activities.

For the blast induced noise, the first point of measurement recorded the highest value of 114.4 db. The results as indicated in Figure 4.7 were in descending order except at 824m position where there was an increase in value. This anomaly could be as result of some meteorological conditions and environmental factors such as temperature, relative humidity, wind speed and direction, trees, rocks etc..

From position 824m to 2000m where there is human settlement the values of 92.3 and 85.2 decibels are high. The Occupational Safety and Health Agency (OSHA) has set the thresholds level at 95 decibels and above for 4 or more hours per day as likely to induce permanent hearing impairment (Nunez, 1998). Blasting takes place once a day in a matter of seconds on the average. The ambient noise levels within the community are very close to the blast induced values (Figure 4.7).

Anon., (December 2006), recommended that blast induced noise should range between 115 dB to 120 dB or less in an annual period. The 92.3 dB and 85.2 dB recorded within the settlement is therefore below the maximum permissible level. During blasting workers could be protected from noise through the use of enclosed, air-conditioned cabs on equipment and, where possible necessary, the use of hearing protectors.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

5.1.1 Heavy Metal Pollution

1. The physical parameters of pH, temperature, conductivity, turbidity and dissolved oxygen of the water samples were below the maximum permissible levels of EPA of Ghana (Appendix 3).
2. Water samples and sediment samples from the Quarry site and factory were collected and chemically analyzed using the atomic absorption spectrometer to quantify heavy metal concentrations.
3. The study ascertained heavy metal pollution levels at the Quarry and Factory sites. The survey was conducted during the rainy season because most of the streams dry up during the dry season.
4. The concentrations of copper, zinc, lead, mercury, cadmium and chromium were quantified. In the case of sediment samples, it can be observed that the metal concentration in sediments is higher than in the water samples in almost all the sampling points.
5. Furthermore, the results showed that higher chromium concentration of GM1s and FS1 is observed from the samples taken and are above the standard set by EPA of Ghana. These results suggest that there could be a route of chromium discharged from Quarry and Factory into water bodies if not properly handled.

5.1.2 Noise Pollution

6. For an ideal "point" source, sound level decreases with distance due to the spreading out of sound waves originating from the source. This geometrical or spherical spreading results in a reduction of sound pressure level of 6 dB per doubling of distance from the source was not observed because of meteorological, environmental and physical conditions (grass, shrub, trees, rock etc.).

7. The Ambient Noise values increased from the Quarry site to the village. Generally, these ambient noise values were much higher than the maximum permissible level set by EPA of Ghana. The human activities contributed to the high values recorded among others.

8. The workers and the inhabitants in the village close by are not subjected to blast induced noise levels for more period of time during blasting which are likely to cause hearing impairment.

9. The measured values of blast induced noise recorded ranged from 85.2dB to 114.4dB. The blasting noise therefore generated was within the maximum permissible level of 115dB in annual period.

10. The study revealed that blasting in the early hours of the day caused annoyance and discomfort for the inhabitants.

5.2 RECOMMENDATION

The following are recommendation for further research and consideration:

5.2.1 Heavy Metal Pollution

1. More detail research work should be carried out on the sludge material (Sample FS1) to find the possibility of using it as a constructional material because of the high percentage of sand in it.
2. The sludge material (FS1) from the factory should be treated to remove the high levels of chromium before disposal.
3. The sample GM1s which is the expansive clay is not environmentally friendly because of the high levels of chromium in it. For a cleaner production a substitute is sought for GM1s or the disposal should be controlled.

5.2.2 Noise Pollution

4. Blasting should generally only be permitted during the hours of 9am to 5pm, Monday to Friday. During this period human activities are ongoing and therefore there is creation of noise which could minimise annoyance and discomfort that may be caused by the blasting activities.
5. A cleaner production method may be used which includes substituting explosive materials with the expansive clay (Fract.Ag) for secondary blasting during the dressing of blocks.
6. Trees and shrubs may be planted in front of building to provide some absorption for the sound.
7. At the quarrying site, vegetation buffer zones must be planted around the site especially towards human settlement.

