

UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

**LIFE-CYCLE ASSESSMENT (LCA) OF LIMESTONE PRODUCTION IN THE LOWER
MANYA AND YILO KROBO MUNICIPALITIES, GHANA**

BY

GIFTY NAKO ANGMOR

(10446263)

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DECLARATION

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



.....
Date: 26th July, 2021

Gifty Nako Angmor

(Student)



.....
Date: 26th July, 2021

Prof. Augustine K. Donkor

(Principal Supervisor)



.....
Date: 26th July, 2021

Dr. Daniel Nukpezah

(Co-Supervisor)

ABSTRACT

Many limestone deposits occur naturally in Ghana and a preliminary investigation by the Geological Survey Department revealed that there are about 3 million tonnes of limestone in the Oterkpolu limestone deposits. This has led to several limestone quarry activities along the Odumase to Asesewa road in the Eastern Region of Ghana. The environmental impacts associated with limestone quarrying have been an issue of local and global concern, in the search for sustainable mining. Therefore, this work assessed the energy consumption and environmental impacts of limestone production in the Lower Manya and Yilo Krobo Municipalities using a life cycle assessment approach. From the study, Yongwa quarry had the highest limestone production of 723,600 tonnes, followed by Klo- Begoro quarry and ABL quarry with a production of 117,735 tonnes and 113,670 tonnes respectively. Also, it was found that Yongwa and ABL quarry use only diesel fuel as energy for limestone production while Klo-Begoro quarry used electricity and diesel as their energy source which influenced the extent of their environmental impacts. The resource category resulted in the greatest environmental impact of 68% followed by climate change (24%), human health (6.8%) and 1.4% for ecosystem quality. Also, from the normalized results, natural land transformation resulted in the biggest environmental impacts for all three quarries. Explosives were the main source of impacts for ABL and Klo-Begoro quarries while diesel usage served as the primary source of impact for the Yongwa quarry. Malaria, cold and catarrh are the most well-known ailments among the quarry workers, with members of the community around the quarry companies complaining of the vibrations from blasting affecting their buildings.

DEDICATION

To my beloved mother, for her endless love, support and encouragement.

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LIST OF ABBREVIATIONS

Abbreviation	Description
ABL	Agyeman Bediako Limited
CO ₂	Carbon (IV) oxide
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
GEPA	Ghana Environmental Protection Agency
GHGs	Greenhouse Gases
ISO	International Organization for Standards
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
NDVI	Normalized Difference Vegetation Index
NO ₂	Nitrogen (IV) oxide
PM ₁₀	Particulate Matter 10
SDG	Sustainable Development Goal
SO ₂	Sulphur (IV) oxide
SOE	State of the Environment
TSP	Total Suspended Particles

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Rapid urbanization and high population growth result in increased infrastructural growth, a burden on natural resources, thereby raising sustainability concerns. The concept of sustainability is still evolving, giving room to variable interpretation across the world as well as different policy recommendations. To this end, governments are seriously promoting the advancement of sustainable practices like sustainable mining and mineral production. However, most natural resources are being exhausted, for example limestone, an important component in cement production and a main source of material for building construction.

Extraction of Limestone is a common activity within mountainous areas in Ghana and has existed since antiquity (Nartey et al., 2012). Limestone mining has contributed remarkably towards Ghana's economic development. As at November, 2016, a total of 259 quarry companies have registered with the Ghana Environmental Protection Agency (GEPA) (EPA, 2017). Limestone quarrying is an energy intense activity that needs significant amount of fuel. In addition, the extraction of limestone does involve a significant quantity of explosives, particularly in sites where traditional working methods are used. Its exploitation also comes with associated environmental impacts such as ecosystem degradation, global warming, noise emission, fugitive dust issues, biodiversity disturbance and high fuel and material consumption.

As indicated by Kittipongvises (2017), in spite of the developing significance of limestone, there has been an expanding worry over the negative environmental impacts connected to its extraction and use, hence there is an urgent need to look at sustainable limestone mining.

There is yet to be a globally acceptable practice on sustainability, and this is partly due to the different development levels of countries in the world (McCann and Rynne, 2010). However, the 2015 United Nations Sustainable Development Goals (SDGs) spell out objectives towards achieving sustainability in all of its member states, of which Ghana is a member.

The impacts of sustainable limestone quarrying have implications in stirring the achievement of the SDGs such as SDG 7 (affordable and clean energy), SDG 13 (climate action), SDG 8 (decent work and economic growth) and SDG 15 (life on land). Therefore, addressing the impacts of limestone mining will contribute to the achievement of the SDGs associated with it.

The high energy consumption involved in the mining of limestone has repercussion on SDG 7; (affordable and clean energy), since most of the energy used in the mining of limestone, such as diesel is not sustainable or renewable. According to Ghana's state of the environment report (Ghana SoE 2016), there is a general rise in emissions from the energy sector as well as increased emissions of Green House Gases (GHG). Increased Green House Gases (GHG) emission therefore pose challenges to the goal of climate action (SDG 13) which is an urgent global sustainability problem. Accordingly, there is the need to adopt good policies and procedures to decrease the environmental impact of limestone production, as it could be predicted that energy and GHGs which impact mining activities will turn out to be substantially more critical. Additionally, to acknowledge sustainability, mining industries can add to it by drawing in with crucial partners to improve various practices so as to lower their environmental impacts.

There are various tools utilized for examining the natural presentation of the quarrying activities but this work employed the use of the Life Cycle Assessment.

The Life Cycle Assessment approach is broadly used to help sustainability. It assesses the environmental impacts of products, systems and services at all stages in their life cycle (ISO 14001:2004).

The primary justification for using the LCA approach is that it permits distinguishing and forestalling the weight moving from one life cycle stage to another that occur if effort for bringing down environmental impacts in a single stage unexpectedly makes environmental impacts in different cycles or stage (Michael et al., 2018).

It additionally provides the likelihood to recognize gaps in the environmental impacts and thus allow comprehension of how to further develop cycles to achieve diminished environmental impacts. The LCA relies on all around recognized standards and is extensively seen as the most ideal tool to manage the environmental impacts of an item on the environment through its life cycle.

1.2 Statement of the Problem

Although many limestone deposits occur in Ghana, the Oterkpolu limestone deposits in the Yilo Krobo Municipality of the Eastern region of Ghana are part of the five deposits that may be considered for economic exploitation (Gaze, 1987). A preliminary investigation into this limestone deposits by the Geological Survey Department revealed that there were about 3 million tonnes of limestone.

This has led to several limestone quarry activities along the Odumase to Asesewa road. The environmental impacts associated with limestone quarrying have been of public concern, hence global interest in sustainable mining. However, there is a paucity of data on Limestone quarrying activities in Ghana. The few studies on this class of mining showed many negative impacts (Nartey et al., 2012).

According to Maepa et al. (2017), not much Life Cycle Assessment studies have been conducted in West Africa especially in Ghana, Nigeria & Ivory Coast and as such more of such studies are needed in these countries.

A review of the literature did not also reveal studies on the total energy and materials used as well as emissions into the environment and their potential impacts via LCA of limestone quarrying in Ghana and particularly the Lower Manya and Yilo Krobo Municipalities. This study aims to fill these knowledge gaps by using LCA to assess the environmental impacts and energy consumption of limestone production in the Lower Manya and Yilo Krobo Municipalities.

1.3 Justification for the Study

Several studies using Life Cycle Assessment as a tool have been documented in the developed world (Agwa-Ejon et al., 2018; Kittipongvises, 2017; Norgate et al., 2012) on the environmental impacts of quarrying operations as well as mining. However, from a systematic review by Maepa et al. (2017), they discovered 31 environmental and life cycle assessment studies in Ivory Coast, Nigeria and Ghana which indicate few studies using LCA as a tool in West Africa. Also, previous investigations in Ghana by Nartey et al. (2012) on limestone quarrying focused mainly on environmental impacts of limestone mining without considering the embodied energy, materials and particulate releases into the environment. Likewise, from a systematic review by Aboka et al. (2018), the few studies on mining in Ghana conducted never employed LCA framework in their assessment. However, knowledge on LCA of limestone quarrying is essential for sustainable mining. Hence, the relevance of this research was to fill knowledge gap of employing LCA in assessing the environmental impact associated with limestone production.

1.4 Aim of the Study

The purpose of the study is to assess the energy consumption and environmental impacts of limestone production in the Lower Manya and Yilo Krobo Municipalities.

The scope is based on the cradle-to-gate approach which looks at the limestone from extraction to the finished product (crushed limestone) as compared to the cradle to grave which looks at the limestone from the extraction to the end of life.

1.5 Research Objectives

The main purpose of the study can be answered through the following objectives, which are to:

- i. Document the quantity of limestone produced monthly/annually and determine which quarry has the highest limestone production monthly/annually.
- ii. Document the type of energy used in the limestone production and determine the embodied energy of the limestone production at the site monthly/annually.
- iii. Assess the health implication of limestone production on workers and community members.
- iv. Assess the potential environmental impacts associated with limestone production at the study area.

1.6 Research Questions

These questions guided the collection of relevant data:

- i. Which limestone quarry has the highest limestone production monthly/ annually?
- ii. What are the types of energy used in limestone production and the amount of embodied energy of limestone produced at the site monthly/annually?
- iii. What are the health implications of limestone production on workers and community members?
- iv. What are the environmental impacts associated with limestone production?

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents review of works done which relates to this study. It covered various issues on energy consumption in the mining industry and life-cycle assessment studies. References were taken from several sources which are closely related to the topic of the study. The chapter dealt with limestone production and its environmental impacts such as reduced photosynthesis, damage to biodiversity, noise, habitat/other potential impacts, nuisance effect, visual intrusion, water quality etc. In addition, health impacts and LCA studies (Merbr LCA concept with LCA studies) were looked at.

2.2 Limestone production and its Environmental Impacts

Limestone is a mineral which occurs naturally and fundamentally made of calcium carbonate sedimentary stone. It is found in numerous structures and is arranged as far as its starting point, synthetic creation, structure, and geographical development and happens generally all through the world, and is a fundamental crude material for some ventures (Oates, 1998).

Limestone is used vastly as a building material, an essential component of concrete, as a total for the base of roads, as white pigment or filler in items like toothpaste or paints, as a chemical feedstock for the creation of lime, as a soil conditioner, or as a popular decorative addition to rock gardens (King, 2020). Like most other sedimentary rocks, most limestone is made out of grains.

Limestone quarrying process creates possible negative effects on the environment both during the

quarrying process and even after the quarry site is closed. This has prompted most countries in the world to use guidelines to direct the negative impacts of mining tasks.

(<http://www.answers.com/theme/mining>.).

Most of the environmental effects created by quarrying are caused during extraction and production. This significant effect might be joined by loss of natural surroundings, commotion, dust, vibrations, substance spills, disintegration, sedimentation, and neglect of the mined site. Most of the effects are brief and most are not difficult to anticipate and simple to notice. Most designing effects can be controlled, relieved, kept at average levels, and confined to the quick area of the total activity by utilizing necessary operational practices that utilize accessible designing methods and innovation.

There are huge environmental impacts related to quarrying, including reduced photosynthesis, damage to biodiversity, noise, habitat/other potential impacts, nuisance effect, visual intrusion, noise, blasting, water quality etc. (Department of the Environment, Transport and the Regions, 1999; treasury.gov.uk/home.htm).

Nartey et al. (2012) assessed the impacts of quarrying on some villages in the Lower Manya Krobo Municipality (Ghana) and the methods of mitigating them. The study made use of Environmental Impact Assessment as a tool. It was observed that though limestone quarrying was beneficial to the people in the study area, it came along with various negative environmental impacts.

Also, Eshiwani (2014) investigated the effect of quarrying practices on the environment in Kenya and set up that there was an association between the quarrying action and the prosperity of both the quarry workers and region occupants. From his work it was found that workers have protectives and paying little attention to the significant role those quarrying exercises played in the financial development; it came about into adverse consequences to the climate, for example land debasement. Also, large portion of the quarry organizations don't adhere to the set rules of environmental enactment, for example, the Occupational Safety and Health Act 2007.

Again, Mbandi (2017) found out that there was a significant association between quarrying and environmental degradation. The study indicated that degradation of environment in Kitengela was as a result of unregulated quarrying activities hence recommended the strict enforcement of existing laws on quarrying.

In a research, Ata-Era (2015) inspected the operational strategies utilized in quarrying exercises by quarry organizations, and basically surveyed the monetary, natural and social impacts of quarrying exercises, and the current alleviating measures attempted by these organizations in the Wenchi District of Ghana. The results revealed that all the quarrying associations in the Region used the open cast procedure for quarry extraction with both essential and current equipment. The adverse consequences observed were the decimation of normal environmental factors, and breaks in structures.

Sharma et al. (2013) emphasized that constant limestone mining in Solan Region of Himachal Pradesh has led to the land being destroyed.

Limestone quarrying in Mussoorie Mountains in Meghalaya, India, have prompted loss of topsoil and therefore speeding up of soil disintegration in the zone, bringing about siltation of close by waterways and streams and rural fields (Rajwar, 1982). Essentially, Ravichandran et al. (2009) contended that the dirt system of Madukkarai, limestone mine, was accounted for to be influenced either straightforwardly or by implication showing low supplement content contrasted with the dirt in agrarian territories. Hanief et al. (2007) detailed adjustment in soil surface because of limestone mining in Sirmaur area of Himachal Pradesh.

In a study at the Oduglase quarry site, Koranteng and Adu-Asare (2018) concluded that there has been modification of the vegetation cover around the quarry. Identified drivers were the development and expansion of the quarry site, the construction of access road and the switch in livelihoods of local community members from Oduglase to those that depend on extracting biological resources, unsustainable farming and wood logging practices, social exclusion, and reforestation programme around the quarry site.

Etim and Adie (2012) also found out from their study that limestone production led to the leak of metals into the soil close to the quarry sites. The Soil samples had low organic matter content and were also contaminated with heavy metals after analyzing the soil samples in the laboratory.

However, Afeni et al. (2012) found no adverse effect of limestone production on the soil condition in Ewekoro (Nigeria) after assessing the impact of limestone production on the soil and water condition in the laboratory.

2.3 Health Impacts

The potential wellbeing impacts of dust are firmly identified with molecule size. Airborne particles changes from under $0.1\mu\text{m}$ up to about $500\mu\text{m}$ or a large portion of a millimeter. Human health impacts of airborne dust are predominantly connected with particles under $10\mu\text{m}$ in size, usually named PM_{10} , which are sufficiently small to be enter into the lower respiratory tract.

PM_{10} particles represent a more prominent peril to human wellbeing since they are of adequate size to go through the filtration components in the upper respiratory tract and enter past the larynx to the lower aviation routes. Openness to PM_{10} particles has been connected with conditions including heart and lung illness, pneumonia, loss of lung capacity and asthma. PM_{10} particles in metropolitan regions can emerge from burning cycles (State of Queensland Environmental Protection Agency, 2008.)

Particulate air contamination is related with a scope of consequences for wellbeing (from particles under $10\mu\text{m}$ in breadth) remembering impacts for the respiratory and cardiovascular frameworks, asthma and mortality (Banez et al., 2010). Ebb and flow research propose that asthma is brought about by a blend of hereditary and natural factors, yet that particulate matter inward breath builds the seriousness of asthma (NASA, 2001).

Olusegun et al. (2009) checked degrees of suspended particulate matter in the ambient air in and around chosen quarries and broke down the pervasive medical conditions endured by nearby residents and quarry laborers. They likewise surveyed the inhabitants' attention to the negative implications of living in nearness to quarry locales. Suspended Particulate Matter (SPM) meter was utilized to screen the degree of particulate matter (PM_{10}) inside and around five quarry destinations selected for their study. Results of the investigation showed that the highest mean SPM levels among the selected quarries shift between $26.03 \pm 1.36 \text{ mg/m}^3$ and $11.03 \pm 1.52 \text{ mg/m}^3$. SPM levels declined fundamentally ($p > 0.05$) with distance from the penetrating and smashing areas at every of the quarry destinations. The mean SPM level significantly reduced to $4.85 \pm 0.20 \text{ mg/m}^3$ and $3.67 \pm 0.40 \text{ mg/m}^3$ at 25metres away from the quarry destinations. Both psychological and health problems suffered by nearby residents include shock (46.0%), nasal infection (29.2%), and asthma (4.6%). The quarry workers suffered predominantly from cough (26.0%), catarrh (20.0%) and sinusitis (15.0%).

