

UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCE,

**AN ASSESSMENT OF ENVIRONMENTAL IMPACT OF MINE BLASTING IN
NEW ABIREM AND ITS ENVIRONS IN THE EASTERN REGION OF GHANA**

BY

AVORNYOTSE CHARLES KWAMI

10806302

**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF
MPHIL IN ENVIRONMENTAL SCIENCE DEGREE**

INSTITUTE FOR ENVIRONMENT AND SANITATION STUDIES

(IESS)

INTEGRI PROCEDAMUS

DECEMBER, 2021

DECLARATION

It is declared that this thesis is the outcome of my research work stated by Charles Kwami Avornyotse and that it has never been submitted for any degree in this university or elsewhere. All references to other materials have been duly acknowledged.

CANDIDATE



Avornyotse Charles Kwami

11-08-2022

Date

PRINCIPAL SUPERVISOR



Dr. Ted Y. Annang

11-8-2022

Date

CO-SUPERVISOR



Prof. Christopher Gordon

11th August 2022

Date

DEDICATION

I hereby dedicate this work to my parents, Mr. George Kojo Avornyotse and Madam Benedicta Yawa Abredu, my beloved wife Juliana Yawa Kodi and my dear sons Michael and Edudzi. Last but not least, to all who cherish to protect the environment for the benefit of posterity.



ACKNOWLEDGEMENTS

I thank Almighty God for his guidance and protection throughout my two-year programme. Second, I would like to express my heartfelt gratitude to my supervisors, Dr. Ted Y. Annang and Prof. Christopher Gordon, for their help, suggestions, constant encouragement, genuine and constructive criticism, and unwavering faith in me to see this wonderful piece of work through during the research period.

I also appreciate Mr. Nash Owusu Bentil's significant commitment to field sampling and laboratory work, as well as his provision of important methodology guidelines on sample digestion and results for this study.

My gratitude also goes to Mr. Patrick Bruce, Newmont Akyem and Mr. Michael Kotoka, Ghana Mineral Commission for their help that had paved way for me to carry out the research at the Newmont Akyem. I am highly grateful to the Mine Blasting and Environmental Staff of Newmont Akyem for their assistance on the field during the samples collection.

I would also like to express my gratitude to Mr. Amoako for his assistance with the analysis and for taking the time to help me run my results. I also appreciate his efforts in helping me with instrumental difficulties and for providing analytical advice.

I am much grateful for the support I had from the staff of Institute for Environment and Sanitation Studies (IESS) at University of Ghana. I also express my appreciation to my classmates, friends and students at the University of Ghana for their support and advice during my MPhil study period.

Last but not least, I want to convey my gratitude to my family for their financial assistance as well as their encouragement.



TABLE OF CONTENTS

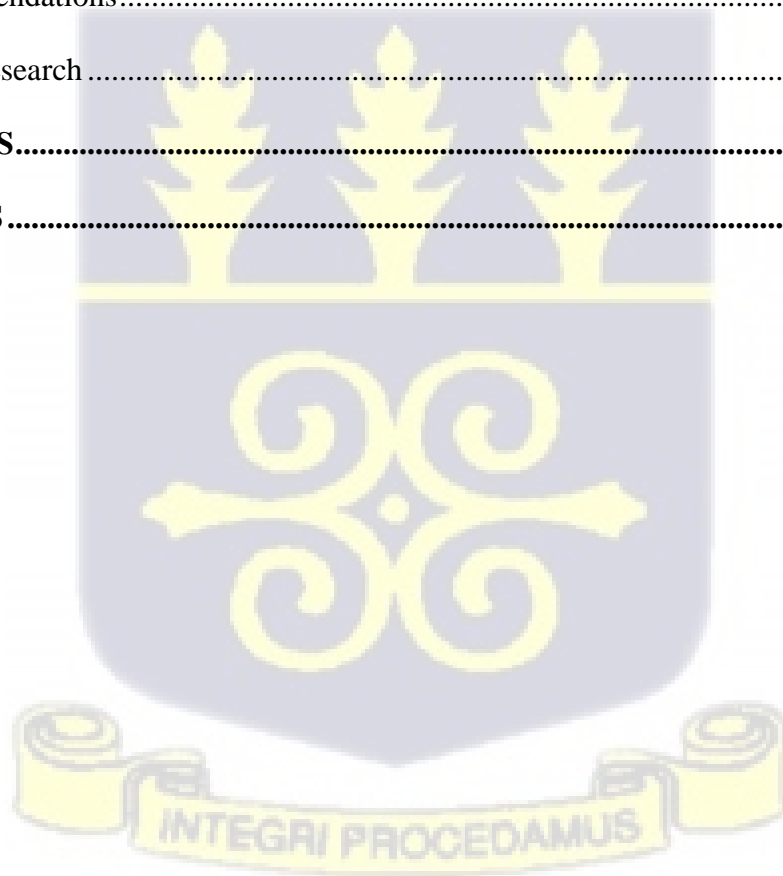
DECLARATION.....	i
DEDICATION.....	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	ix
LIST OF FIGURES	x
ABSTRACT.....	xi
CHAPTER ONE	1
1.0 INTRODUCTION.....	1
1.1 Background.....	1
1.2 The Problem Statement.....	2
1.3 Justification of the Study	4
1.4 Objectives of the Study.....	5
1.4.1 General Objective	5
1.4.2 Specific Objectives	5
1.5 Research Questions	5
CHAPTER TWO	7
2.0 LITERATURE REVIEW	7
2.1 Impact of Mining on Economy	7
2.2 Impact of Mining on Health.....	8
2.3 Impact of Mining on the Environment.....	9
2.4 Environmental Pollution	10
2.4.1 Degradation of Land and Vegetation.....	11
2.4.2 Water Pollution	11