8. The nearby communities should locate non-critical areas such as corridors, kitchens, bathrooms, etc. in the noisy side and critical areas each as bedrooms and living spaces at the quiet side.
9. The company should use part of the money voted for environmental management plan for the inhabitants to be educated through seminar, radio, TV, etc. about noise pollution.
10. There must be proper land use zoning which will lead to separation of activities which are incompatible due to noise levels. For example, heavy industrial area should be separated from residential areas by light industrial, recreational facilitates and/or retail activities.
11. Workers could be protected from noise through the use of enclosed, air-conditioned cabs on equipment and, where necessary, the workers should use hearing protectors such as earplugs and earmuffs to protect their ears from damage because of the localize nature of the source of noise.

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APPENDICES

Appendix 1 - Glossary Of Terms

Blast Monitor – an instrument that measures seismic waves along three mutually perpendicular axes (x, y, z) to determine peak particle velocity. Consists of geophones, electronic circuitry and a display.

Decibel – a unit of sound measurement which quantifies pressure fluctuations associated with noise and overpressure. Abbreviated as dB.

Bench height - a reference point peculiar to a specific site, used to determine elevations from the baseline (datum).

Blasting is the use of explosives to fracture –

- rock, coal and other minerals for later recovery; or
- structural components or other items to facilitate removal from a site or for reuse.

Burden is the distance between blastholes and the nearest exposed face.

dB(Lin Peak) – decibel associated with the maximum excess pressure in the overpressure wave. Lin represents linear - indicates that no weighting or adjustment is made to the measurement.

Independent variable - the variable you purposely manipulate (change).

Dependent variable - the variable that is being observed, which changes in response to the independent variable.

Controlled variables – the variables that are not changed.

Ground Vibration – motion of the ground caused by the passage of seismic waves originating from a blast. The rate of the ground vibration movement is called Peak Particle Velocity (PPV) and is measured in millimetres per second (mm/sec).

Maximum instantaneous charge (MIC) - the maximum amount of explosive in kg on any one specific delay detonator in any one blast hole.

Overpressure – a pressure wave in the atmosphere which is caused by the detonation of explosives. Overpressure consists of both an audible (noise) and inaudible energy is measured in dB (L in Peak).

Sound Level Meter – an instrument that measures sound pressure levels in *decibels*. Consists of a microphone, electronic circuitry and a display.

Stemming - inert material used to maximize the effect of an explosion, by filling the remainder of hole after they have been charged with explosives.

Appendix 2 - List of Abbreviations

As	Arsenic
Be	Beryllium
Cd	Cadmium
Cm	Centimeter
Cr	Chromium
Cu	Copper
EPA	Environmental Protection Agency
Hg	Mercury
Mg	Milligram
Mg/l	Milligrams per Liter
Ng/g	Namograms/grams
Ni	Nickel
Pb	Lead
Sb	Antimony
Se	Selenium
μg/l	Micrograms per Liter
Zn	Zinc
μS/cm	Microsiemens per Centimeter

Conversion Factors

Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
gallon (gal)	3.785	liter
inch (in.)	25.4	millimeter
inch per second (in/s)	25.4	millimeter per second
pound, avoirdupois (lb)	4.536	kilogram
pound per square inch (lb/in2)	6.895	kilopascal
square mile (mi2)	2.590	square kilometer

Temperature is given in degrees Celsius (C), which can be converted to degrees Fahrenheit (F) by the following equation: F= 1.8(C) + 32