2.4 Life Cycle Assessment (LCA)

The Life cycle assessment is a tool used to assess the environmental impacts of a product, process, or activity. Although the term life-cycle assessment or analysis, is used most frequently to describe the cradle-to-grave approach, however, there are other approaches such as cradle-to- gate, gate-to-gate and cradle-to-cradle.

LCA has been applied in several industries including the mining industry. Nigri et al. (2014) made use of LCA strategy to assess the environmental impacts using a comparative LCA of industrial and artisanal production processes: A case of “Minas Cheese” Information was gathered through interviews with the makers, perception, and a writing survey. The analysis for the study was done using SimaPro 7 LCA programming. The study found that artisanal production exerted lower environmental impacts.

Ntiamoah (2009) also applied cradle to-grave environmental assessment to acquaint the idea of LCA with the cocoa business in Ghana and explicitly played out an LCA on chocolate creation including the phases of cocoa creation, transportation of cocoa beans, modern cocoa preparing and chocolate producing. The study used GaBi software. The outcomes obviously showed that freshwater amphibian eco-toxicity, trailed by energy assets utilization, human poisonousness and a worldwide temperature alteration are the main ecological effects related with the chocolate creation chain in Ghana.

Manure and pesticides as contributions to the cocoa creation stage were the primary driver of the freshwater sea-going eco-toxicity and human poisonousness impacts, while diesel utilization at the cocoa preparing stage contributed the most to a dangerous atmospheric changes and asset energy utilization. It was additionally clear from the outcomes that chocolate assembling and transportation were the most harmless to the ecosystem phases of the existence cycles stages examined.

Engelbrecht (2012) led a life cycle assessment of wooden intermediate bulk containers utilized for bringing in input like sodium cyanide for gold extraction in Ghana to decide the natural weight of this bundling which additionally incorporates a polyethylene liner and a polypropylene liner. International Organization for Standardization (ISO) 14040 administration standard was utilized as a methodological system in which the objective and extension was characterized, a day-to-day existence cycle stock and life cycle sway evaluation was led.

The examination presumed that the starting point of the Intermediate Bulk Container (IBC) and the related liners were outside of Ghana, showing that assets, for example, crude material extraction and mineral use didn't influence the Ghanaian climate. Likewise, the tonnage of cyanide imported to Ghana would differ from one year to another as the ore body and number of mines operating changes. This, thus, will influence the quantity of IBCs and liners that will enter the country and furthermore the emissions. Also, incineration as a method of disposal appeared to have the biggest impact on the Ghanaian environment.

Ntiamoah and Afrane (2008) assessed the environmental impact of cocoa production and handling in Ghana using Life cycle assessment as a tool. The investigation considered the whole framework needed to create and deal with 1 kg of cocoa bean. It incorporated the extraction of crude materials, the creation of cultivating inputs for example manures and pesticides and all farming tasks in the field, transportation of beans to handling production line and modern preparing of the beans into cocoa margarine, alcohol, cake and powder were additionally included. A critical number of effect classifications were covered. The outcomes uncovered that the utilization of the pesticides and compost were inside adequate cutoff points and are significant supporters of the effects in the cocoa creation stage.

Partey et al (2016) conducted a study using LCA against the backdrop of a rise in wood fuel consumption and charcoal which had been related with increased deforestation in Ghana. The results showed that comparative with *B. balcooa*, the total eco-cost of a support to-door creation of 1 MJ energy charcoal was 140% higher with *T. grandis* and 113% higher with *A. auriculiformis*. The expanded natural effects related with *T. grandis* and *A. auriculiformis* happened at their biomass creation stage including nursery and ranch foundation which established about 85% of the all-out eco-cost because of the utilization of generally enormous amounts of pesticides, weedicides and composts with high fermentation, ozone consumption and a worldwide temperature alteration possibility.

Maepa et al. (2017) discussed the accessibility of LCA and comparable studies in Ghana, Nigeria, and Ivory Coast. From the study, 31 LCA and environmental studies was discovered in Nigeria, Ghana, and Ivory. The energy sector, waste management, real estate, food sector and others such as timber and gold were the industries considered. The study attributed the insignificant number of studies on LCAs and environmental impacts in these West African states to organizations neglecting to advance quantitative environmental studies, or it could be that studies are kept internally for the use of other assessment techniques. Their study also opined that LCAs are viewed as basic quantitative environmental methods to break down the environmental impacts of items as well as administrations all through their whole life cycle.

Several studies using LCA as a tool have been documented in the developed world (Agwa-Ejon et al., 2018; Kittipongvises, 2017; Norgate et al., 2012) on the environmental impacts of quarrying operations as well as mining. However, a systematic review by Maepa et al. (2017) discovered a total of 31 LCA and environmental studies in Nigeria, Ghana, and Ivory Coast which indicate few studies using LCA as a tool in West Africa.

Also, previous investigations in Ghana by Nartey et al. (2012) on limestone quarrying focused mainly on the environmental impacts of limestone quarrying operations without considering the embodied energy, materials and particulate releases into the environment. Likewise, from a systematic review by Aboka et al. (2018), the few studies on mining in Ghana conducted never employed LCA framework in their assessment.

However, knowledge on LCA of limestone quarrying is essential for sustainable mining. Hence, the relevance of this research was to fill knowledge gap of employing LCA in assessing the environmental impact and energy consumption of limestone production in the Lower Manya and Yilo Krobo Municipalities.

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The study was conducted in the Lower Manya and Yilo Krobo Municipalities. Geographically, there are huge deposits of limestone within these areas; Lower Manya Municipality shares boundaries with the Yilo- Krobo Municipality in the west, Upper Manya- Krobo and Asuogyaman Districts in the north, North Tongu District in the east and Akwapim North and Dangme West Districts.

Agyeman Bediako Limited (ABL), Yongwa and Klo-Begoro limestone quarry operation sites, within the Krobo Municipalities in the Eastern region of Ghana were chosen as case study for this research. ABL and Yongwa quarry sites are located in Oduglase in the Lower Manya Krobo Municipality whiles Klo-Begoro quarry is located in Klo-Begoro in the Yilo Krobo Municipality (Figures 3.1 and 3.2).

ABL quarry is owned by Love Enterprises Limited, Yongwa Limestone Quarry is owned by to West African Quarry Limited, a subsidiary company of Ghana Cement Manufacturing Company (GHACEM) with Klo-Begoro quarry being owned by to Agyapado Construction Limited.

The quarries, though in different Municipalities are not far from each other and located behind the Yongwa mountain, which is about 500 meters from the Odumase-Asesewa road.

The largest of the three quarries, Yongwa Limestone Quarry is being operated by De Simone Limited, a contracted company by West Africa Quarry Limited. They started operating in May, 2019. Earlier, the quarry was being operated by A. J. FANJ Company Limited since November 17, 2004 before De Simone Limited took over in May 2019. There was however a break in operations from 2016 to 2019 after which Desimone Limited took over.

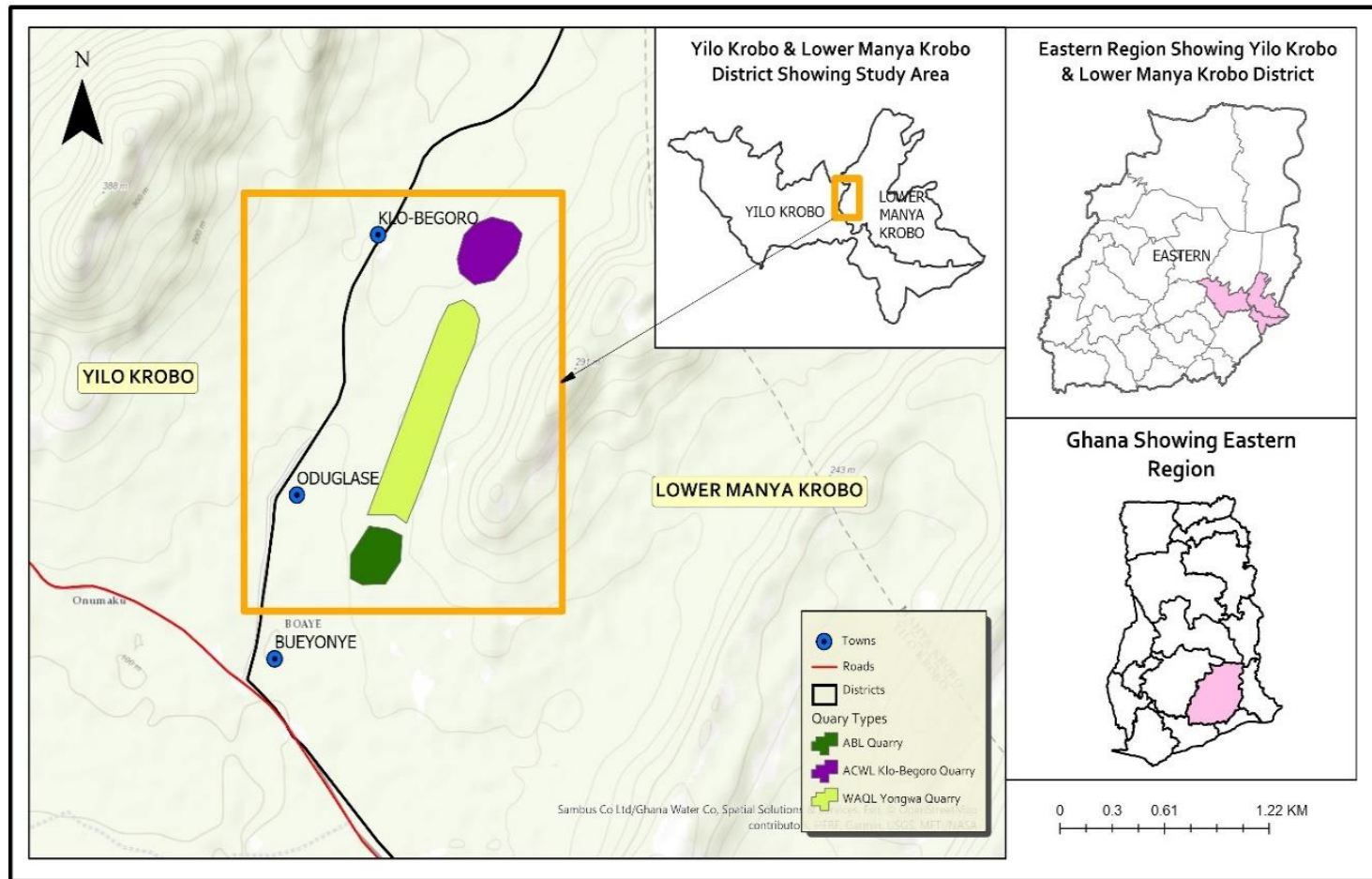


Figure 3. 1 : Map showing the study area.

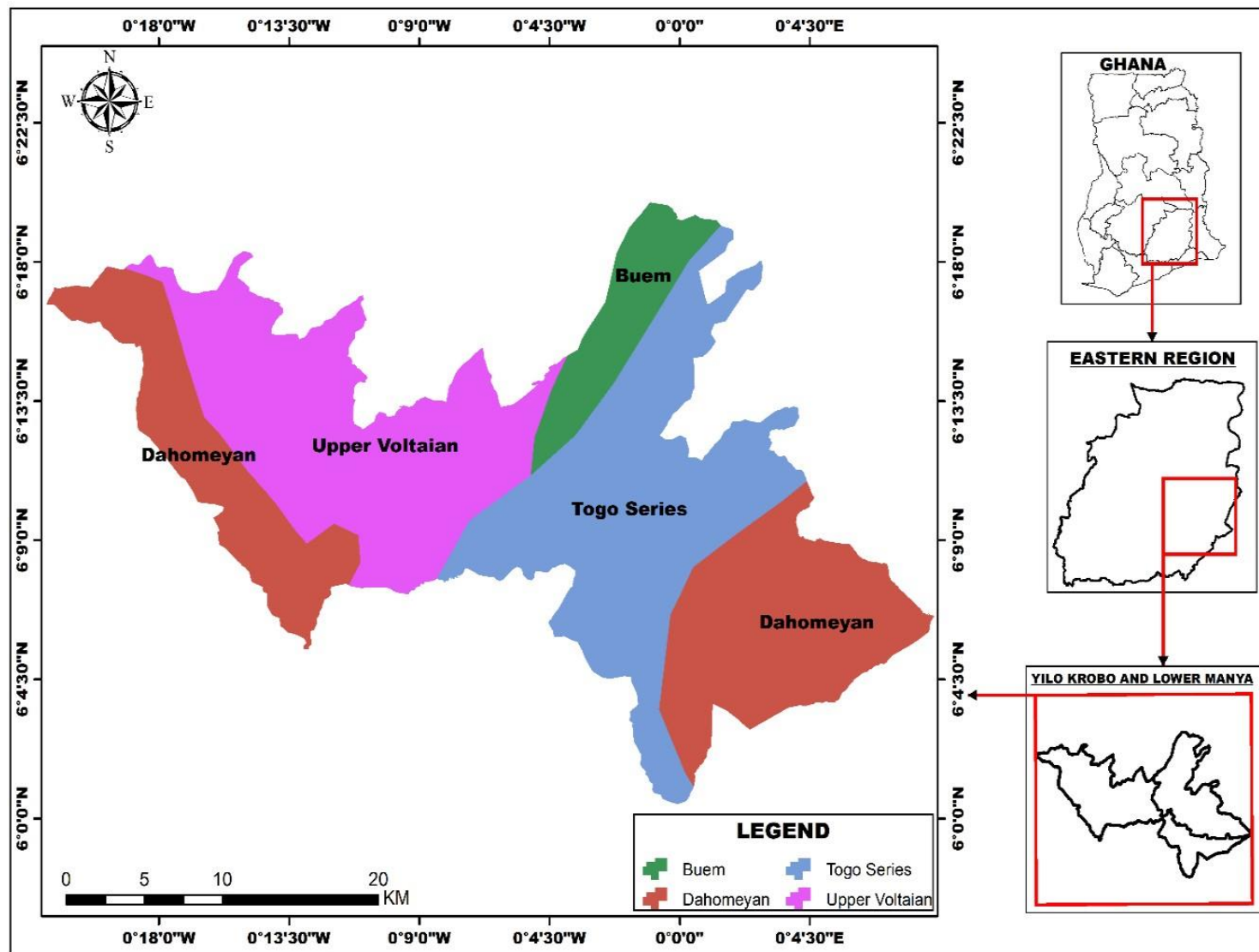


Figure 3. 2 : Geological map of study area.

3.2 Research Design

Yin (2003) describes research design as the structure which guides the data collection procedure and subsequently the technique for analyzing the data from a study. This works with the analyst's capacity to interconnect exact information to its decision, from the underlying examination question to the last exploration question of the investigation, in an organized and coherent grouping towards the fulfillment of the examination targets (Bryman, 2004 and Yin, 2003). Likewise, the historical information gotten from writing additionally educated the exploration and helped in the plan of the research framework. The study employed a mixed method approach i.e. Quantitative and qualitative and a case study research design.

3.3 Data Collection

The sources of data acquired were primary and secondary data. The primary data made up of biodata information and information on the health of the quarry workers was obtained from workers of quarrying companies in Lower Manya and Yilo Krobo municipalities in the Eastern region using a well-structured open and close-ended questionnaire. The secondary data was obtained from monthly and annual reports, books and other materials related to the three quarrying companies.

3.3.1 Limestone Quarrying Operations Data

Secondary data made up of explosives (i.e., ANFO) consumption (unit: kg), diesel fuel consumption (unit: l), quantity of limestone produced (unit: kg), electricity consumption (unit: KWh) and emissions i.e. TSP, NO₂, PM₁₀, SO₂ (units: kg) were obtained from the various companies through their monthly and annual reports.

3.3.2 Health Impact Data

Structured questionnaires were employed for the health impact data and was administered. The questionnaires consisted of both open and closed-ended questions. Questions, response format and instructions were designed to facilitate the direction of the study. The questionnaires were divided into three sections. The first set of questions dealt with the biodata information of the quarrying workers or respondents (i.e., gender, age, educational level, job title, name of company, marital status and years working with the company).

The second set of questions was related to the quarrying and health of the workers. Fourteen questions were asked under this section in order to obtain information about the health of the worker and their families.

The third and final part of questions dealt with the role of Environmental Protection Agency within the quarrying sector. With this section, view of quarrying workers were sought on six questions relating to the role of Environmental Protection Agency (EPA) (see Appendix A).