2.4.3 Noise and Vibration	12
2.5 Blasting Chemicals	12
2.5.1 The Blasting Chemicals Pollution in the Surface Water	13
2.6.0 Physicochemical Parameters.....	13
2.6.1 Dissolved Oxygen.....	13
2.6.2 Electrical Conductivity	14
2.6.3 pH.....	15
2.6.4 Temperature	15
2.6.5 Ammonia.....	15
2.6.6 Nitrate	16
2.7 Heavy Metals	16
2.7.1 The Toxic Effects of Heavy Metals to the Human Body.....	17
2.7.2 Copper.....	17
2.7.3 Iron.....	18
2.7.4 Zinc	18
2.7.5 Chromium	19
2.7.6 Manganese	19
CHAPTER THREE	21
3.0 METHODOLOGY	21
3.1 The Study Area	21
3.2.1 Location and Size.....	22
3.2.2 Physical Features	23
3.2.3 Population	24
3.2.4 Occupational Distribution.....	24
3.2.5 The Structure of the Local Economy	25

3.2.6 Health Care Systems and Delivery in the District	25
3.3 Research Methodology	25
3.3.1 Methods of Data Collection	25
3.3.2 Sources of Data Collection	26
3.3.3 Research or Sampling Design	27
3.3.4 Sampling	28
3.3.5 Sampling and Storage of Surface Water	29
3.3.6 Collection and Preparation of Samples for Analysis	30
3.3.7 Analysis of Water samples for Physicochemical Parameters	30
3.3.7.1 Dissolved Oxygen	30
3.3.7.2 Electrical Conductivity	31
3.3.7.3 PH	31
3.3.7.4 Temperature	31
3.3.7.5 Ammonia	32
3.3.7.6 Nitrate	32
3.3.8 Digestion Protocol of Water Samples for Heavy Metals	33
3.3.10 Data Processing and Statistical Analysis	34
3.3.11 Pollution indices of Water	34
3.3.11.1 Degree of Pollution Index (Pd)	34
3.3.10.2 Heavy Metal Contamination Index (HCI)	35
CHAPTER FOUR.....	37
4.0 RESULTS	37
4.1 Perception of the community towards mine blasting and its impact	37
4.2 Air Overpressure From three Blast Monitory Points (BMP)	39
4.3 Ground Vibration From three Blast Monitory Points (BMP)	42

4.4 Physicochemical Parameters.....	46
4.4.1 Dissolved Oxygen (DO)	47
4.4.2 Electrical Conductivity (EC).....	47
4.4.3 PH	48
.....	49
4.4.4 Water Temperature	49
4.4.5 Nitrate (NH ₃).....	50
4.4.6 NO ₃	51
4.5 Heavy Metal Concentrations in Surface Water	52
4.5.1 Copper (Cu) Concentration (mg L ⁻¹)	53
4.5.2 Iron (Fe) Concentration (mg L ⁻¹)	54
4.5.3 Zinc (Zn) Concentration (mg/L)	55
4.5.4 Chromium (Cr) Concentration (mg L ⁻¹)	56
4.5.5 Manganese (Mn) Concentration (mg L ⁻¹)	57
4.6 The Pollution Indices of Locations	58
4.7 Results on Policy Assessment.....	58
5.0 DISCUSSION	60
5.1 The Air overpressure.....	60
5.3 Ground Vibration.....	60
5.4.0 Physicochemical Parameters.....	60
5.4.1 Dissolved Oxygen.....	61
5.4.2 Electrical Conductivity	62
5.4.3 pH.....	62
5.4.4 Temperature	63
5.4.5 Ammonia (NH ₃).....	64

5.4.6 Nitrate (NO ₃).....	64
5.5.0 Heavy Metals	65
5.5.1 Copper (Cu)	65
5.5.2 Iron (Fe)	65
5.5.3 Zinc (Zn)	66
5.5.4 Chromium (Cr).....	67
5.5.5 Manganese (Mn)	68
5.6 The Evaluation of Pollution Indices	68
CHAPTER SIX	70
6.0 CONCLUSIONS AND RECOMMENDATIONS.....	70
6.1 Conclusions.....	70
6.2 Recommendations.....	71
Further Research.....	71
REFERENCES.....	72
APPENDICES.....	84



LIST OF TABLES

Table 3.1: Age and Sex Distribution of the Population24

Table 3.2: Distribution of Sample.....28

Table 3.3 Location coordinates and height of locations in Afosu River and Adausena streams.
.....30

Table 3.4 Standard Used for the Calculation of Pollution Indices.....35

Table 4.1: Perception on Effects of Mine Blasting on the communities37

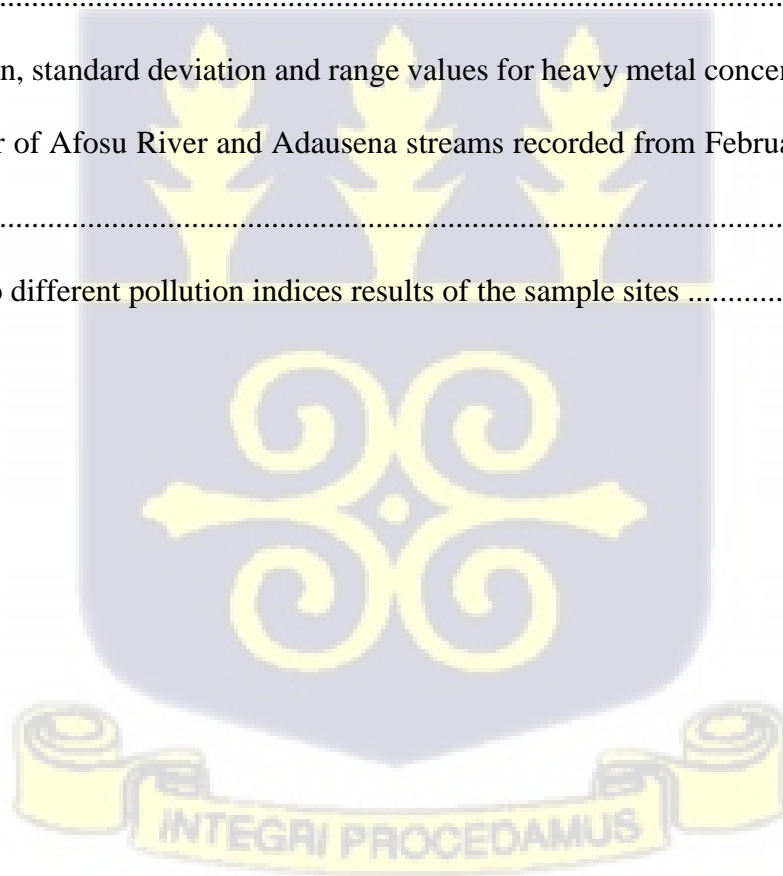
Table 4.2: Mean and range values for air overpressure at the locations.....40