Appendix 3 - Ghana EPA – Maximum Permissible Level

GHANA EPA – GENRAL EFFLUENT QUALITY GUIDELINES FOR DISCHARGES INTO NATURAL WATER BODIES	
PARAMETER	**MAXIMUM PERMISSIBLE LEVEL**
Ph	6 – 9
Temperature	<3°C above ambient
Colour (TCU)	200
Oil and Grease (mg/l)	10
BOD_5 (mg/l)	50
COD (mg/l)	250
Total Dissolved Solids (mg/l) (TDS)	50
Total Suspended Solids (mg/l) (TSS)	50
Turbidity (NTU)	75
Conductivity (μS/cm)	750
Total Coliforms (MPN/100m)	400
E. Coli (MPN/100m)	0
Ammonia as N (mg/l)	1.5
Nitrate – N (mg/l)	0.1
Flouride (mg/l)	1.5
Phenol (mg/l)	0.5
Sulphide (mg/l)	1.0
Total phosphate (mg/l)	2
Total Cyanide (mg/l)	1.0
Free Cyanide (mg/l)	0.1
Cyanide as Weak Acid Dissociable	0.5
Total Pesticides (mg/l)	0.5
Total Arsenic (mg/l)	1.5
Soluble Arsenic (mg/l)	0.1
Cadmium (mg/l)	0.1
Chromium (+6) mg/l	0.1
Total Chromium	0.5
Copper (mg/l)	1.0
Lead (mg/l)	0.1
Nickel (mg/l)	0.5
Selenium (mg/l)	1.0
Zinc (mg/l)	2.0
Mercury (mg/l)	10
Silver (mg/l)	0.1
Tin (mg/l)	2.0

Source: Anon., (1997)

Appendix 4 - Schedule 4 - (Regulation 10) - Ambient Noise Level Standards

ZONE	DESCRIPTION OF AREA OF NOISE RECEPTION	PERMISSIBLE NOISE LEVEL IN dB (A)	
		DAY 0600 - 2200	NIGHT 2200 – 0600
A	Residential areas with low or infrequent transportation	55	48
B1	Educational (school) and health (hospital, clinic) facilities	55	50
B2	Areas with some commercial or light industry	60	55
C1	Areas with some light industry, places of entertainment or public assembly, and places of worship located in this zone	65	60
C2	Predominantly commercial areas	75	65
D	Light industrial areas	70	50
E	Predominantly heavy industrial areas	70	70

Permissible adjustment to measured noise level for intermittent noise

Cumulative period for which intermittent noise is present in any hour	Maximum allowable adjustment above the permissible ambient level (dB_A)
More than 15 minutes	±
Exceeding 5 minutes but not Exceeding 15 minutes	-5
Exceeding 1 minute but not Exceeding 5 minutes	-10
Not exceeding 1 minute	-15

Note 1 : Schedule 4 is for the calculation (of noise level) from its duration of the potential annoyance level where any noise present and measured is intermittent and not measured by statistical method.

Note 2 : These duration adjustments are not applicable when noise being assessed includes discrete noise impulses or consists of repetitive noise with an impulsive character e.g. hammering or riveting.

Note 3 : Ambient noise level standards in dB(A) refer to Rating Level Lr.

Appendix 5 - Questionnaire for Employees and Inhabitants

COLLEGE OF ENGINEERING

KNUST

IMPACT OF DIMENSION STONE PRODUCTION ON THE ENVIRONMENT. A

<u>CASE STUDY AT GRANITES & MARBLES CO. LTD., ACCRA, GHANA.</u>

Questionnaire for Employees and Inhabitants

Answer the following questions and tick the appropriate answer or fill in the space provided.

1. What kind of Environmental impact do you experience?

   (a) Dust (b) Noise (c) Water pollution (d) Land

2. Do you have any idea as to the items the company uses as inputs for production?

   (a) Yes (b) No

3. Are you happy about the establishment of the company within your area?

   (a) Yes (b) No

If no, give reasons ....

....

4. What are the sources of your water and which of them do you drink from?

....

....

....

......