3.3.3 Focus Group Discussion (FGD)

Focus Group Discussion section was organized using an interview guide (see Appendix D) to help document the common complaints and ailments affecting the community with respect to limestone production.

3.4 Validity of Questionnaire

Validity is an assessment of the degree to which an instrument measures what it is supposed to measure. In this context, the content validity was ascertained. According to Anastasi and Urbina (1997, p. 114), “content validity” is a non-statistical type of validity that involves "the systematic examination of the test content to determine whether it covers a representative sample of the behaviour domain to be measured." Based on this assertion, the supervisors of this research perused the items in the questionnaire and ensured that they were properly constructed and covered all the relevant areas. Also, a pretest of the questionnaire was done among ten of the respondents and questions which were not clear were clarified.

3.5 Sampling and sampling procedure

3.5.1 Population of the Study

The research sample was drawn out of majority termed as population. For the purposes of this study, the population included the community members and workers in the quarrying companies in both Lower Manya and Yilo Krobo municipalities in the Eastern region. The workers ranged from all job categories/titles such as managers, supervisors, administrators, quality control officers, mechanics, operators, transport officers, security officers to store keepers, among others. The community members were the inhabitants living near the quarrying sites at Klo-Begoro and Oduglase. In all, the population size was estimated to be around 112, Agyapaddo Construction Works (35), Desimone Mining Services Ghana (30) and Love Enterprise Limited (27) and 20 community members respectively.

3.5.2 Sampling Technique

The stratified probability sampling method was employed because there were three quarrying companies involved in the study. Since the quarrying companies are in strata, each quarrying company was classified as a stratum. Therefore, in each stratum, simple random sampling was used to select the respondents which allowed every worker to have an equal chance of being selected to be part of the sample. Therefore, the main respondents such as managers, supervisors, administrators, quality control officers, mechanics, operators, transport officers, security officers and store keepers were chosen using simple random sampling. The rationale behind was to get certain groups of respondents who are skilled and involved in a sizable amount of quarrying works and contribute meaningfully to the research (Adjei, 2009).

3.5.3 Sample size

Based on the Central Limit Theory (CLT) of research population, which states that sampling size should not be less than 30% of the population in quantitative research, but in qualitative research the sampling size could be less than 30%. Thus, sample size of thirty-four (34) quarrying workers from the 3 quarrying companies in Yilo Krobo and Lower Manya Krobo municipalities were given questionnaires to answer. The technique used was Proportional Allocation, since it determines the appropriate sample size in each quarrying company. The formula used was

$$n_1 = n \frac{N_1}{N},$$

Where, n_1 is the sample size in quarrying company 1

N_1 is the population size of quarrying company 1

n is the sample size for the three quarrying companies

N is the population size for the three quarrying companies

Therefore, $n = n_1 + n_2 + n_3$

The sample size for Agyapaddo Construction Works, $n_1 = 34 \times \frac{35}{92} = 13$

The sample size for Desimone Mining Services Ghana, $n_2 = 34 \times \frac{30}{92} = 11$

The sample size for Love Enterprise Limited, $n_3 = 34 \times \frac{27}{92} = 10$

Thus, $n = 13 + 11 + 10 = 34$

3.6 Data analysis and interpretation

Ecochain, GaBi, Mobius, oneClickLCA, openLCA, SimaPro and Umberto are some software tools for LCA. However, SimaPro 8.3.0.14 software was employed to develop LCA model and analyze Life Cycle Inventory (LCI) data. This is because it is easier and more accurate to use as compared to the other softwares above.

Statistical Package for Social Science (SPSS) version 23 was used for the statistical analysis of data collected from the questionnaires as its more accurate to use than other statistical analysis tools.

Data collected were analysed quantitatively by determining the variabilities among the observed variables. Also, descriptive tools like frequencies, percentages, bar charts, pie chart and chi-square test were employed in the data analysis.

The following hypotheses was set for the chi-square test:

H_0 : Diseases suffered by the family members is independent of the diseases suffered by the workers.

H_1 : Diseases suffered by the family members is dependent of the diseases suffered by the workers.

All analysis was done at 5% level of significance

3.7 The LCA Framework

The general framework defined by ISO 14040 series was used to assess the environmental impacts and energy consumption of limestone production in the Lower Manya and Yilo Krobo Municipalities. The framework is made up of four stages:

- I. Goal and scope
- II. Life cycle inventory
- III. Life cycle impact assessment
- IV. Interpretation.

3.7.1 Goal and Scope definition

The goal of this study was to assess the environmental impacts and energy consumption of limestone production in the Lower Manya and Yilo Krobo Municipalities.

The scope of the study covers all related environmental impacts generated and energy consumption from the quarrying process and is based on a cradle-to-gate approach. This involves the extraction of mineral, transportation of extracted mineral to crusher, crushing and grinding as the cradle, and transportation of crushed limestone rock to the final delivery as the gate.

A process flow diagram shown in Fig 3.3, of this assessment indicate the process used for limestone production at all three quarry sites. The functional unit (FU) was defined as one tonne of crushed limestone.

3.7.2 Life cycle inventory

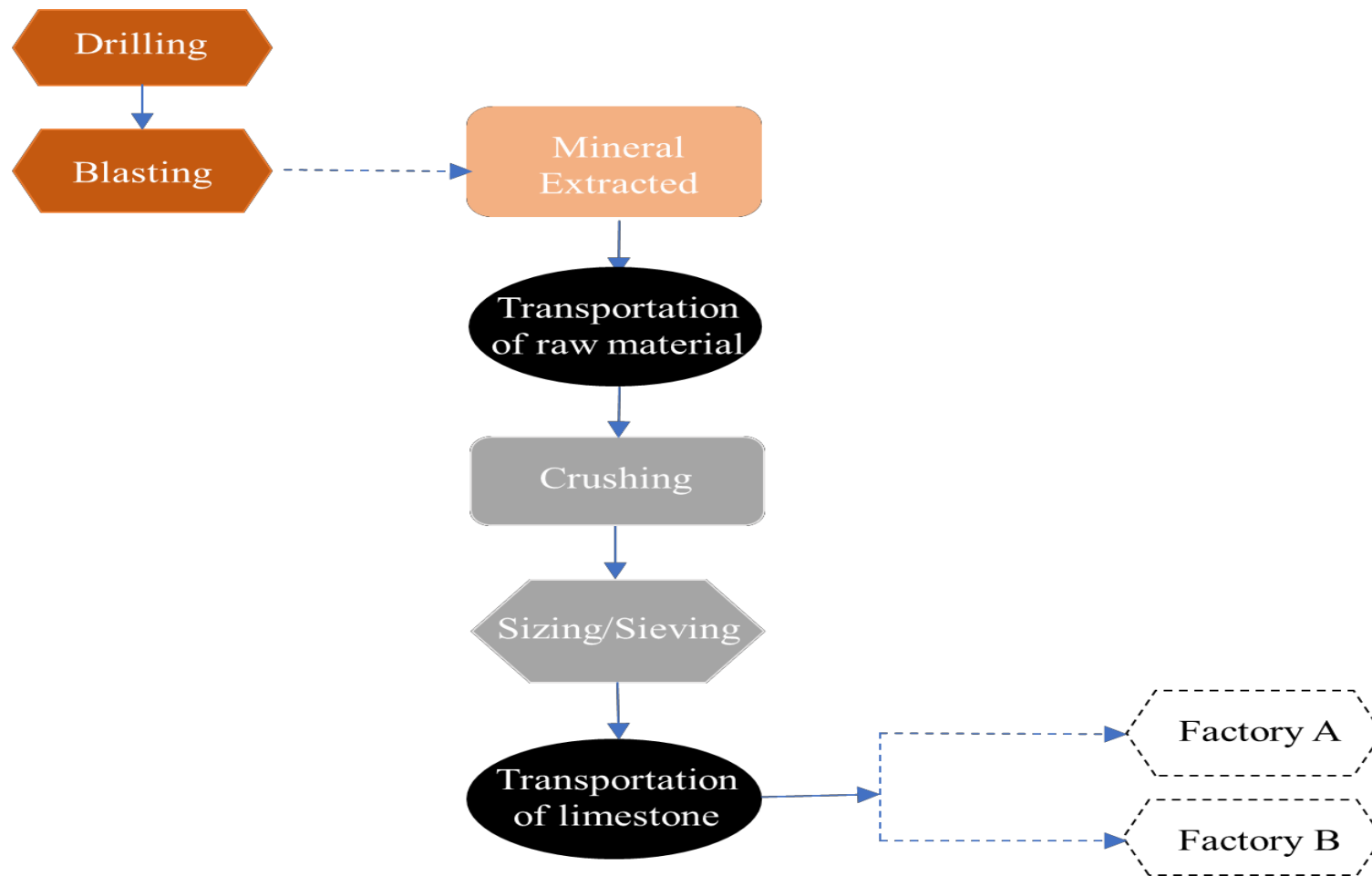
Primary and secondary data was used to develop life cycle inventory (LCI) for the study. The primary data were collected using interviews, structured questionnaires and observation from the three limestone quarry sites. Secondary data sources include weekly, monthly and annual reports obtained from the various companies and used as case study. The following data and related inputs used for the production of limestone were collected: explosives (i.e. ANFO) (unit: kg), diesel fuel consumption (unit: l), and emissions (unit: kg) as shown in fig. 3.4.

3.7.3 Life cycle impact assessment

The Life cycle impact assessment (LCIA) was conducted using a data base for characterization factors of LCA. The Sima Pro software gave eighteen impact categories and all the individual impact categories were grouped into four damage categories; climate change and resources, human health, ecosystem quality.

3.7.4 Interpretation

The outcome of the Life cycle impact assessment was interpreted as the final phase of life cycle analysis. As the impact's aggregation, both characterizing and normalizing the estimated environmental impacts were considered to understand the total impacts and to determine which impacts are the most significant.



The boundaries in short dashes were not included in the study

Figure 3. 3: Process flow diagram of limestone production.

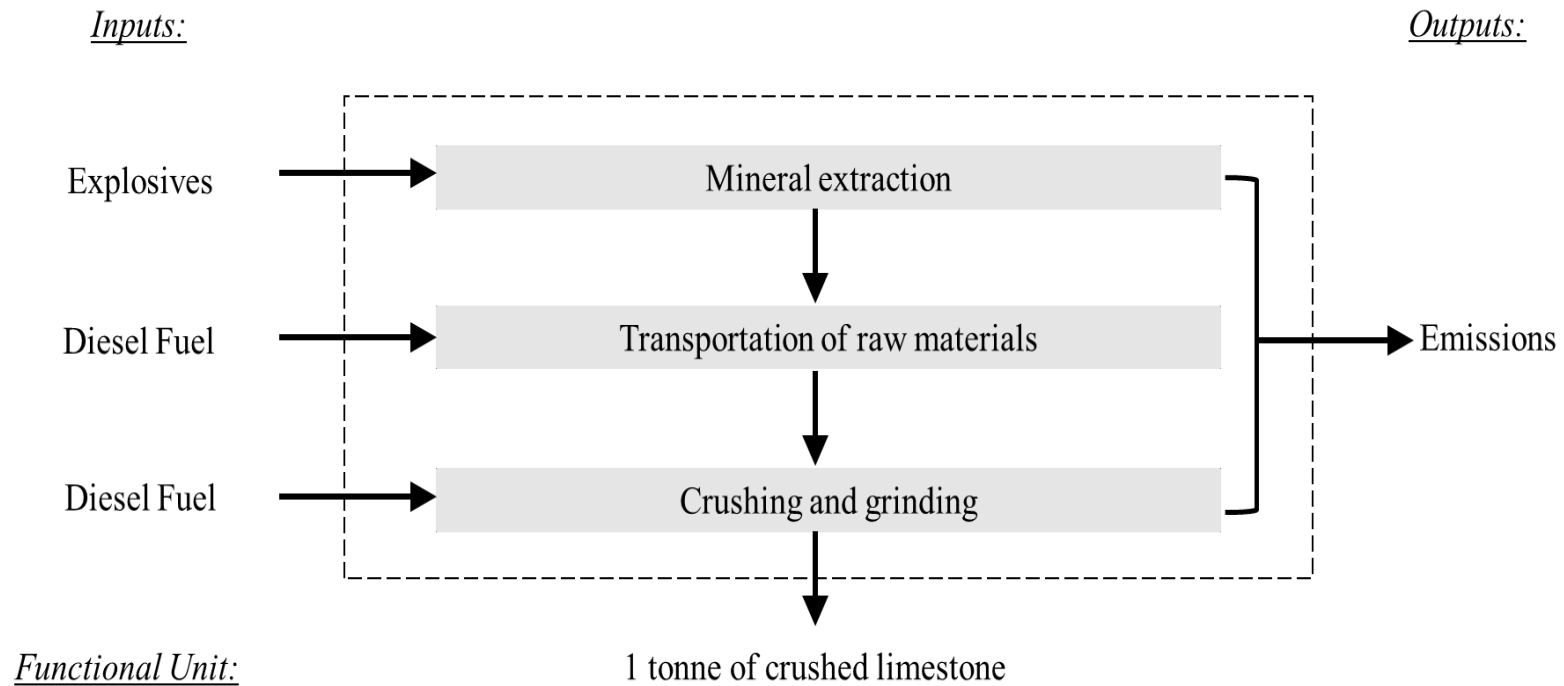


Figure 3. 4 : Process flow diagram of limestone quarrying operations in Lower Manya and Yilo Krobo Municipalities.

3.8 Limitation of the Study

All the data that was used for the LCI was obtained from the quarrying companies, hence there could be some degree of uncertainties in the input data, because data from self-assessment would have been preferred.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents the result of the study. First, the quantity and energy consumption of limestone production are ascertained. The health implication of the quarry activities on workers and communities around the environs is also presented and Greenhouse emission from the limestone production is evaluated.

4.2 Limestone Production

The quantity of limestone produced monthly by the quarry companies are presented in Fig. 4.1 Yongwa quarry, which belongs to West African quarry Limited, a subsidiary company of GHACEM had the highest limestone production in 2019, with a production of 723,600 tonnes, followed by Klo-Begoro quarry with a production of 117,735 tonnes and then ABL quarry with a production of 113,670 tonnes.