Table 4.3: Mean, standard deviation and range values for ground vibration at the locations.43

Table 4.4: Mean, standard deviation and range values for physiochemical parameters at
locations.....46

Table 4.5: Mean, standard deviation and range values for heavy metal concentration (mg L-1)
in surface water of Afosu River and Adausena streams recorded from February to June 2021.
.....52

Table 4.6: Two different pollution indices results of the sample sites58



LIST OF FIGURES

Figure 3.1: A map of Birim North District showing the location of Newmont and sampling sites21

Figure 3.2: Newmont Akyem Mine Pit and Waste Dump.....22

Figure 4.1: Comparison of percent perception of the respondents on mine blasting at three different communities.38

Figure 4.2: Graph of noise (dB) at three different blast monitory locations.41

Figure 4.3: Graph of Ground vibration (mm/s) at three different monitory locations.....44

Figure 4.4: Variations in DO (mg L-1) between January and December 2021 in different sampling sites.....47

Figure 4.5: Temporal variations in electrical conductivity ($\mu\text{S}/\text{cm}$) between January and June 2021 in different sampling sites at.48

Figure 4.6: Variations in PH between January and June 2021 in different sampling sites. ...49

Figure 4.7: Variations in surface water temperature ($^{\circ}\text{C}$) between January and June 2021 at different sampling sites50

Figure 4.8: Variations in NH_3 between January and June 2021 at Afosu River and Adausena streams sites.50

Figure 4.9: Variations in NO_3 concentration between January and June in different sampling sites.51

Figure 4.10: Mean concentration Cu recorded at indicated sites and control.....53

Figure 4.11: Mean concentration of Fe recorded at indicated sites and control.....54

Figure 4.12: Mean concentration Zn at recorded at indicated sites and control.....55

Figure 4.13: Mean concentration Cr recorded at indicated sites and control56

Figure 4.14: Mean concentration Mn recorded at indicated sites and control.....57

ABSTRACT

Blasting can lead to morbidity and mortality of human as well as damage of properties when not monitored and managed properly. Mine Blasting activities generate seismic effects including vibrations, air overpressure, flyrock, fumes and dusts. The environment can be polluted by blasting residues of rocks like hexogen, trinitrotoluene and octogen which have caused a lot of biodegradation and hazardous effects on ecosystem survival in a mine vicinity. The seismic effects also result in leaching of chemicals to pollute both surface and underground waters in New Abirem and its environs which lead to reduction of terrestrial plant biomass and fertility of earthworm.

In view of this, the study was conducted to assess the ecological impact of mine blasting residues, ground vibration, air blast and heavy metals on the ecosystems around Newmont by collecting and analyzing water samples in three communities (New Abirem, Afosu and Ahausena) as well as measured seismic effects. The noise and vibrations were determined by using the Seismograph from twenty (20) blast shot at the mine pit from October, 2020 to March, 2021. Focus group discussions and household interviews techniques were utilized to assess community perceptions of mine blasting effects on the mine environment.

Physicochemical parameters including temperature, dissolved oxygen, pH, electrical conductivity, ammonia and nitrate, were determined. Heavy metal concentrations in 108 water samples collected from five different locations, made up of two sites along one of the tributaries of Birim River, one site each from two streams, and the Newmont pit were determined using the technique of Milestone Acid Digestion Microwave ETHOS 900 followed by the atomic absorption spectrophotometry (AAS). The data was examined with a one-way analysis of variance and significant differences of $p < 0.05$ were adopted as well as Tukey's HSD to separate means.

The average blast vibration measured at the compliance locations AF-BMP (Afosu), NAB-BMP (New Abirem) and AD-BMP (Ahausena) were compared with 2mm/s [Explosives Regulations, 2012 (L.I. 2177), Section 199]. The average blast air overpressure measured at AF-BMP (Afosu), NAB-BMP (New Abirem) and AD-BMP (Ahausena) were also compared with 117 dBL [Explosives Regulations, 2012 (L.I. 2177), Section 199]. The mean, minimum and maximum blast on air overpressure and ground vibration for each monitoring point respectively were measured and the results were found to be within mining explosives limits. The physicochemical parameters mean level were ranged 24.93 – 27.53 °C (water temperature), 4.66 - 5.36 mg/L (Dissolved Oxygen), 109.79 – 125.98 µS/cm (EC), 7.51 – 7.88 (pH), 0.01 – 0.53 mg/L (NH₃) and 0.22 – 0.42 mg/L (NO₃). The results revealed significant difference in all the physicochemical parameters ($p < 0.05$). The Dissolved Oxygen concentrations at all the five sampling sites were below 5 mg/L which indicated that the water was polluted and adversely affected aquatic life. The pH measurements in the site of Holy Child and Afosu have slightly acidic pH.

The minimum and maximum concentration levels of Cu, Fe, Zn, Cr and Mn in the water were (0.01- 0.02) mgL⁻¹, (0.02 – 0.33) mgL⁻¹, (0.08 – 0.93) mgL⁻¹, (0.01) mgL⁻¹ and (0.02 – 0.10) mgL⁻¹ respectively and there were significant differences between the various sites ($p < 0.05$) compared with the control. The mean levels of Cu, Fe, Zn, Cr and Mn were recorded to be within the permissible limits.

The degree of contamination levels identified in a location are categorized as follows: unpolluted ($Cd < 1$), moderately polluted ($Cd = 1 - 3$) and strongly polluted ($Cd > 3$). The calculated degree of contamination index, Cd values for Holy Child, Aboabo and Adenkyensu locations were greater than 3 mgL⁻¹, the criteria limit for drinking, therefore sites were strongly contaminated. In addition, the pollution index of heavy metals in the water samples from all

locations used were greater than the critical value for drinking water, 100 mgL⁻¹ except Newmont site which recorded 93.91 mgL⁻¹.