5. Has your water source been polluted by the company?

   (a) Yes (b) No (c) I don't know

6. What period does the company operate?

(a) Day time (b) Night time (c) Both times

7. Are you happy about the time of operation?

(a) Yes (b) No

8. What operations produce dust in a typical working day?

(a) Clearing (b) Blasting (c) Drilling (d) Cutting of slab

9. Do workers wear nose mask during operations?

(a) Yes (b) No

10. Do you experience dust during drilling at the surrounding community?

(a) Yes (b) No

11. Which of these operations produce louder noise?

(a) Machinery (b) Blasting (c) Drilling

12. Do workers use earplugs?

(a) Yes (b) No

Appendix 6 – Statistical Analysis of Responses

SUMMARY OF POTENTIAL ENVIRONMENTAL IMPACT FROM RESPONSES

ENVIRONMENTAL VARIABLES	FREQUENCY	PERCENTAGE
Noise	7	41
Dust	5	29
Water	2	12
Land Degradation	3	18
Total	17	100

Appendix 7 Results of Particle Size Distribution

GRADING TEST Total Dry Weight (g) 50.0

Sieve size BS designation	Metric (mm)	Weight retained (g)	Percentage Retained (%)	Percentage passing (%)
3 in	75.00			
2 ½ in	63.00			
2 in	53.00			
1 ½ in	37.10			
1 in	26.50			
¾ in	19.00			
½ in	13.20			
⅜ in	9.50			100.00
¼	6.35		0.00	100.00
3/16	4.75		0.00	100.00
1/8	3.18	1.27	2.54	97.46

Total Dry Weight (g) 50.0

Sieve size BS designation	Metric (mm)	Weight retained (g)	Percentage retained (%)	Percentage passing (%)
No. 7	2.36	1.77	3.54	93.92
No. 14	1.18	0.70	1.40	92.52
No. 25	0.600	2.64	5.28	87.24
No. 36	0.425	2.61	5.22	82.02
No. 52	0.300	3.84	7.68	74.34
NO. 72	0.212	5.39	10.78	63.56
No. 100	0.150	5.30	10.60	52.96
No. 200	0.075	8.35	16.70	36.26

HYDROMETER TEST

Total Dry Weight (g) = 50.0 S.G = **2.6502**

Time	Temp. T (oc)	Elapsed time, t (min)	Direct hydrometer reading, RH'	Transformed hydrometer reading, Rh'	Rh=Rh'+Cm	Effective depth, Hr (mm)	Viscosity, h (mPa.s)	D (mm)	M_c	$R_d=R_h'+M_c-R_o'$	K (%)
11:52	28.5	0.5	1.0125	12.5	13.0	149.25	0.819	0.0673	1.9218	11.32	36.37
	28.5	1.0	1.0108	10.8	11.3	155.97	0.819	0.0487	1.9218	9.62	30.90
	28.5	2.0	1.0096	9.6	10.1	160.71	0.819	0.0349	1.9218	8.42	27.05
	28.5	4.0	1.0088	8.8	9.3	163.87	0.82	0.0249	1.9218	7.62	24.48
	28.5	8.0	1.0081	8.1	8.6	166.63	0.82	0.0178	1.9218	6.92	22.23
	28.5	15.0	1.0077	7.7	8.2	168.21	0.82	0.0130	1.9218	6.52	20.95
	28.5	30.0	1.0074	7.4	7.9	169.40	0.82	0.0093	1.9218	6.22	19.98
	28.5	60.0	1.0070	7.0	7.5	170.98	0.82	0.0066	1.9218	5.82	18.70
	28.5	120	1.0065	6.5	7.0	172.95	0.82	0.0047	1.9218	5.32	17.09
	28.5	240	1.0063	6.3	6.8	173.74	0.82	0.0033	1.9218	5.12	16.45
	29.5	1440	1.0060	6.0	6.5	174.93	0.80	0.0013	2.1991	5.10	16.38