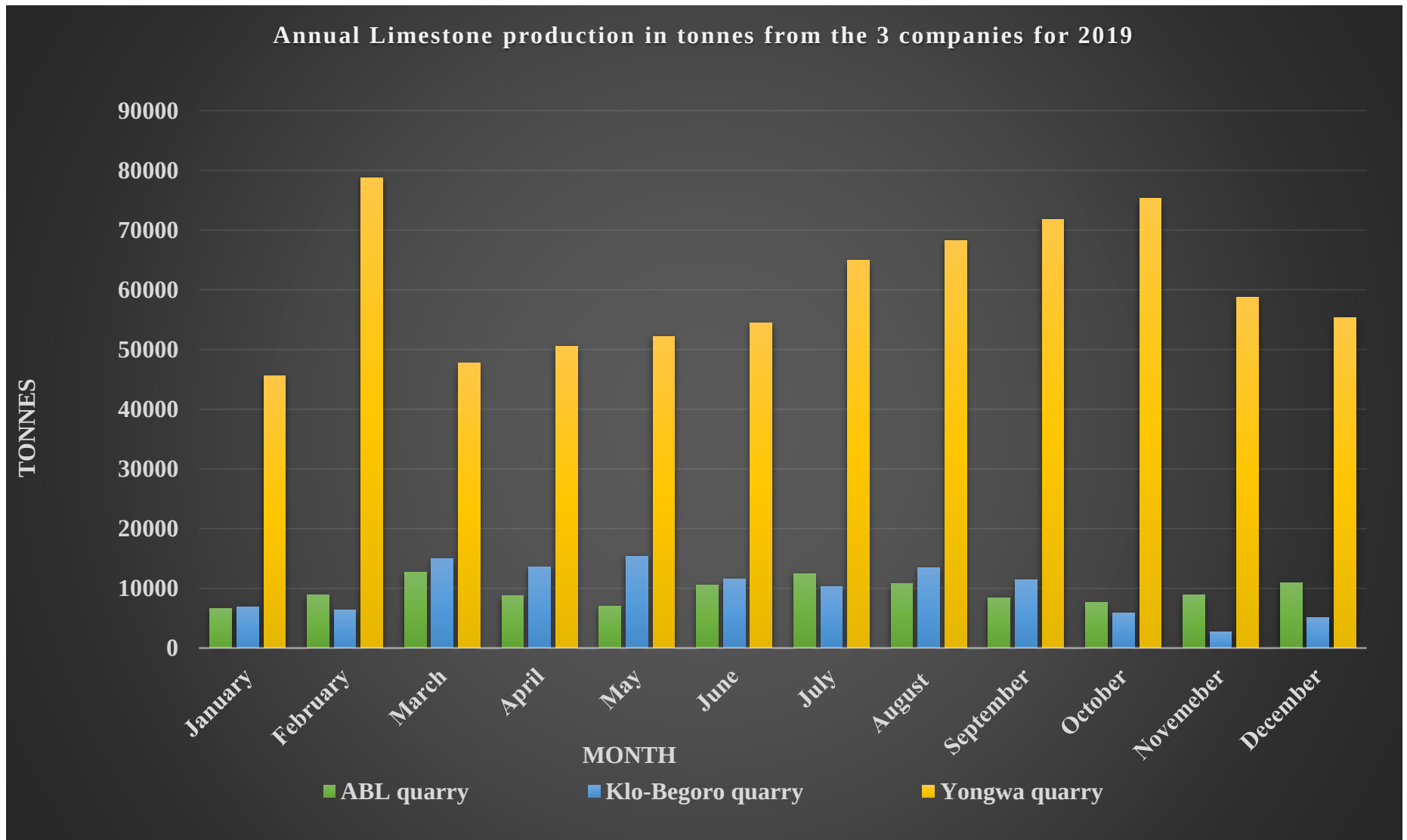


Figure 4. 1: A bar graph showing annual limestone production from the 3 companies for 2019

4.3. Energy consumption

The energy consumption of the examined limestone and processing indicated that Yongwa and ABL quarry use only diesel fuel as energy. Diesel is used to power plant for office operations, operate machines, transport extracted limestone to crusher for crushing as well as transporting the processed limestone to the consumer cement factories. Klo-Begoro quarry, however, uses electricity and diesel as energy for limestone production. Electricity is used for office operations and diesel fuel to operate machines, transport extracted limestone to crusher for crushing as well as transporting the processed limestone to the consumer (cement factory). Fig 4.2 represents the embodied diesel consumption for limestone production for the year 2019. Yongwa quarry has the highest embodied diesel consumption, throughout the months, followed by Klo- Begoro quarry and then ABL quarry. This implies that the production rate is linked to the energy consumption as Yongwa quarry had the highest limestone production.

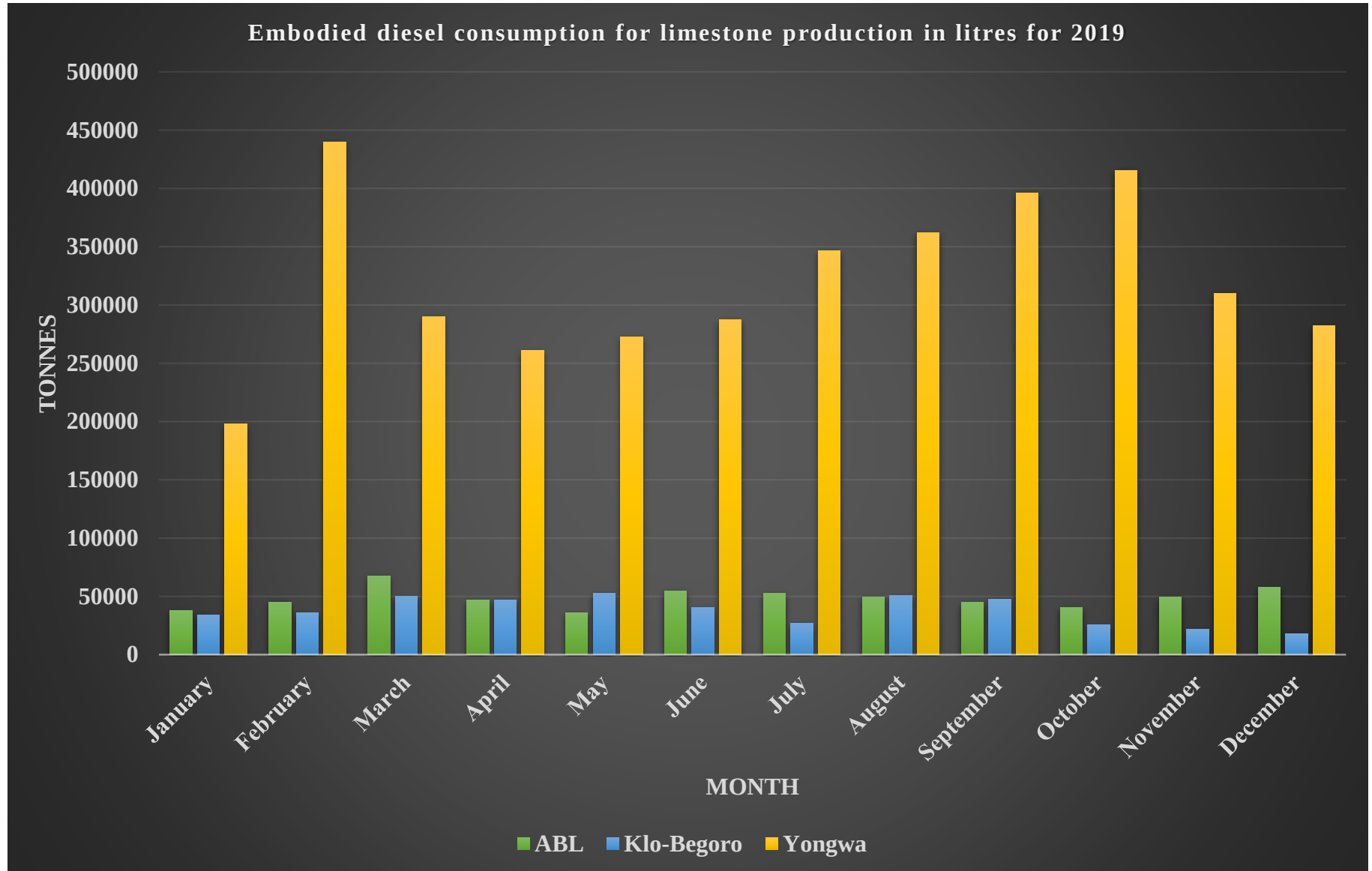


Figure 4. 2 : A bar graph showing embodied diesel consumption for limestone production in litres for 2019

4.4 Health Implication of Limestone production workers and community members close to the quarries

4.4.1 Social-Demographic Characteristics of the Study Area

The distribution of summary of the variables used in the analysis was explored and the summary statistics of the respondents is provided in Table 4.1.

Table 4. 1: Socio-Demographic Characteristics of Respondents

Demographic	Number of Respondents	Minimum	Maximum	Mean	Std. Deviation
Age (in years)	34	22	52	33.7	7.9
Years Working	34	2 Months	8 years	2.5	1.77

The result, indicated that out of the 34 sampled respondents, the average age was 33.7 years, with this, the minimum age 22 years and the highest age was 52 years. Similarly, the average duration a worker has spent in a quarrying company in the study area was 2.5 years. The least time spent in a quarrying company was 2 months and the maximum years spent by a worker was 8 years.

4.4.2 Demographic Characteristics

The demographic information such as gender, marital status, quarrying company and level of education of the workers in the study area were explored. Table 4.2 below describes the background characteristics of the respondents in the study area. The result of the study indicates that all the workers sampled were males. This does not come as a surprise because, majority of the populace in Ghana believe that everything about mining and quarrying is dominated by males and since the population of the study is quarrying company, the outcome of the study seems to side with the general perception of the populace.

Table 4. 2: Demographic Characteristics of the Respondents

Background	Frequency	Percentage (%)
<u>Sex:</u>		
Male	34	100
Female	0	0
<u>Quarrying Company:</u>		
Agyapaddo Construction Works	13	38
Desimone Mining Services Ghana	11	32
Love Ent. Ltd	10	30
<u>Marital Status:</u>		
Married	19	56
Single	15	44
<u>Educational Level:</u>		
None	2	6
Basic	16	47
Secondary	11	32
Tertiary	5	15
Total	34	100

Furthermore, the results revealed that Agyapaddo Construction Works Limited had the highest number of employees (38%), followed by Desimone Mining Services Ghana (32%) and Love Ent. Ltd. with 30%.

From Table 4.2, majority (56%) of the sampled workers are married whilst the rest of the respondents are single. In addition, majority of the workers, represented by (47%) have obtained basic education, followed by secondary education (32%), with 6% of the workers having no formal education. This

means that vast of the respondents had at least some level of education, thus can lead to easy understanding of the items on the questionnaire.

4.4.3 Quarrying and Health

The workers in the three quarrying companies in the study area were asked about the health-related issues they face in their course of executing duties at work. Table 4.3 below depicts the issues of importance at workplaces.

Table 4.3: Self-Reported Health Issues by Respondents

Indicator/Disease	Yes (%)	No (%)
Health and Safety Measures	100	0
PPEs	100	0
<u>Diseases and Conditions:</u>		
Malaria	38	62
Diarrhea	12	88
Skin Disease	18	82
Fever	21	79
Cold and Catarrh	35	65
Headache	12	88
Back and Waist Pain	21	79

From Table 4.3, all the workers admitted that their companies have health and safety measures in place for them. The quarrying companies provide them with protective equipment to use when working. Moreover, the health conditions the workers suffer from workplaces are malaria, diarrhoea, skin disease, fever, cold and catarrh, headache and back and waist pain, but the most common disease the workers suffer from is malaria (38%), followed by cold and catarrh (35%). Diarrhea (12%) and headache (12%) are the least of the diseases and conditions suffered by the workers at the study area.

Table 4.4 shows some of the demographic information such as age, education and working experience as against most common diseases and health conditions quarry workers suffer in their various workplaces. The results suggest that years of working in the quarry company least predict mining risk, that is, years of working recorded the highest figures for “No” in all the three common diseases. On the contrary, level of education is the likely most mining risk variable for the workers.

The workers aged between 25 and 34 years are the most highly risk age among the three common diseases. Also, workers with Secondary education have high mining risk in the study. Finally, workers with one to four years working experience have the high mining risk in the study.

Table 4. 3: Age, Education and Years of Working among Quarry Workers

		<u>Malaria</u>		<u>Colds and Catarrh</u>		<u>Fever</u>	
		<u>Yes</u>	<u>No</u>	<u>Yes</u>	<u>No</u>	<u>Yes</u>	<u>No</u>
Age:	Less than 25 years	2	1	1	2	3	0
	25-34 years	15	2	11	6	12	5
	35-44 years	7	2	7	2	8	1
	45 years and above	1	4	3	2	4	1
	Total	25	9	22	12	27	7
Education:	None	2	0	2	0	2	0
	Basic	10	6	10	6	13	3
	Secondary	9	2	9	2	11	0
	Tertiary	4	1	4	1	4	1
	Total	25	9	25	9	30	4
Years Working:	Less than 1 year	4	3	4	3	7	0
	1-4 years	14	7	12	9	12	5
	5 years and above	3	3	4	2	4	6
	Total	21	13	20	14	23	11

Table 4.5 shows the diseases and conditions families of workers in the quarrying companies frequently contract or exhibit (the questions under this were answered by the workers themselves). The results in the study revealed that majority (73%) of the workers' families suffer or exhibit the symptoms of malaria than any other disease. Also, only few (3%) of the families of workers contracted skin diseases at the time of this study. In contrast, none of them had fever or showed symptoms of fever during this study. Nevertheless, 94% of the workers said the diseases or conditions of their family members they outlined are not related to the quarrying activities they are involved in currently (Table 4.5).

Table 4. 4: Frequently Contracted Diseases and Conditions by Families of Quarry Workers

Diseases	Yes (%)	No (%)
<u>Diseases and conditions:</u>		
Malaria	73	27
Diarrhea	6	94
Skin Diseases	3	97
Fever	0	100
Colds and Catarrh	6	97
Are the diseases related to the quarrying activities	6	94

The Chi-Square test analyses in Table 4.6 was used to test whether or not diseases suffered by the family members are independent of the diseases suffered by the quarrying workers. The results from Table 4.11 revealed that since the p-value of 0.384 is greater than the significance level ($\alpha = 0.05$), we do not reject the null hypothesis. Thus, we say that there is not enough evidence to suggest a relationship between the diseases suffered by the workers and the diseases suffered by the family members. Therefore, diseases suffered by the workers are not transmitted to the family members (Table 4).

Table 4. 5: Chi-Square Tests Outcome for Diseases Suffered against Family Diseases and Conditions

Parameter	Value	df	Asymptotic Significance (2- sided)	Exact Sig. (2- sided)	Exact Sig. (1- sided)
Pearson Chi-Square	1.056 ^a	1	0.304		
Continuity Correction ^b	0.018	1	0.892		
Likelihood Ratio	0.871	1	0.351		
Fisher's Exact Test				0.384	0.384
Linear-by-Linear Association	1.024	1	0.312		
N of Valid Cases	33				

^a 2 cells (50.0%) have expected count less than 5. The minimum expected count is .42.

^b Computed only for a 2x2 table

Table 4.7 elaborates the health care centres or places workers involved in this study seek their medical attention or care from when they are not feeling well. It is observed that majority (59%) of the workers seek their medical attention or care from clinics, followed by hospitals (35%). On the contrary, only 6% of them go to herbal centres for medical care when unwell.

In addition, reasons respondents gave as to why they opted for a particular health centre included they receiving better treatment from the centre, good interpersonal relations between health workers and patients; only the available or nearby health centre, that is, proximity, preference, and standard medical care.

Table 4.7: Health Care Centres Respondents Seek Medical Care

Health Centre	Frequency	Percent (%)
Clinics	20	59
Hospitals	12	35
Herbal Centres	2	6

Moreover, all the respondents stated that the companies have put in place an intervention to handle health problems associated with their work, including insurances by the quarrying companies for each worker. Also, the companies pay the hospital bills of all workers when they receive medical care, and also pay them risk allowances.

However, from the focus group discussion to investigate common complaints and ailments affecting the community with respect to limestone production, members of the community complained about vibration as a result of the blasting but did not have any complaints of ailments as a result of the limestone production.

Figure 4.3 illustrates the quarrying companies' corporate social responsibilities undertaken to improve the health condition of the people living in the study area. Figure 4.3 revealed that majority (62%) of the respondents said the quarrying companies do not undertake any exercise or activity to improve the health condition of the people living in the catchment areas.

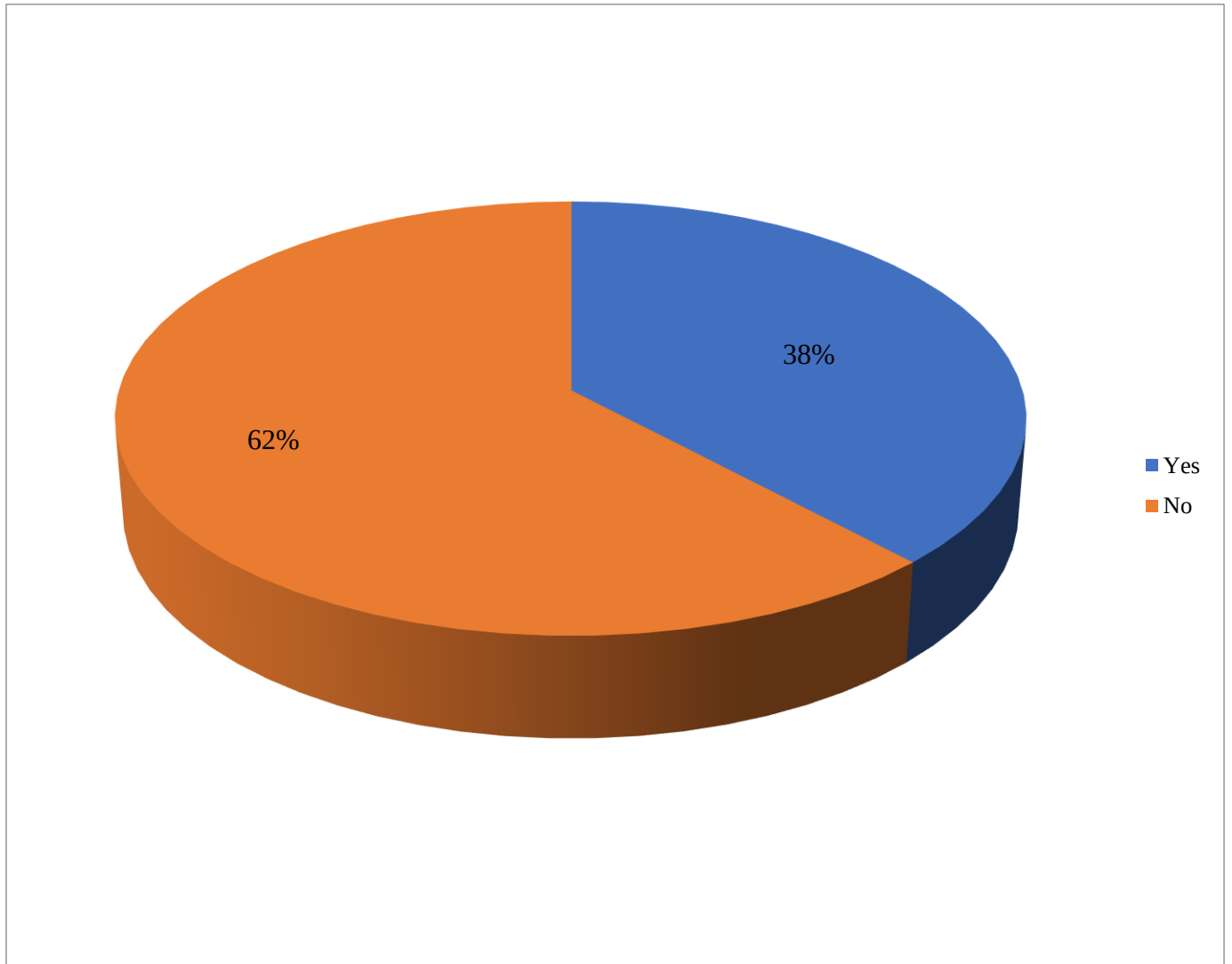


Figure 4.3: Respondents' Perception on whether Quarrying Companies undertake any Exercise/Activity to Improve Health Conditions

Furthermore, 38% of the respondents indicated that the companies sometimes bring vehicles to water the untarred roads in the communities.