Generally, the blasting operation at Newmont, Akyem mine is within the Explosives Regulations, 2012 (L.I. 2177), Section 199 as well as the international Standard quoted AS 2187.2 – 1993. It is recommended that water used for drinking, domestic chores, agricultural (irrigation) or industrial use by communities along the tributaries of the Birim River must be treated before use. There is also a need for research and academic institutions to support non-governmental organizations (NGOs) in their efforts to protect and manage water resources through research for long-term sustainable management.



CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The pollution of ecosystems by mining activities including blasting is an important environmental concern as blasting generates air overpressure, dust, ground vibration and fly rocks in some cases, causes leaching of chemicals to pollute ground water. Others are undesired events that associated with blasting collectively affect the nearby environment unfavorably.

Mine blasting is identified as cost-effective way of fragmenting undisturbed rock masses in surface and underground mines to extract mineral ores. It is also a crucial process that involves drilling of holes of specific diameter and length, charging the holes with explosives and detonating rock masses to extract the ore from the wastes. The energy released by the ignition of explosives generates basic effects like ground vibration, rock fragmentation, rock displacement and air blast. Emulsion composed of about 94% ammonium nitrate and 6 % fuel oil known as Fortis extra or advantage and ammonium-nitrate fuel oil (ANFO) are utilized to disintegrate rock masses in order to help excavate the area to extract the gold.

During blasting process, explosive produces chemical energy which changes into the gas energy and shock energy. It is also recognized that only twenty percent of this energy causes the disintegration of the rock whereas the others display itself in the form of waste energy which is transformed into seismic energy, heat and light. Further, there is rock fragmentations during the blasting process which is caused by the generation of air blast, noise, dust, ground vibrations and fly rock. The negative impact of this blasting causes a great damage to the safety of the nearby structures and the people in adjoining settlements (Abubakar *et al.*, 2011).

The utilization of explosives in blasting of rocks to obtain ore deposits at open pits has negative effects on nearby environment. Winfield et al (2004) reported that the presence of 2, 4, 6-trinitrotoluene, hexogen and Octogen in soil, surface water and groundwater where these explosives have been detonated. Further residues from blasting of rocks have caused a lot of biodegradation and hazardous impacts on ecosystem survival in a mine environment (Juhasz and Naidu, 2007).

Due to the explosives' chemical composition, residues are persistent in soil and can bond to soil organic matter, making soil remediation challenging (Rylott et al, 2011). Also, several studies reported that the high concentration of Trinitrotoluene, Hexogen and Octogen had resulted in a decrease in terrestrial plant biomass and abnormal growth as well as decrease in biomass and fertility of earthworm (Best et al., 2006).

There was an increase in explosives and blasting agents in the world during the year 2002 which was about 2.51 billion kilograms (USGS, 2003). Out of this, about 1.72 billion kilograms (68.5%) were used in coal mining, 0.53 billion kilograms (21.1%) in metal and nonmetal mining, and 0.19 billion kilograms (7.5%) in construction blasting (USGS, 2003). Therefore, explosives and blasting agents are one of the pollutants found in the mine environments.

1.2 The Problem Statement

Dynamite was initially used to fragment the rock masses to initiate the extraction of the gold. The detrimental impacts of ignition of explosives are ground vibration, air blast, fly rock, dust and fumes. The air overpressure and the ground vibrations that occur through blasting within the adjoining communities negatively affect the organisms in that environment. This causes

structures in the mine areas to crack and the breakage of glass wares in their homes. In addition, inhabitants experience a shock when blasting occurs.

Explosives also seep down into the soil causing death of plant roots. In addition, the wastes deposited at the waste dumped leached into the nearby water bodies to pollute them. Undoubtedly, it is evident that the drinking water in the surrounding communities are contaminated with chemicals that lead to morbidity and mortality among inhabitants. Unsuitable blasting planning, design, and field operating faults, such as unpredictably changing site conditions, the diversity of rock mass attributes, and the characteristics of explosives and accessories, could all have negative consequences in the blast zone (Akande and Awojobi, 2005).

Despite the fact that mining corporations are expected to take steps to promote the health of residents in nearby areas, the extent to which negative environmental and health impacts have been reduced has yet to be effectively evaluated. For instance, the Newmont Gold Ridge Limited, Akyem in Ghana is committed to an environmental law and policy which is supervised by the Safety, Health and Sustainable Development Board. The Environmental Protection Agency (EPA) is responsible for reviewing the company's Environmental Impact Assessment (EIA) report and Environmental Management Plan (E.P.A., 2005).

Nonetheless, the mining communities have yet to recognize the extent to which these shareholder organizations are assisting in the reduction of blasting's detrimental consequences. Blasting-related health and environmental issues are a source of worry among mining communities. In view of this, this research sought to carry out an in-depth study into the current environmental and health impacts of blasting in Newmont, Akyem Mine is the key areas of

operation by this Company that are alarming on the adjoining communities which is therefore not complete. Mining firms' investments have once again resulted in significant environmental and health costs for the people. This fuels public uproar against mining firms operating in Ghana, who have refused to acknowledge that their operations are a major polluter and source of social unrest in the country (Awudi, 2002). Therefore, the blasting operation is a hazardous activity that can occur in a mine environment.

1.3 Justification of the Study

Ghana is rich with natural resources and mining activities are critical in the growth of the country's economy through exploitation. The employment of the blasting process as a means of extracting mineral resources has economic benefits such as job creation, revenue generation, and significant foreign exchange that are made available to the country.

In recent years, studies have shown that the detrimental environmental and health repercussions of mining activities are more dangerous than beneficial to economic development. As a result, certain mining corporations in the country have responded by creating and implementing a variety of policies aimed at reducing the harmful environmental and health effects of their operations on the general public. The country is concerned about whether any of these mitigation methods have the ability to decrease the negative health impacts of mining to the bare minimum on the environment and adjacent mining sites.

As a result, the study aims to suggest healthy policy directives to lower the rate of hazardous health impacts associated with blasting activities in New Abirem and its environs. It also attempted to determine the extent of contaminated water bodies in New Abirem and the surrounding area.

1.4 Objectives of the Study

1.4.1 General Objective

The goal of this study is to determine some of the factors that influence mine blasting's environmental impact and the level of pollution in New Abirem, the Akyem mines and their environs.

1.4.2 Specific Objectives

Specifically, the following are set to achieve the general objective:

1. Evaluate the perception of inhabitants of the communities within the mine area on air overpressure and ground vibration effects on people and structures respectively.
2. Examine the levels of air overpressure effects experienced by people in New Abirem and its environs.
3. Ascertain the levels of ground vibration on structures in New Abirem and its environs.
4. Determine the level of selected physicochemical parameters of surface water available to communities in New Abirem and its environs.
5. Determine the levels of predisposition of New Abirem and its environs to trace metal pollution in surface water.
6. Evaluate mining policy directives in order to improve the health of mining communities' residents.

1.5 Research Questions

This study aimed to address the following research questions in order to meet its goals: -

1. What are the perception of inhabitants of communities within the mine area on air overpressure and ground vibration effects on people and structures respectively?

2. What are the levels of air overpressure on people in New Abirem and its Vicinity?
3. What are the levels of ground vibration on structures?
4. What are the levels of selected physicochemical parameters of surface water available to communities in New Abirem and its vicinity?
5. What are the levels of predisposition of New Abirem and its environs to trace metal pollution in surface water?
6. What recommendations and policy directives on mining can be implemented for improved health for residents in mining communities?



CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Impact of Mining on Economy

The contributions of mining to economic development are enormous. Mining is the method of obtaining minerals ores from rocks through blasting. According to mining, is the bedrock for human growth and wealth creation. The mining company has been vital to the development of civilization, supporting gold, silver, copper and iron ages, the development industries and the technology. Over 5.44 trillion tons of raw material worth several trillion dollars were generated by the mining industry.

Ghana's mining industry generates more than 41% of the country's foreign exchange and is the country's top earner. Gold, the most valuable resource, generates about US\$600 million in revenue for the government and has displaced cocoa as the primary source of foreign cash (Awudi, 2002). According to Akabzaa and Darimani (2001), the most commonly recognized benefits of increasing mining industry investments as a result of Ghana's economic reforms are: providing substantial government revenue as well as foreign exchange, generating direct and indirect employment, and contributing to community development in mining areas. Salaries, wages, and other payments to workers and contractors are among the sources of revenue for the industry's internal economy. Concession rents, corporate income taxes, royalties, customs, and harbour levies are also included.

In addition, the mining business pays taxes on employee salaries, employee social security contributions, and shareholder dividends, all of which contribute to economic growth. Furthermore, mining projects are typically located in distant locations, requiring mining corporations to invest significantly in physical and social infrastructure such as roads, schools,

hospitals, electricity, and water supplies as part of their corporate social responsibility. Some of these facilities have typically benefited communities near mine areas. As a result, mining initiatives do not contribute significantly to the national economy and have a significant economic impact (Akabzaa and Darimani, 2001). Mining has received nearly \$2 billion in foreign direct investment (FDI) in mineral exploration and mine development over the last decade, accounting for over 56% of total FDI flows to the country. Despite a huge growth in mineral exports, the country's overall economy has yet to see any significant impact (Awudi, 2002). This is due to a lack of interconnection between the mineral industry and the rest of the economy. The tremendous investment hasn't resulted in a big increase in employment, says the report. As a result, labor-intensive underground gold mines have been phased out in favor of capital-intensive surface mining, which employs fewer people.

2.2 Impact of Mining on Health

Health is the state of an individual's total mental, bodily, and social well-being, rather than the absence of infirmity and disease (World Health Organization, 2005). A range of anthropogenic activities, including as farming, migration, mining and industrialization have caused health problems. According to Stephens and Ahern (2001), mining is still one of the world's most dangerous jobs, not just in terms of short-term injuries and deaths, but also in terms of long-term repercussions like cancer and respiratory disorders including silicosis, asbestosis, and pneumoconiosis. It puts health concerns on humans who are exposed at all levels of mining (Stephens and Ahern, 2001). Noise, water, air, emissions, and food contamination are among the health-related environmental monitoring requirements under Ghana's National Environmental Policy for mining sites (Minerals Commission and Environmental Protection Council, 1994). Ghana Newmont Limited, Akyem has developed hospital and clinics in the district to assist both workers and inhabitants in the mining villages to help alleviate any health

difficulties within the catchment area, due to the health problems that may arise from the environmental monitoring strategy. The corporation also conducts additional health education programs and encourages citizens to report health problems as soon as possible so that they can be treated. There is evidence that mining has a negative influence on employees' health, indicating that the sector's actions are currently undermining human development goals. According to a study by Stephens and Ahern, openness, transparency and a comprehensive assessment of the effects of mining on the health of residents in mining communities is required.

2.3 Impact of Mining on the Environment

The negative environmental effects of mining activities are extensively established (Heath et al., 1993; Veiga and Beinhoff, 1997; Warhurst 1999), with special focus paid to chemical contamination. While mineral development causes significant soil degradation, chemical contamination from blasting wastes places an enormous strain on the environment. Chemical contamination from the gold extraction process is particularly harmful to mining towns and people who live in close proximity to such activities (Yelpaala, 2004).

According to other researches, most miners in Africa and Latin America are mercury exposed and drunk from the extraction through the processing phases of gold prospecting because of the informal nature of the industry, they claimed (Camara, Filhote, and colleagues, 1997; Malm, 1998; Harada et al., 1999; Tirado et al., 2000; van Straaten 2000a;). During the gold amalgamation process, some investigations discovered patterns of mercury toxicity (Camara, Filhote et al. 1997; Tirado, Garcia et al. 2000; van Straaten 2000a; Drasch, Bose-O'Reilly et al. 2001).