Also, all the respondents revealed that the quarrying companies do not undertake any programme to educate the people in the communities about their well-being.

4.4.4 Role of Environmental Protection Agency (EPA) within the Quarrying Sector

The Environmental Protection Agency has a wide scope of capacities to secure the environment. Some of the duties of EPA is to enforce environmental laws, educate and protect the environment, regulate greenhouse gas emissions and analyze and report on the environment.

Table 4. 6: Respondents' Views on the Role of Environmental Protection Agency within the Quarrying Sector

Role of EPA:	Yes (%)	No (%)
Environmental Impact Assessment	100	0
Request for Environmental Impact Assessment	100	0
Monitoring/inspection	100	0
Issues of Environmental degradation/pollution	0	100

Table 4.8 depicts respondents view on the role of Environmental Protection Agency (EPA) Ghana within the quarrying sector. The results revealed that all the workers admitted that their companies have undertaken environmental impact assessment on the activities of the quarrying companies. Also, all the respondents admitted that EPA request environmental impact assessment on the activities of the quarrying companies. In addition, they said EPA conduct monitoring/inspection of their companies' activities with respect to the environment. They further stated that the monitoring/inspection is done annually. On the contrary, the respondents revealed that EPA has never cautioned the quarrying companies on issues of environmental degradation or pollution.

4.5. Life Cycle Inventory Data

Life cycle inventory (LCI) involved the quantification of both inputs and outputs for limestone production. Table 4.9 shows all inputs used in the production processes. Data from annual report and monthly data on diesel fuel consumption and blasting permit were used to develop the LCI data. There was no co-product nor by-products generated during the mining process, hence only the processed limestone was considered as the output.

Table 4. 7: Life Cycle Inventory of processed limestone for ABL, Klo-Begoro and Yongwa quarry

LCI data

Inputs	Process	Unit Per Ton for ABL	Unit Per Ton for Klo-Begoro	Unit Per Ton for Yongwa	Unit
Explosives	Limestone extraction	0.603	0.48	0.26	Kilogram
Diesel oil	Limestone extraction Crushing/grinding Transportation	5.12	3.82	5.34	Litre
Electricity	Office	-	0.04	-	kWh
<i>Outputs</i>					
Crushed limestone rock		1	1	1	Ton

Table 4. 8: Emissions during limestone extraction

Gases	Annual average quantity for ABL/ Kg	Annual average quantity for Klo-Begoro/ Kg	Annual average quantity for Yongwa/ Kg	EPA limit/ Kg
TSP	0.000066	0.000104	0.000111	0.00023
NO ₂	0.00234	0.00268	0.0406	0.15
PM ₁₀	0.00000033	0.00000034	0.00000049	0.0000007
SO ₂	0.00334	0.00332	0.0256	0.15

4.6. Life cycle impact assessment

SimaPro 8.3.0.14 software was used to simulate the potential environmental impacts. ReCiPe Midpoint H method / Europe ReCiPe method was used excluding infrastructure process and long-term emissions.

Tables 4.11, 4.12 and 4.13 represent the outcome of the environmental impacts assessment of 1 ton of crushed limestone by using ReCiPe Midpoint H method for ABL, Klo-Begoro and Yongwa quarry respectively.

The damage categories were calculated using weighing and normalization factors with respect to the ReCiPe Midpoint method. With normalization, the value is regarded to show the scale of the problem. The idea of ‘disability-adjusted life years’ (DALY) was used to assess the human health damage category. Human health statistics in terms of life years both lost and disabled was used to arrive at the DALY of a disease. The DALY concept is applied in ReCiPe, which includes the number of years of life lost and years of life disabled, but does not include age weighting and discounting, as an automatic setting for quantifying the damage contributing to the human health area of protection within the LCA.

The normalization factors, as stated by the ReCiPe Midpoint H/A (Hierarchist/Average), are as follow for the following damage categories: for ecosystem, 8.32E-01 species/yr, for human health, 3.92E+0 DALY/yr, for resource, 3.947E+01 and climate change, 13.55E+00.

All data sources assessed the expected environmental impacts using proper characterization factors. In view of a particular unit of estimation (i.e., kg CO₂ eq.), the higher the value, the more prominent environmental impacts.

Form Tables 4.11, 4.12 and 4.13, for the climate change impact category, the amount of CO₂ emissions in the limestone production were 5.5kg, 4.3kg and 3.7kg for ABL, Klo-Begoro and Yongwa quarries respectively. The CO₂ emission for ABL was highest among the three companies.

Explosive consumption for extraction processes was the main source of CO₂ emissions for ABL and Klo-Begoro quarry with a lower contribution from diesel consumption. Electricity consumption for office work however gave a smaller contribution to the CO₂ emissions for Klo-Begoro quarry. However, diesel consumption for crushing and grinding and transportation was the main source of CO₂ emissions for Yongwa quarry company. This is because the limestone from Yongwa quarry serves two cement processing plants located in Tema and Takoradi.

The amount of water depletion in the limestone quarrying operation were about 9.3m³, 7.4m³ and 4.9m³ for ABL, Klo-Begoro and Yongwa quarries respectively. ABL quarry had the highest water depletion potential among the three companies. The use of explosive for extraction processes gave a greater contribution to the water depletion for all the three companies with diesel and electricity giving a significantly lower contribution.

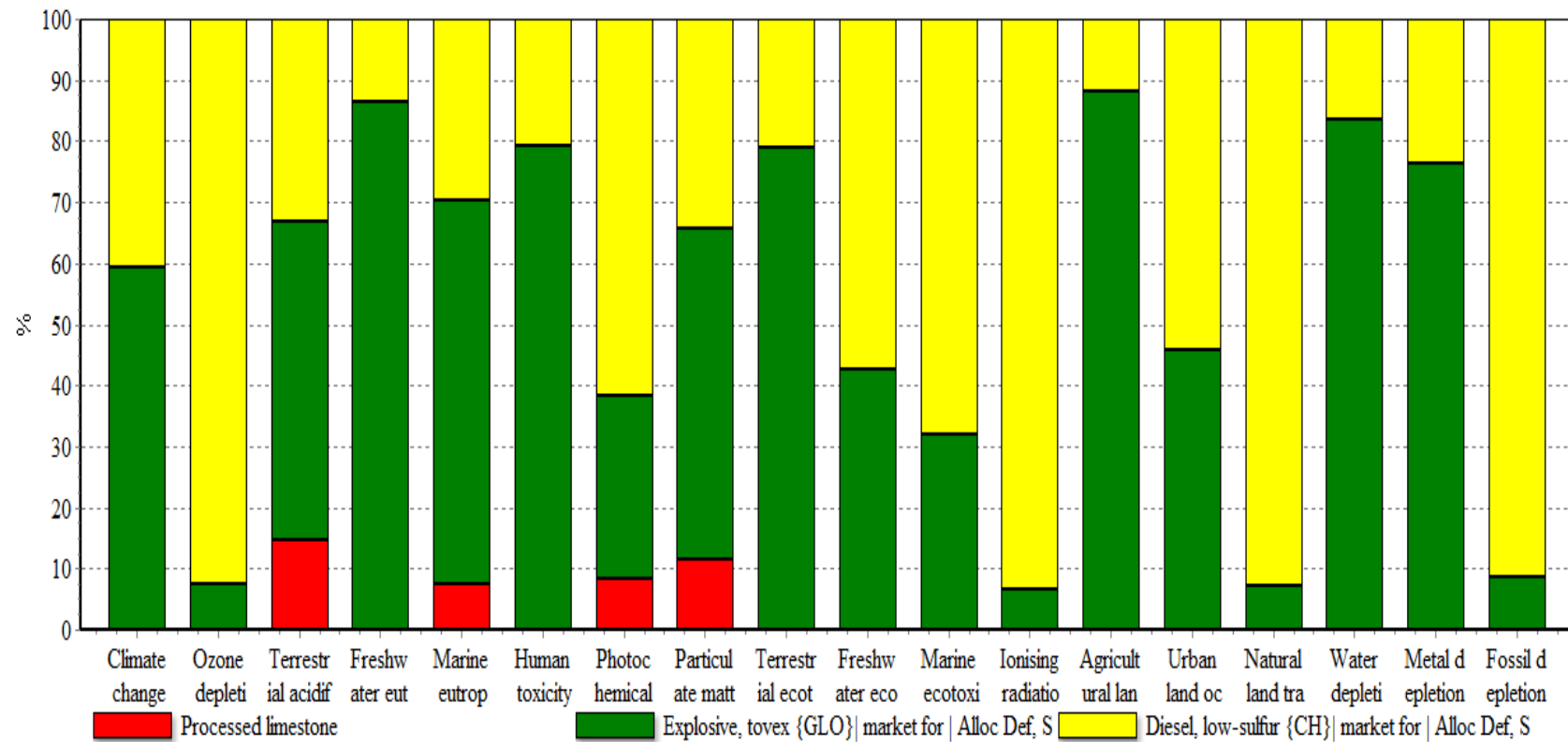
The amount of fossil depletion in the limestone quarrying operation were about 6.3kg, 4.7kg and 6.2kg for ABL, Klo-Begoro and Yongwa quarries respectively. ABL quarry had the highest fossil depletion potential among the three companies. Diesel consumption was the dominant source of fossil depletion for all the three companies with explosive and electricity giving a significantly lower contribution.

Fig 4.7, 4.8 and 4.9 represent the outcome of the normalization of environmental impacts assessment of 1 ton of crushed limestone by using ReCiPe Midpoint H method for ABL, Klo-

Begoro and Yongwa quarry respectively. Natural land transformation presented the greatest environmental impacts for all three quarries. Diesel consumption for crushing and grinding and transportation contributed about 93% to the natural land transformation for ABL, about 92% for Klo-Begoro and about 96% for Yongwa

Each of the impact categories was compiled to the four damage categories i.e., climate change, ecosystem quality, human health and resources (Fig 4.10). The resource category that is the sum of fossil, metal and water depletion gave the greatest environmental impacts of 68%, followed by climate change (24%), human health (6.8%) and 1.4% for ecosystem quality. This result is in contrast with the findings of Kukfisz and Maranda (2014) who reported human wellbeing as the primary category of damage of all the impacts involved in producing blasting materials.

Fig 4.11, 4.12 and 4.13 represent the network for 1 ton of processed limestone for ABL, Klo-Begoro and Yongwa quarry respectively. Explosive gave a greater contribution to the network for ABL, Klo-Begoro quarries while diesel gave a greater contribution to the network for Yongwa quarry.



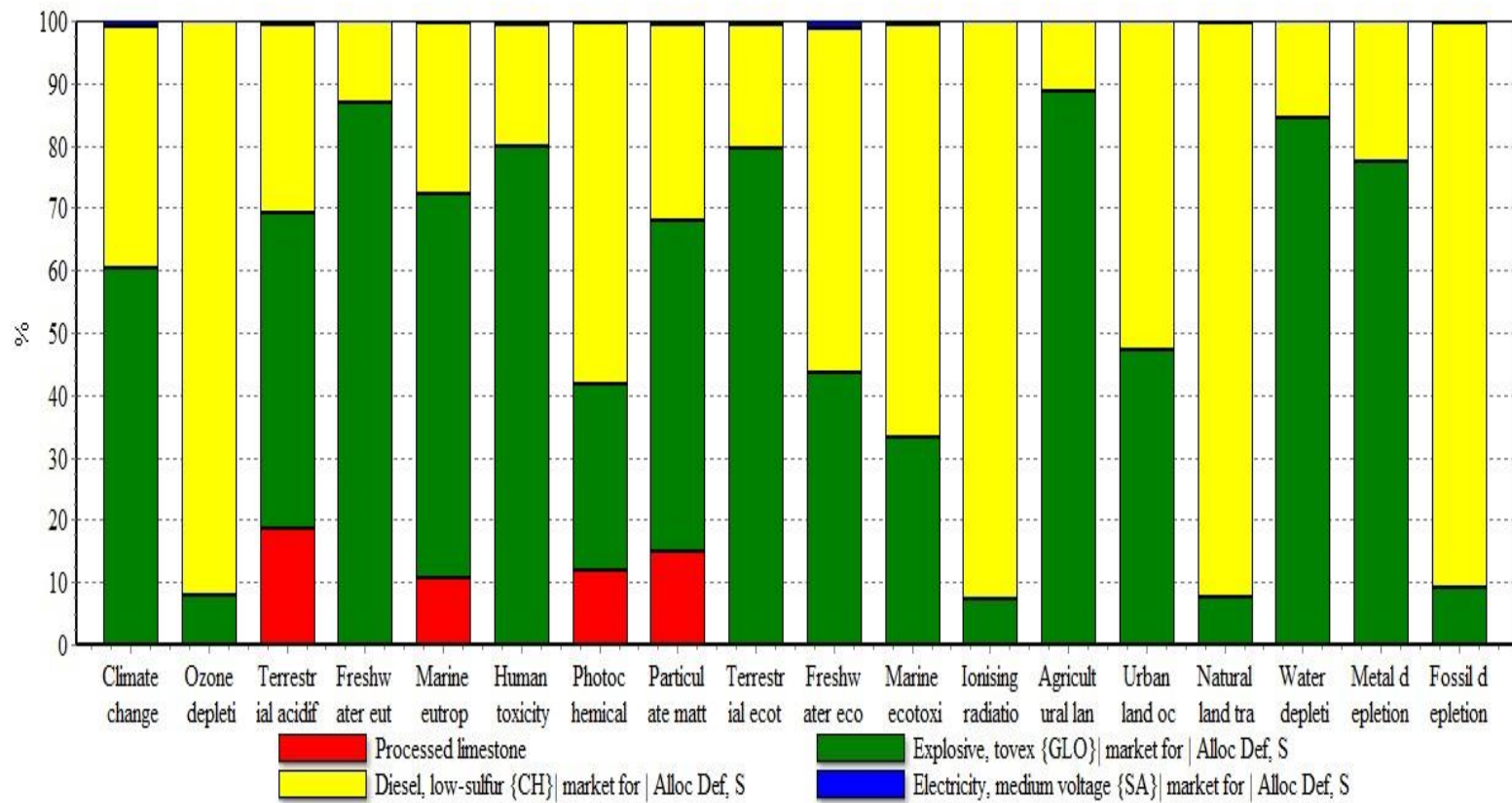
Analyzing 1 ton 'Processed limestone';

Method: ReCiPe Midpoint (H) V1.10 / Europe Recipe H / Characterization / Excluding infrastructure processes / Excluding long-term emissions

Figure 4. 4: Characterization graph of 1 ton processed limestone for Agyeman Bediako Limited quarry.