According to Drasch and Bose-O'Reilly (2001), a limited number of people are sensitive to chemical intoxication and predisposition, while some people try harder to acquire it. 102 workers, predominantly Hg-burdened ball-millers and amalgam-smelters, 63 more residents exposed to the environment, 100 people living downstream of the mine, and 42 people from another location were included in the study (as controls). Workers and the general public were asked to provide bio-monitors and medical scores. 0 percent of controls, 38 percent downstream, 27 percent non-occupationally exposed from Mt. Diwata, and 71.6 percent of employees were classed as Hg inebriated using this technique. In Tanzania, Harada and Nakachi (1999) found lower levels of intoxication as well as a more complicated mix of mining-related and ambient mercury exposures through household objects, whereas Rojas and Drake (2001) found no mercury intoxication despite occupational and community exposures in Venezuela.

2.4 Environmental Pollution

The increasing concerns about environmental quality can be tracked from the beginning to the present, both on a local and global basis, says the report. Hazardous material emissions have a negative impact on the environment, human health, and agricultural output (Gadzala-Kopciuch, 2004). When environmental pollution problems become obvious, it is sometimes too late to prevent them because they are difficult to spot at the beginning of the process and may not show for many years (Alloway and Ayres 1998). Toxic chemical compounds can enter the environment through air, water, soil, and living organisms, where they can become part of the natural biogeochemical cycle and accumulate in the food chain (Gadzala-Kopciuch, 2004).

The natural environment is undergoing changes as a result of technological advancements, which have the potential to degrade its quality and frequently result in unfavorable interactions

between ecosystem components. Many of the explosive compounds used in rock blasting and heavy metals are harmful to living beings in the environment, says the report. However, heavy metals such as copper, iron, manganese, and zinc are also necessary elements. In most cases, critical element concentrations in organisms are homeostatically maintained, with environmental uptake adjusted according to nutritional requirement. When this control process fails as a result of either insufficient or excessive metals being released into the system, the negative influence on the organisms' manifests (Duffus, 2002).

2.4.1 Degradation of Land and Vegetation

To allow mining activities to begin, large tracts of land and vegetation in the Ajenjua Bepo Forest cover have been cleared. At the moment, it covers more than 70% of the total land area of New Abirem and its environs. It is expected that a mining corporation would use 40-60 percent of its total land bought for its activities. Akabzaa and Darimani (2001) write, suggesting that the area would be deteriorated after mining. In general, large-scale mining activities continue to degrade the area's land cover to levels that are harmful to biological diversity. This significant negative impact on the land and its cover would have an influence on people's livelihoods. The scenario is similar in New Abirem and its environs

2.4.2 Water Pollution

Mining companies have a proactive plan in place to keep major waterways out of the mines. These activities have a negative impact on ground water quality and availability. A main cause of water pollution has been the concentration of mining activity in Birim north. The main problems of water pollution recognized in mining sites include siltation through increased sediment load, chemical pollution of ground water, and dewatering impacts, according to Akabzaa and Darimani (2001).

2.4.3 Noise and Vibration

Noise is the transient pressure transformation caused in air, water or any other fluid medium affected by explosions. Two causes of noise and vibration in the area are automobile mechanical air blasts and blasting vibration. Noises that are high-pitched or other have been demonstrated to harm the auditory system, produce stress and pain. These noises and vibrations can startle animals, prevent them from mating, and even result in miscarriages. The communities living within Newmont Akyem's concessions have complained about the mines' increased ground vibration and noise. However, the Newmont Company's actions have failed to sufficiently address the problem in the area.

2.5 Blasting Chemicals

Chemicals used are explosives which break down rocks bearing mineral ores to extract important components out of the residues. A blasting agent is therefore any substance made up of a fuel and oxidizer that aid in blasting. Inorganic nitrates such as ammonium and sodium nitrates, as well as carbonaceous fuels, make up a blasting agent. Adding a sufficient amount of an explosive element, such as 2, 4, 6-trinitrotoluene, changes the mixture's categorization from a blasting agent to an explosive. Explosives are described as materials that have ability to undergo a rapid chemical reaction without the participation of atmospheric oxygen (Erick et al. 2013).

The surface mining applications of explosives include quarrying and open pit mineral extraction for the production of granite aggregates, stone base and asphalt used in construction of building, bridges and roads; limestone, marble, shale for cement factories; metal productions such as copper, gold, iron ore for steel companies (Meyer et al. 2007). Meanwhile, the

underground mining applications of explosives include coal production, metal production, uranium and radioactive. In Newmont, Akyem mine explosives are used to breakdown gold mineral bearing rocks to extract its ore for processing of gold.

2.5.1 'The Blasting Chemicals Pollution in the Surface Water'

Ammonia and nitrate are two principal nutrients found in blasting chemical that leached into freshwater and later accumulate in organisms at concentrations between 0.53 and 22.8 mg/L. Nutrients are major environmental stressors in river and other aquatic ecosystems. Levels of nutrients in water bodies impact the trophic status thus influencing the sedimentation of abiotic and biotic particles. High levels of nutrients in water bodies can potentially cause eutrophication and hypoxia' (USGS, 2006).

Algal blooms can be induced by nutrient enrichment, which can reduce the recreational and aesthetic value of water, produce odor and taste problems in drinking water, and, in extreme cases, stress or kill aquatic species due to dissolved oxygen depletion or poison release as algal blooms die. The most frequent forms of nitrate ion and ammonium ion are nutrients for aquatic plants, large volumes of nitrogen rich water could result in algal blooms and eutrophication, and consequently oxygen deficiency and changed species composition in the waters receiving mine drainage (Koren et al, 2000; Mattila et al, 2007). Ammonia and nitrogen are the most common limiting nutrients found in surface waters from mining operations.

2.6.0 Physicochemical Parameters

2.6.1 Dissolved Oxygen

The measure of how much oxygen is dissolved in water is referred to as dissolved oxygen. Dissolved oxygen values specify the concentration of oxygen demanding contaminants that

can enter ground water from their sources (Elbag, 2006). Without free dissolved oxygen water bodies become uninhabitable to aerobic organisms such as fish and invertebrates. The amount of oxygen in natural water bodies fluctuates depending on atmospheric pressure, turbulence, temperature, and algae and other aquatic plants' photosynthetic activities. Fast-moving waters have more dissolved oxygen because they combine with air when they come into touch with rocks and logs, according to Vigil (2003). Photosynthesis is the primary cause of increased dissolved oxygen concentrations, whereas respiration and nitrification result in decreased oxygen concentrations (Best et al., 2007).