Table 4. 9: Characterization table for Agyeman Bediako Limited quarry

Impact category	Unit	Total	Explosive	Diesel
Climate change	kg CO ₂ eq	5.505198431	3.266771	2.238427
Ozone depletion	kg CFC-11 eq	1.24641E-06	9.44E-08	1.15E-06
Terrestrial acidification	kg SO ₂ eq	0.031707442	0.016531	0.010526
Freshwater eutrophication	kg P eq	0.000183877	0.000159	2.51E-05
Marine eutrophication	kg N eq	0.001226121	0.000771	0.000364
Human toxicity	kg 1,4-DB eq	0.471775936	0.374034	0.097742
Photochemical oxidant formation	kg NMVOC	0.03122053	0.009343	0.019267
Particulate matter formation	kg PM ₁₀ eq	0.010369862	0.005633	0.003554
Terrestrial ecotoxicity	kg 1,4-DB eq	0.000659488	0.00052	0.00014
Freshwater ecotoxicity	kg 1,4-DB eq	0.004107469	0.001752	0.002356
Marine ecotoxicity	kg 1,4-DB eq	0.014321778	0.004599	0.009722
Ionising radiation	kBq U235 eq	0.963688691	0.065208	0.89848
Agricultural land occupation	m ² a	0.219229345	0.193132	0.026097
Urban land occupation	m ² a	0.05237473	0.02396	0.028415
Natural land transformation	m ²	0.005350716	0.000388	0.004963
Water depletion	m ³	9.3293002	7.798047	1.531253
Metal depletion	kg Fe eq	0.266180143	0.203376	0.062804
Fossil depletion	kg oil eq	6.26563368	0.538716	5.726918



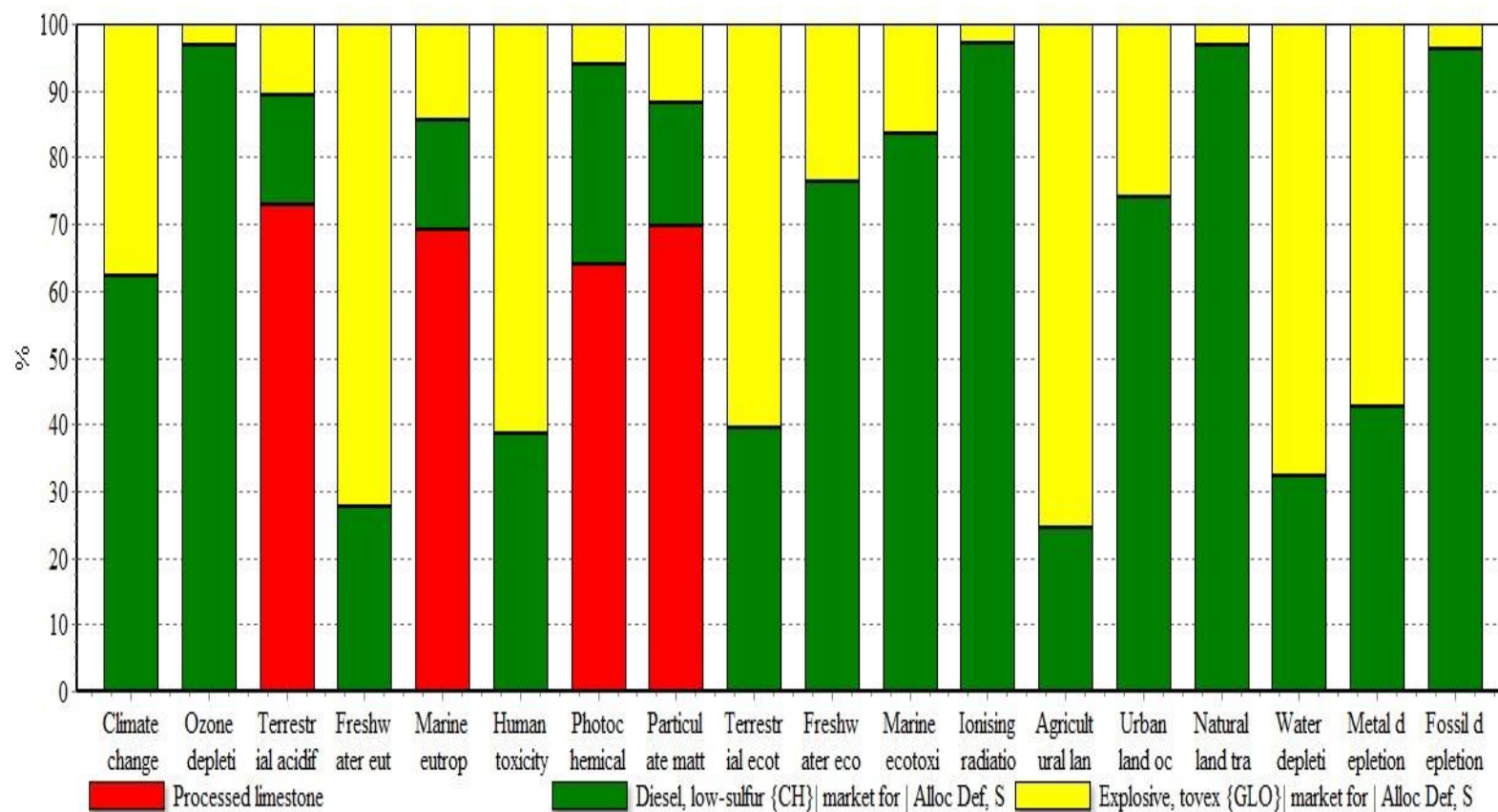
Analyzing 1 ton 'Processed limestone';

Method: ReCiPe Midpoint (H) V1.10 / Europe Recipe H / Characterization / Excluding infrastructure processes / Excluding long-term emissions

Figure 4. 5: Characterization graph of 1 ton processed limestone for Klo-Begoro quarry

Table 4. 10: Characterization table for Klo- Begoro quarry

Impact category	Unit	Total	Explosive	Diesel	Electricity
Climate change	kg CO ₂ eq	4.30468	2.600415	1.670077	0.034189
Ozone depletion	kg CFC-11 eq	9.36E-07	7.52E-08	8.59E-07	1.36E-09
Terrestrial acidification	kg SO ₂ eq	0.025989	0.013159	0.007853	0.000165
Freshwater eutrophication	kg P eq	0.000145	0.000126	1.87E-05	1.65E-07
Marine eutrophication	kg N eq	0.000995	0.000613	0.000272	4.49E-06
Human toxicity	kg 1,4-DB eq	0.372562	0.297738	0.072925	0.001899
Photochemical oxidant formation	kg NMVOC	0.02488	0.007437	0.014375	0.000101
Particulate matter formation	kg PM ₁₀ eq	0.008435	0.004484	0.002652	4.53E-05
Terrestrial ecotoxicity	kg 1,4-DB eq	0.000521	0.000414	0.000104	2.77E-06
Freshwater ecotoxicity	kg 1,4-DB eq	0.003194	0.001395	0.001757	4.19E-05
Marine ecotoxicity	kg 1,4-DB eq	0.010969	0.003661	0.007254	5.35E-05
Ionising radiation	kBq U235 eq	0.723311	0.051907	0.670351	0.001053
Agricultural land occupation	m ² a	0.173233	0.153737	0.019471	2.47E-05
Urban land occupation	m ² a	0.040306	0.019073	0.0212	3.36E-05
Natural land transformation	m ²	0.004021	0.000309	0.003703	9.5E-06
Water depletion	m ³	7.355528	6.207401	1.142458	0.005669
Metal depletion	kg Fe eq	0.209046	0.161891	0.046858	0.000297
Fossil depletion	kg oil eq	4.713633	0.428828	4.272818	0.011987



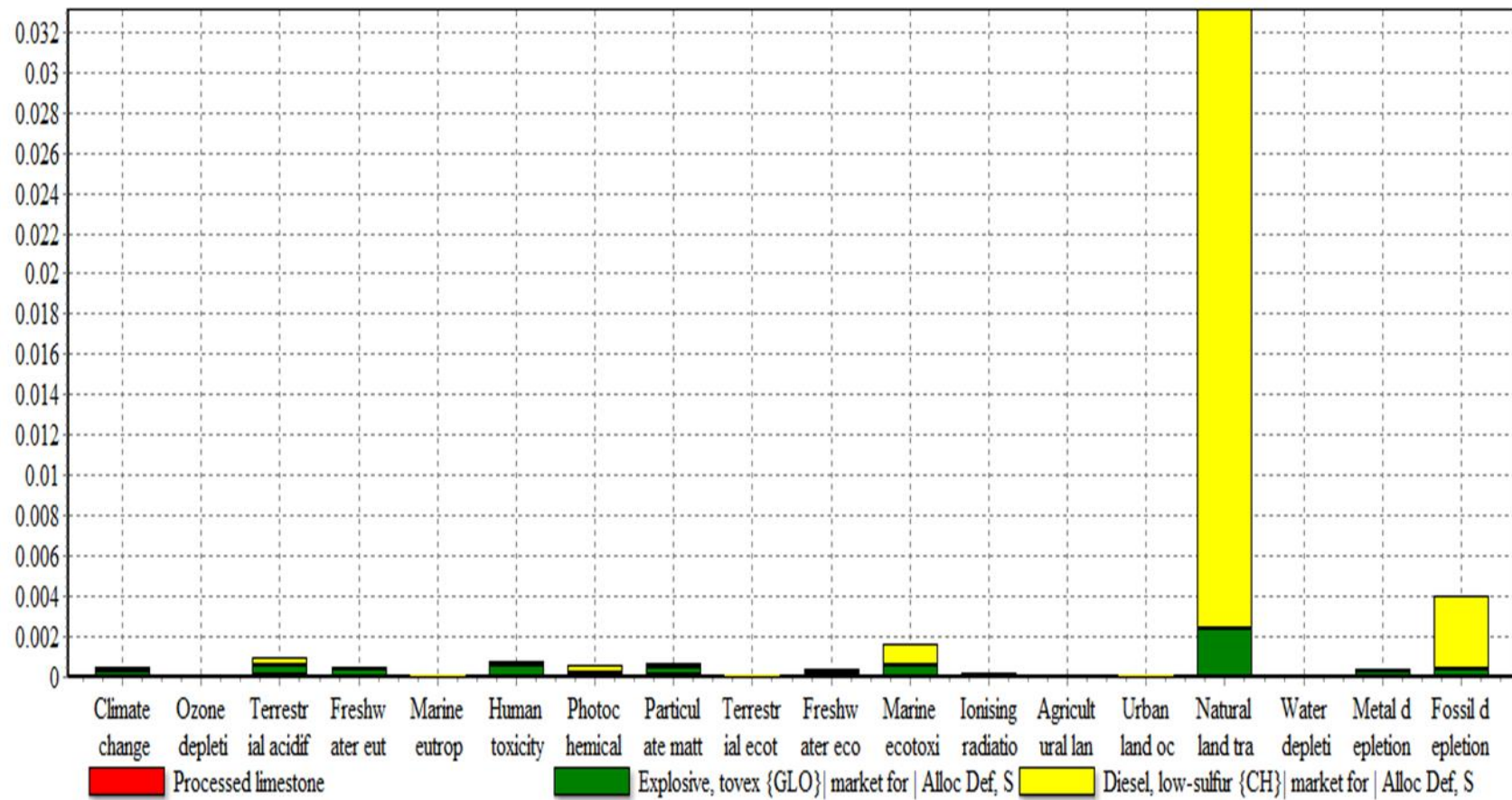
Analyzing 1 ton 'Processed limestone';

Method: ReCiPe Midpoint (H) V1.10 / Europe Recipe H / Characterization / Excluding infrastructure processes / Excluding long-term emissions

Figure 4. 6: Characterization graph of 1 ton processed limestone for Yongwa quarry

Table 4. 11: Characterization table for Yongwa quarry

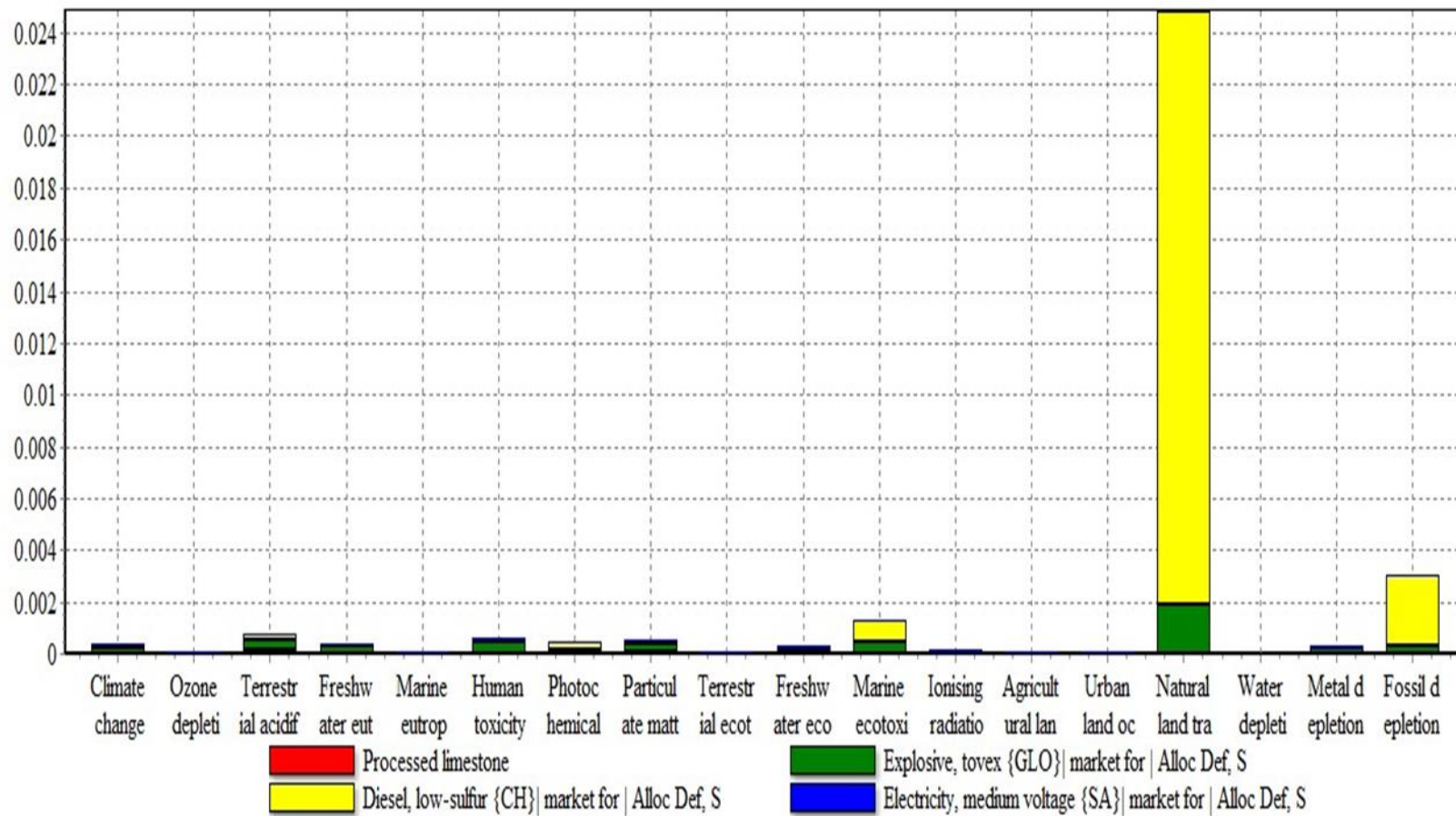
Impact category	Unit	Total	Explosive	Diesel
Climate change	kg CO ₂ eq	3.743168	1.408558	2.33461
Ozone depletion	kg CFC-11 eq	1.24E-06	4.07E-08	1.2E-06
Terrestrial acidification	kg SO ₂ eq	0.067066	0.007128	0.010978
Freshwater eutrophication	kg P eq	9.46E-05	6.85E-05	2.62E-05
Marine eutrophication	kg N eq	0.002311	0.000332	0.00038
Human toxicity	kg 1,4-DB eq	0.263217	0.161275	0.101942
Photochemical oxidant formation	kg NMVOC	0.067232	0.004028	0.020095
Particulate matter formation	kg PM ₁₀ eq	0.020356	0.002429	0.003707
Terrestrial ecotoxicity	kg 1,4-DB eq	0.00037	0.000224	0.000146
Freshwater ecotoxicity	kg 1,4-DB eq	0.003212	0.000755	0.002457
Marine ecotoxicity	kg 1,4-DB eq	0.012123	0.001983	0.01014
Ionising radiation	kBq U235 eq	0.965203	0.028116	0.937087
Agricultural land occupation	m ² a	0.110493	0.083274	0.027218
Urban land occupation	m ² a	0.039967	0.010331	0.029636
Natural land transformation	m ²	0.005343	0.000167	0.005176
Water depletion	m ³	4.959391	3.362342	1.597049
Metal depletion	kg Fe eq	0.153194	0.087691	0.065503
Fossil depletion	kg oil eq	6.205279	0.232282	5.972997