Low DO levels have a deleterious impact on plant and aquatic species in the water, as well as changing the character of a water body. Values of dissolved oxygen below 5 mg/L may have an impact on aquatic habitat function and survival, whereas concentrations below 2 mg/L may result in the death of most fish. As temperature and salinity rise, as well as pressure falls, oxygen solubility drops.

2.6.2 Electrical Conductivity

According to Michaud (1991), Conductivity of water is the ability of dissolved solids or dissolved ions in that water to conduct an electricity. In effect, the measured electrical conductivity value is an indirect measure of the total dissolved solids concentration including salinity in water. In freshwater ecosystems, conductivity is influenced by the size of the watershed, the mineral composition of the rocks, and other ions sources (Hudson-Edwards et al., 2003; Nielsen et al., 2003). According to Fatoki and Awofolu (2003), excessive consumption of water with high electrical conductivity has health effects in humans which may cause diseases like myocardia and high blood pressure.

2.6.3 pH

According to APHA (1998), pH is described as the acidic or alkaline nature of a water body. Acid rain, local rock breakdown, and chemical leaching catalyze pH, which measures the concentration of hydrogen ions in drinking water. The pH of water affects the solubility and availability of elements in it (Chapman, 1996). Aquatic life can be harmed by water bodies with a pH of less than 4.8 or greater than 9.2. According to the EPA (2005), a low pH might cause trace element accumulation and availability in water for organism uptake.

2.6.4 Temperature

Water temperature is a measure of the hotness of physical, biological and chemical characteristics of ground water. Temperature affects the health of aquatic creatures ranging from microorganisms to fish. Seasonal variations in air temperature cause changes in water temperature (UNEP/GEMS, 2006). Seasonal changes are gradual, especially in bigger bodies of water, and deeper water receives little temperature fluctuation due to subsurface insulation (Spellman and Drinan, 2000).

Organisms become stressed and may die if temperatures are outside their optimal range for an extended period of time. The most temperature-sensitive stage of a fish's life is the reproductive stage (Ecology, 2011b).

2.6.5 Ammonia

Ammonia poisoning is one of the most common causes of unexplained losses in fish hatcheries. Different fish species may tolerate different quantities of ammonia, but in general, the lower the ammonia level, the better. Rainbow trout fry can withstand up to 0.2 mg/L, while hybrid striped bass may withstand up to 1.2 mg/L. Fish may experience a loss of equilibrium, as well

as increased respiratory activity and oxygen consumption, as well as a faster heart rate. Fish may endure convulsions, unconsciousness, and death if their ammonia levels are too high.

2.6.6 Nitrate

Nitrate is an essential nutrient for numerous photosynthetic autotrophs and can occasionally be a growth-limiting nutrient (Akan et al., 2013), however it is required for plant growth and usage (Helen et al., 2005).

Man's uses of synthetic or inorganic fertilizers have resulted to the largest change in the global nitrogen cycle and the increasing fertilizer use is the cause of more than half of the total human-driven alteration of the Nitrogen cycle (Selman and Greenhalgh, 2009). The increasing burning of fossil fuels such as coal and oil and extensive plantings of leguminous crops such as soya beans, peas and alfalfa has caused high nitrate levels in rivers. Nitrate contamination occurs in surface water through leaching into the water supply from various sources.

According to the United States Environmental Protection Agency (USEPA), high levels of nitrate in drinking water are hazardous to infant humans and animals, and can cause the blue baby syndrome, also known as methemoglobinemia.

2.7 Heavy Metals

A group of metals and metalloids having an atomic density greater than 4 g/cm is referred to as heavy metal (Duffus, 2002). According to the United Nations Economic Commission for Europe (UNECE), they are also known as those metals or, in some cases, metalloids that are stable and have a density more than 4.5g/cm, as well as their compounds (UNECE, 1998).

Heavy metals are chemical elements having an atomic density more than 6g/cm, according to

Alloway (1995). Heavy metal pollutions are relevant because of their potential toxicity to ecosystems and humans (Gueu et al., 2007; Lee et al., 2007; Adams et al., 2008; Vinodhini et al., 2008).

The most significant anthropogenic sources of heavy metals in the environment are metalliferous mining and smelting, irrigation and application of sewage water and sludge, fossil fuel burning, and metallurgical industries (Alloway, 1995).

2.7.1 The Toxic Effects of Heavy Metals to the Human Body

The toxicity of a metal is usually expressed as the concentration required to cause an acute (usually fatal) or sublethal reaction (Smith, 1986). Because metals might be necessary or non-essential, predicting the effects of metal exposure on living organisms is difficult. Essential metals at extremely low amounts might be just as dangerous as those in extremely high concentrations. At low quantities, several heavy metals are harmful to organisms.

Heavy metals like as copper, iron, manganese, and zinc, which are regarded as trace elements, are, however, necessary components. Essential element concentrations in organisms are generally homeostatically maintained, with environmental absorption adjusted according to nutritional requirement. Trace metal toxicity are linked to a number of health problems (Romero et al., 2004). Heavy metal accumulation in the body can contribute to a decline in a person's mental, cognitive, and physical health.

2.7.2 Copper

Copper is a necessary component of all life systems (Carolyn et al., 2004; Nicholas et al., 1998).

There are three types of copper in the aquatic environment: soluble, colloidal, and particulate.

Excessive copper consumption is hazardous, resulting in bone disease, hypertension, and degenerative alterations in brain tissues (Krishnamurthy and Pushpa 1995). High doses can also harm the liver and kidneys, cause anemia, and irritate the stomach and intestines (Tirkey et al., 2012; Madsen et al, 1990). In trace amounts, copper is moderately poisonous to mammals and extremely poisonous to invertebrates.

Most life forms are toxic to copper ions (Cu^{2+}), with 0.5mgL^{-1} lethal for many algae species (O'Dell and Campell, 1971). Copper pollution is caused by mining activities and the widespread use of copper pellets in pig rearing. Anemia, growth inhibition, and blood circulation problems are all symptoms of copper deficiency (Jennings, et al., 1996).