Analyzing 1 ton 'Processed limestone';

Method: ReCiPe Midpoint (H) V1.10 / Europe Recipe H / Normalization / Excluding infrastructure processes / Excluding long-term emissions

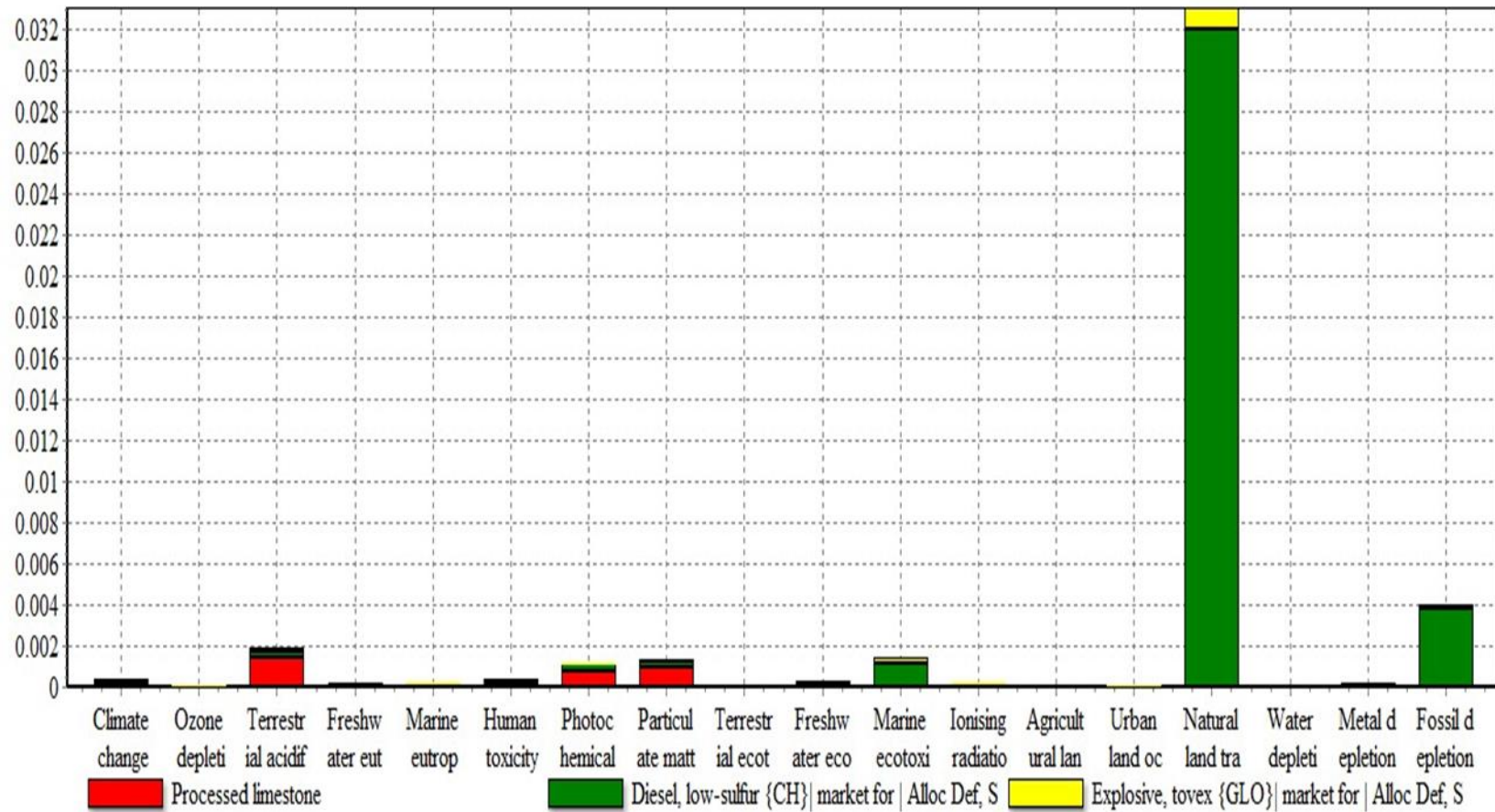
Figure 4. 7: Normalization graph of 1 ton processed limestone for ABL quarry.



Analyzing 1 ton 'Processed limestone';

Method: ReCiPe Midpoint (H) V1.10 / Europe Recipe H / Normalization / Excluding infrastructure processes / Excluding long-term emissions

Figure 4. 8: Normalization graph of 1 ton processed limestone for Klo-Begoro quarry



Analyzing 1 ton 'Processed limestone';

Method: ReCiPe Midpoint (H) V1.10 / Europe Recipe H / Normalization / Excluding infrastructure processes / Excluding long-term emissions

Figure 4. 9: Normalization graph of 1 ton processed limestone for Yongwa quarry.

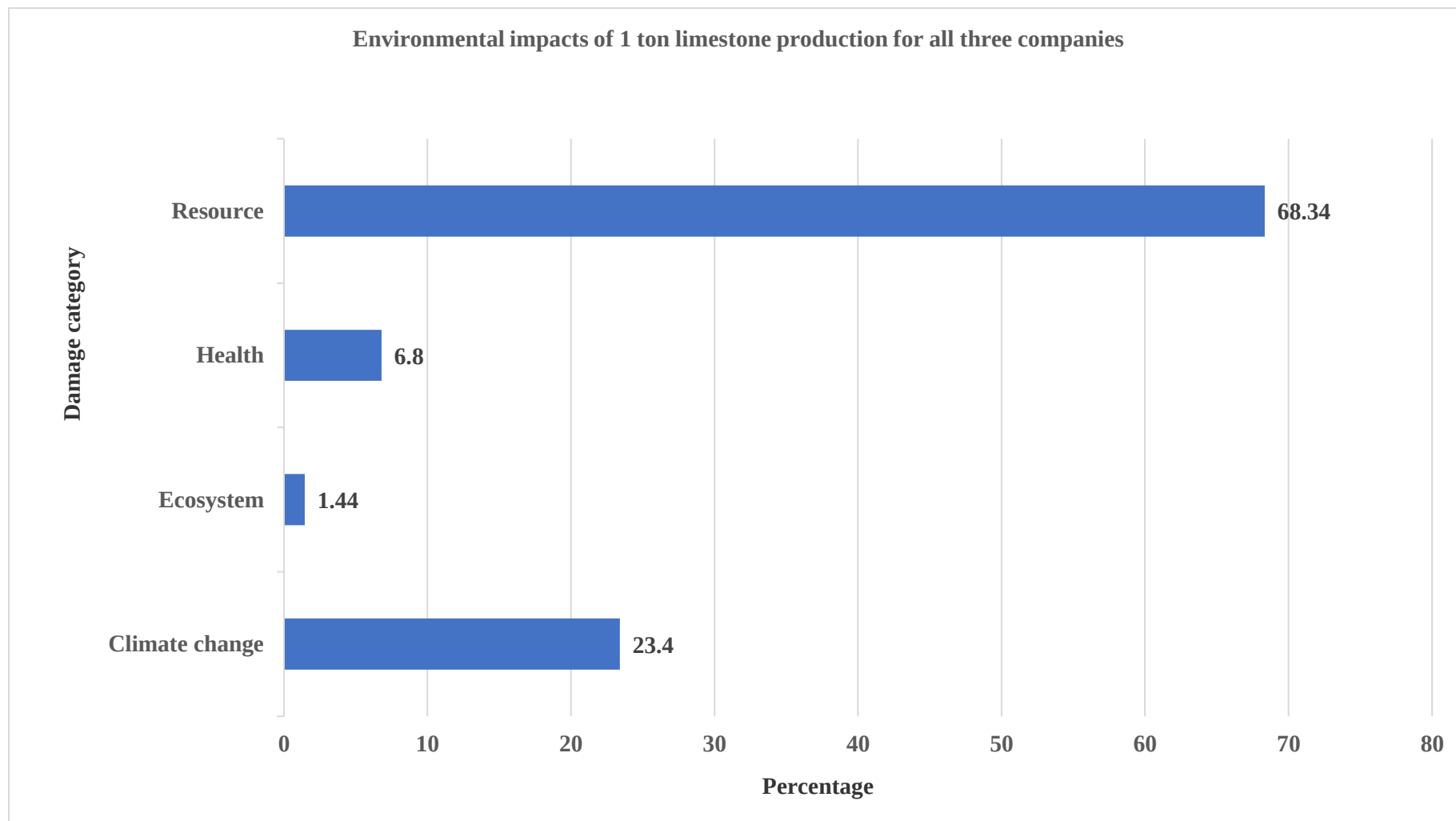


Figure 4. 10: A bar graph showing the Environmental impact categories of 1 ton processed limestone.

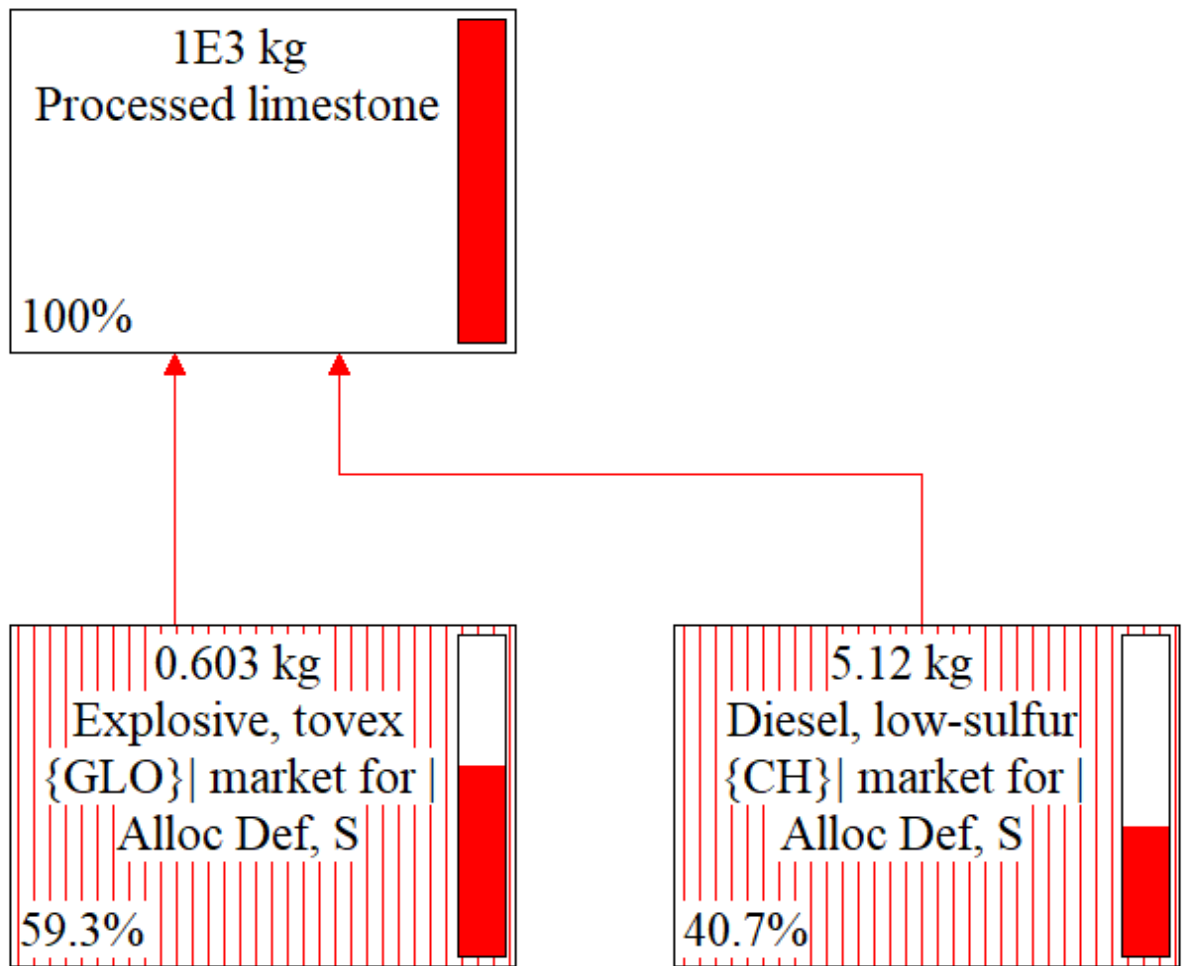


Figure 4. 11: Network for 1 ton processed limestone for ABL quarry

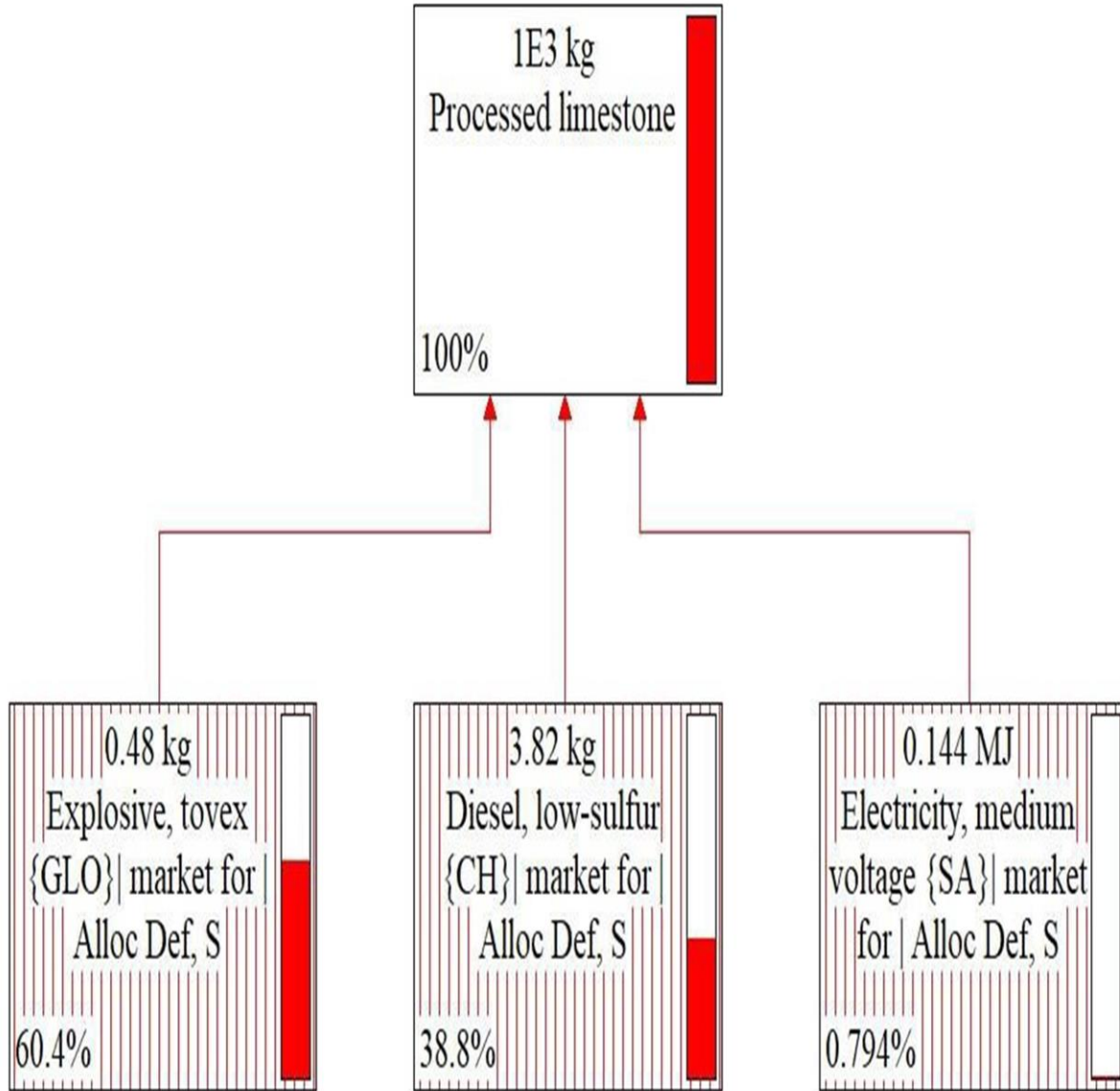


Figure 4. 12: Network for 1 ton processed limestone for Klo-Begoro quarry.

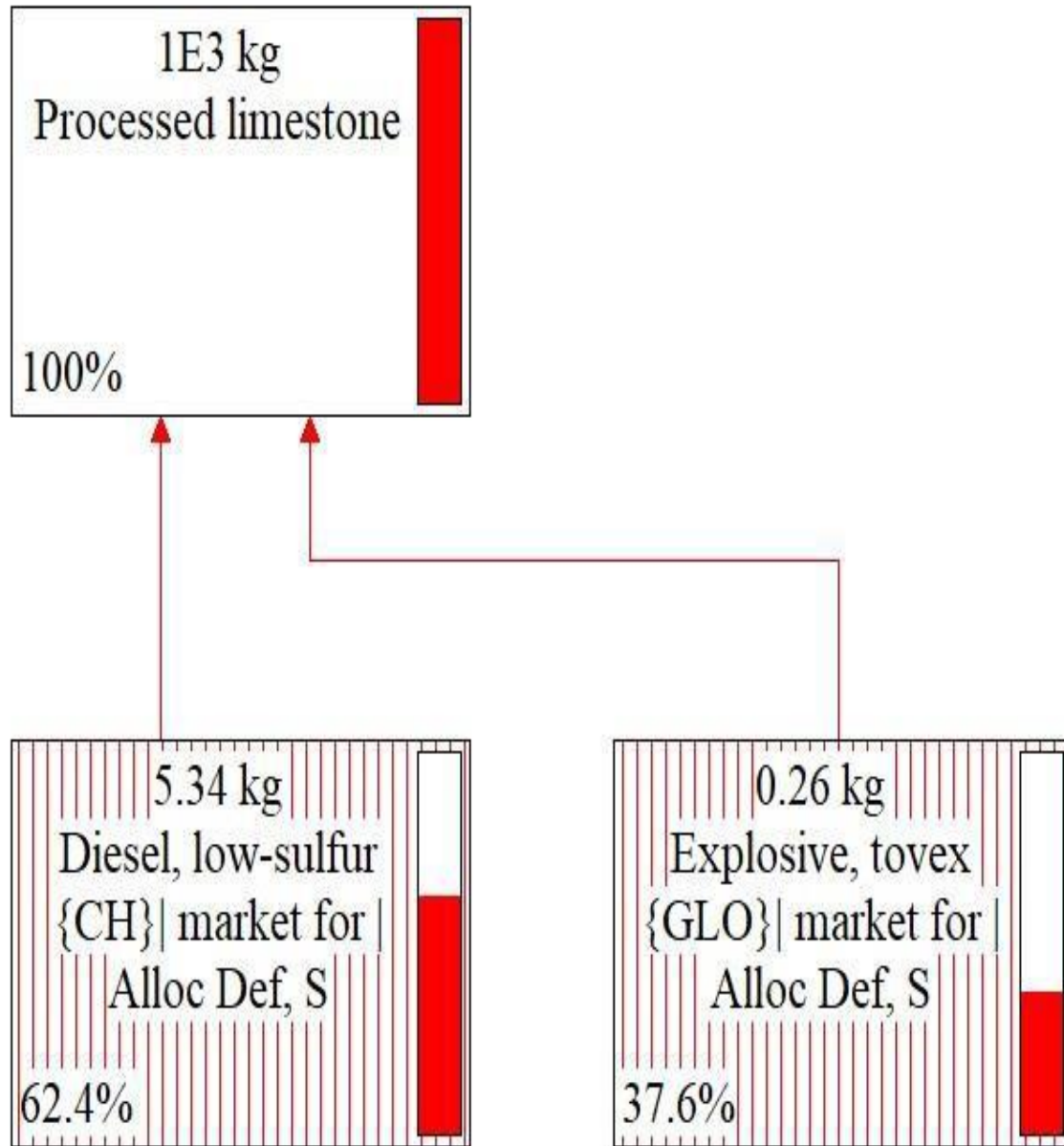


Figure 4. 13: Network for 1 ton processed limestone for Yongwa quarry.

CHAPTER FIVE

DISCUSSION

Yongwa limestone quarry had the highest limestone production and energy consumption throughout the months in 2019. This is because it belongs to West African quarry Limited, a subsidiary company of GHACEM which is the biggest cement manufacturing company in the country and hence a high demand for limestone, a basic component in cement production. Klo-Begoro quarry had the second highest limestone production and energy consumption because they supply their limestone to CIMAFA as well as GHACEM to help meet their limestone demand. ABL quarry on the other hand supplies their produce to only CIMAFA, another cement manufacturing company hence had the lowest limestone production and energy consumption. This implies that the production rate is linked to the energy consumption as Yongwa quarry had the highest limestone production.

The Chi-Square test was used in this study to test whether diseases suffered by the family members are independent of the diseases suffered by the quarrying workers. The results revealed that the significance level ($\alpha = 0.05$) is lower as compared to the p-value and therefore presume that there is not sufficient proof to propose an association between the diseases suffered by the workers and the diseases suffered by the family members. Therefore, diseases suffered by the workers are not transmitted to the family members.

From the focus group discussion, the community members revealed common complaints and ailments affecting the community with respect to limestone production and vibration as a result of the blasting.

Also, the results of this present study revealed that all the workers admitted that their companies have undertaken environmental impact assessment on the activities of the quarrying companies.

Additionally, all the respondents admitted that EPA request environmental impact assessment on the activities of the quarrying companies.

In addition, they said EPA conduct monitoring/inspection of their companies' activities with respect to the environment on yearly basis and that EPA has never cautioned the quarrying companies on issues of environmental degradation or pollution.

The results also indicated that all the workers sampled said their companies have health and safety measures in place for them as well as the quarrying companies give them protective equipment to use when working.

Eshiwani (2014) observed from his research that there was an association between quarrying and the well-being of the quarry workers and community members close to the quarries. Also, quarry workers did not have protectives and regardless of the significant role those quarrying exercises played in the financial development; it came about into adverse consequences to the environment. He also found out from his study that large portion of the quarry organizations don't withstand to the set ecological enactment, for example, the Occupational Safety and Health Act 2007. This disparity between the present study and Eshiwani (2014) study may be due to the factors each study deployed in the chi-square testing.

More so, this study observed that most of the workers suffer from malaria (38%) and, cold and catarrh (35%). The least of the diseases and conditions the workers suffer from at workplaces are diarrhoea (12%) and headache (12%).

A research by Olusegun et al. (2009), they checked the degrees of particulate matter in the ambient air in and around selected quarries, likewise the inhabitants' attention to the negative implications of living in nearness to quarry locales and also the pervasive medical conditions endured by nearby residents and quarry laborers. Their research found that the highest mean SPM

levels among the selected quarries was between $26.03 \pm 1.36 \text{ mg/m}^3$ and $11.03 \pm 1.52 \text{ mg/m}^3$ with SPM levels declining fundamentally ($p > 0.05$) with distance from the penetrating and smashing areas at every of the quarry destinations.

Also, the common ailments the quarry workers had were cough (26.0%), catarrh (20.0%) and sinusitis (15.0%) with the people living close to the quarries also experiencing health and psychological problem. The quarry workers suffered predominantly from cough (26.0%), catarrh (20.0%) and sinusitis (15.0%). Albeit, the people living close to the quarries knew about hazards related with living close to quarries, but could not move away due to lack of money.

Notwithstanding, the results of this study revealed that most quarrying companies in the study area do not undertake any exercise or activity to improve the medical condition of individuals living in the communities and furthermore, do not complete any wellbeing effort program to educate individuals in the communities. Only a few times the companies bring vehicles to water the untarred roads in the communities.

Also, workers sought their medical attention or care from clinics and hospitals when unwell. This is because the workers receive better treatment from these centres and proximity was also paramount in the decision. More so, companies had put in place an intervention to handle health problems of workers associated with work. These interventions include health insurance scheme and payment of risk allowances to workers.

Because diesel and electricity are the energy sources used in the limestone production in the study area, the research focused on, SO_2 , and NO_2 emissions. The use of diesel fuel for transportation and explosives for blasting come up with carbon dioxide (CO_2) emission, whereas transportation, crushing and grinding of the limestone both accounted for SO_2 and PM_{10} emissions.

Climate change, water depletion and fossil depletion were the greatest impacts for all three quarries from the characterization results with natural land transformation presenting the greatest environmental impacts for all three quarries from the normalization results. Diesel consumption for crushing and grinding and transport operations accounted for about 93% of the natural land transformation for ABL, about 92% for Klo-Begoro, and about 96% for Yongwa. Explosive (mineral extraction) is the main source of impacts for ABL and Klo-Begoro quarry while diesel (crushing, grinding and transportation) is the main source of impacts for Yongwa quarry.

The result of this study is inconsistent with previous studies by Kittipongvises (2017), Carras (2008), Yahaya (2012), Sterling (2009), Ditsele (2010) and Silvia (2003). These researches reported that electricity was used for crushing and grinding processes and diesel fuel for transportation with more than 50 percent of electricity consumption used in the mining operations used at the crushing and grinding stage. It is also inconsistent with a study by Gazi et al. (2011) where a processing plant that uses coal generated electricity is used for cutting and finishing processes of marble tiles. However, the results from this present study indicated that diesel fuel was used for crushing, grinding and transportation and electricity was only used for office work by Klo-Begoro quarry company.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From the findings, the following conclusions were made:

Firstly, Yongwa quarry which belongs to West African quarry Limited, a subsidiary company of GHACEM had the highest limestone production in 2019, with a production of 723,600 tonnes, followed by Klo-Begoro quarry with a production of 117,735 tonnes and then ABL quarry with a production of 113,670 tonnes.

Secondly, Yongwa and ABL quarry use only diesel fuel as energy. Diesel is used to power plant for office operations, to operate machines, to transport extracted limestone to crusher for crushing as well as transporting the processed limestone to the consumer (cement factory). Klo-Begoro quarry, however, uses electricity and diesel as energy for limestone production. Electricity is used for office operations and diesel fuel to operate machines, transport extracted limestone to crusher for crushing as well as transporting the processed limestone to the consumer (cement factory).

Thirdly, Malaria, cold and catarrh are the most common ailments among the workers. However, diseases suffered by the workers were not transmitted to family members. More so, the quarrying companies do not undertake activities to improve the well-being of the indigenes in the catchment areas, nor undertake any programme to educate the members in the communities healthy living, apart from few occasions that they bring vehicles to water the untarred roads in the communities. However, the community members around the quarries did not seem to have any issues with the quarry operations aside the vibrations from the blasting.

Fourthly, the resource category i.e., the sum of fossil, metal and water depletion gave the greatest

environmental impacts of 68%, followed by climate change (24%), human health (6.8%) and 1.4% for ecosystem quality.

Lastly, from the normalized results, natural land transformation gave the greatest environmental impacts for all three quarries. Diesel consumption for crushing and grinding and transport operations accounted for about 93% of the natural land transformation for ABL, about 92% for Klo-Begoro, and about 96% for Yongwa. Explosive gave a greater contribution to the network for ABL, Klo-Begoro quarries, while diesel gave a greater contribution to the network for Yongwa quarry.

6.2 Recommendation

The study recommends that:

- Quarry companies should use green technologies such as diesel blending as reported in a work done by Hafizan et al., (2021).
- Future research should be conducted on the gate to grave life cycle assessment of limestone.

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APPENDICES

Appendix A

QUESTIONNAIRE ON ASSESSMENT OF THE HEALTH IMPACT OF LIMESTONE QUARRYING

Instructions: Tick (✓) where appropriate or fill in the required information.

A. PERSONAL INFORMATION

1. Sex.... Male [] Female []
2. Age.....
3. Name of quarrying company.....
4. Position.....
5. How long have you been working with the quarrying company?
6. Marital status: a. Married [] b. Single [] c. Divorced []
7. Have u been to school before? Yes [] No []
8. If yes what is the highest level attained? a. Basic [] b. Secondary [] c. Tertiary [] d. Others, specify.....

B. QUARRYING AND HEALTH

9. Does your company have health and safety measures in place for its workers? Yes [] No []
10. Does your company give you protective to use when working? Yes [] No []
11. Which of the following diseases and conditions do you usually suffer from or contract? (Tick all that apply) A. Malaria [] B. Diarrhoea [] C. Skin diseases [] D. Fever [] E. Colds and catarrh [] F. Other disease(s)
12. How often do you suffer from the diseases and condition stated in Q11 above?

13. What diseases and conditions do people in your family frequently contract or exhibit? (Tick all that apply) A. Malaria [] B. Diarrhoea [] C. Skin diseases [] D. Fever [] E. Colds and catarrh [] F. Other disease(s)

14. Would you say the disease(s) chosen above are related to the quarrying activities?

Yes [] No []

15. Which of the following places do you usually seek medical attention when unwell?

A. Clinics [] B. Hospitals [] C. Herbal centers [] D. Chemical shops/ pharmacies [] E. Other, specify

16. Give reasons for your answer in Q15

.....
.....
.....

17. Has your company put in place an intervention to handle health problems associated with your work? Yes [] No []

18. If yes, what are some of these interventions?

.....
.....
.....
.....

19. Has your company, as part of her corporate social responsibility undertaken any exercise or activity aimed at improving the health condition of the people living in your catchment area?

Yes [] No []

20. If yes indicate the activity or exercise

.....
.....
.....

21. Does your quarrying company carry out any health campaign programme to educate people in the community? Yes [] No []

22. If yes, give any example of such campaigns you know of
.....
.....
.....

C. ROLE OF ENVIRONMENTAL PROTECTION AGENCY (EPA) WITHIN THE QUARRYING SECTOR

23. Has your company undertaken environmental impact assessment on the activities of your quarrying company?

24. Does EPA request Environmental Impact Assessment on the activities of your quarrying company? Yes [] No []

25. Does EPA conduct monitoring/inspection of your company's activities with respect to the environment?

26. If yes, how often are such exercises carried out? A. Monthly [] B. Quarterly [] C. Bi-annually [] D. Yearly [] Other, Specify.....

27. Has EPA ever cautioned the company on issues of environmental degradation or pollution? Yes [] No []

28. If yes, what steps did the company take in any of such instances?
.....
.....
.....
.....

Appendix B

Table 4A: A table showing annual limestone production from the 3 companies for 2019

Month	Limestone produced in tonnes		
	ABL quarry	Klo-Begoro quarry	Yongwa quarry
January	6615	6945	45600
February	8955	6340	78800
March	12735	14955	47704
April	8775	13620	50600
May	6975	15355	52200
June	10530	11540	54400
July	12420	10355	64900
August	10800	13520	68300
September	8415	11390	71800
October	7605	5920	75300
November	8865	2695	58700
December	10980	5100	55296
Total	113670	117735	723600
Average	9472.5	9811.3	60300

Appendix C

Embodied diesel consumption for limestone production in litres			
Month	ABL quarry	Klo-Begoro quarry	Yongwa quarry
January	37650	33895	197684
February	45110	35750	439976
March	67270	49825	290228
April	46865	46875	260949
May	36180	52675	272540
June	54643	40235	287219
July	52727	27010	346802
August	49395	50680	362153
September	44810	47515	395816
October	40175	25305	415567
November	49590	21665	310092
December	57540	17895	281920
Total	581955	449325	3,860,946
Average	48496.25	37443.7	321,746

Appendix D

Interview Guide for Focus Group Discussion (FGD) on complaints and ailments by community members with respect to limestone production

1. What are your complaints about the limestone quarrying?
2. Do you wish the companies stop the quarrying?
3. Do you wish to relocate to a different community?
4. Does the quarrying affect your health and well-being?
5. Does the vibration from the blasting affect your buildings?
6. How is the relationship between you and the quarry workers?
7. Does the dust come to your homes?
8. Do you feel the vibrations in your homes when they are blasting?
9. Has there ever been a fly stone from the quarry during blasting to your homes?
10. Do the companies fix or compensate you the cracks their blasting cause in your buildings?