2.7.3 Iron

Iron is essential to most life forms, including normal human physiology, according to the Institute of Medicine (2001), as it is a component of numerous proteins and enzymes that keep us healthy. For example, iron is a necessary component of proteins involved in human oxygen transport as well as cell growth and differentiation (Dallman, 1986; Andrews, 1986).

Iron deficiency impairs oxygen delivery to cells, resulting in fatigue, decreased work performance, and weakened immunity (Institute of Medicine, 2001). Excess iron (more than 10 mg/kg) causes hypertension, sleepiness, and even mortality, as well as a rapid increase in pulse rate and blood coagulation in blood vessels (Corbett, 1995). Its presence in water is caused by natural geological sources, industrial waste, and mining.

2.7.4 Zinc

Zinc is a vital element that can be found in almost all foods and drinking water as salts or organic complexes (WHO, 2011). It functions as a nutrient in the human body and is essential

for good health (Hortz et al., 2003). Zinc has a physiological and metabolic role in many species, according to Rajappa et al. (2010). Several enzymes involved in energy metabolism, as well as transcription and translation of RNA, use it as a catalytic or structural component. Zinc also plays an important function in influencing pregnancy outcomes and sustaining neurobehavioral development (Hortz et al., 2003).

Zinc is employed in various industries, including the fabrication of dry cell batteries and alloys such as bronze and brass, according to Momtaz (2002). Zinc fertilizers, sewage sludges, and mining are the main causes of Zn contamination in the environment (Bradi, 2005). Drainage from mines, urban runoff.

2.7.5 Chromium

According to Rajappa et al. (2010), chromium is an important element for plants and animals, as well as a biological and pollution significance element. Electroplating can result in the emission of chromic acid spray and air-borne Cr-trioxide, both of which can cause immediate skin and lung harm (Grounse, et al, 1983). Sub-chronic and chronic chromic acid exposure can cause skin irritation and ulceration (U.S.EPA, 1999).

Long-term exposure can harm the kidneys, liver, circulatory system, and nerves. Chromium is released into the environment by mining operations, runoff and leaching into groundwater, fossil-fuel burning, cement-plant emissions, mineral leaching, and waste incineration.

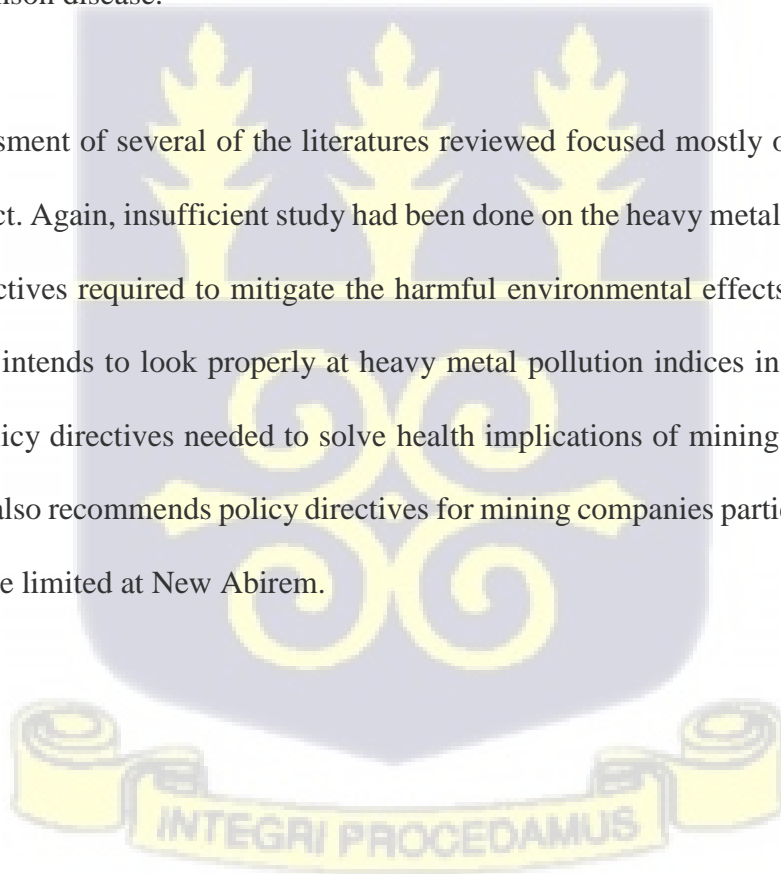
2.7.6 Manganese

Manganese is a plentiful element that can be found in soils, sediments, rocks, water, and biological things (NCSU, 2006). Manganese concentration in the earth's crust is estimated to

be around 1000 mg/kg (NAS/NRC, 1973). Manganese is primarily obtained from the production of alloys, mining activities, fertilizer and fungicide production and use, and the production of synthetic manganese oxide and dry cell batteries. According to Damodharan (2013), manganese is present in roughly 100 common salts and mineral complexes that are extensively distributed in soils, rocks, and the bottoms of lakes and seas.

Manganese is an essential micronutrient found in all living things that serves as a cofactor for a variety of enzyme activity (Suresh et al., 1999). It's also required for glucose and lipid metabolism, connective tissue and bone production, growth, embryonic inner ear development, and reproductive function (WHO, 2011 and DWAF, 1996). Manganese is a low-toxicity metal that has a significant biological effect and appears to accumulate in fish (Kumar et al., 2011). According to Bradi (2005), elevated Mn levels cause liver cirrhosis as well as a poisoning known as Parkinson disease.

A critical assessment of several of the literatures reviewed focused mostly on mining and its economic impact. Again, insufficient study had been done on the heavy metal pollution indices and policy directives required to mitigate the harmful environmental effects of mining. This study therefore intends to look properly at heavy metal pollution indices in the environment and provide policy directives needed to solve health implications of mining on the adjoining ecosystems. It also recommends policy directives for mining companies particularly Newmont Gold Rich Ridge limited at New Abirem.



CHAPTER THREE

3.0 METHODOLOGY

The study area is broadly summarized under physical, human and economic environments. The research methodology details issues such as sampling design, sampling procedure, sample frame and sample size determination, data sources, data collection modes, digestion of samples and data analysis.

3.1 The Study Area

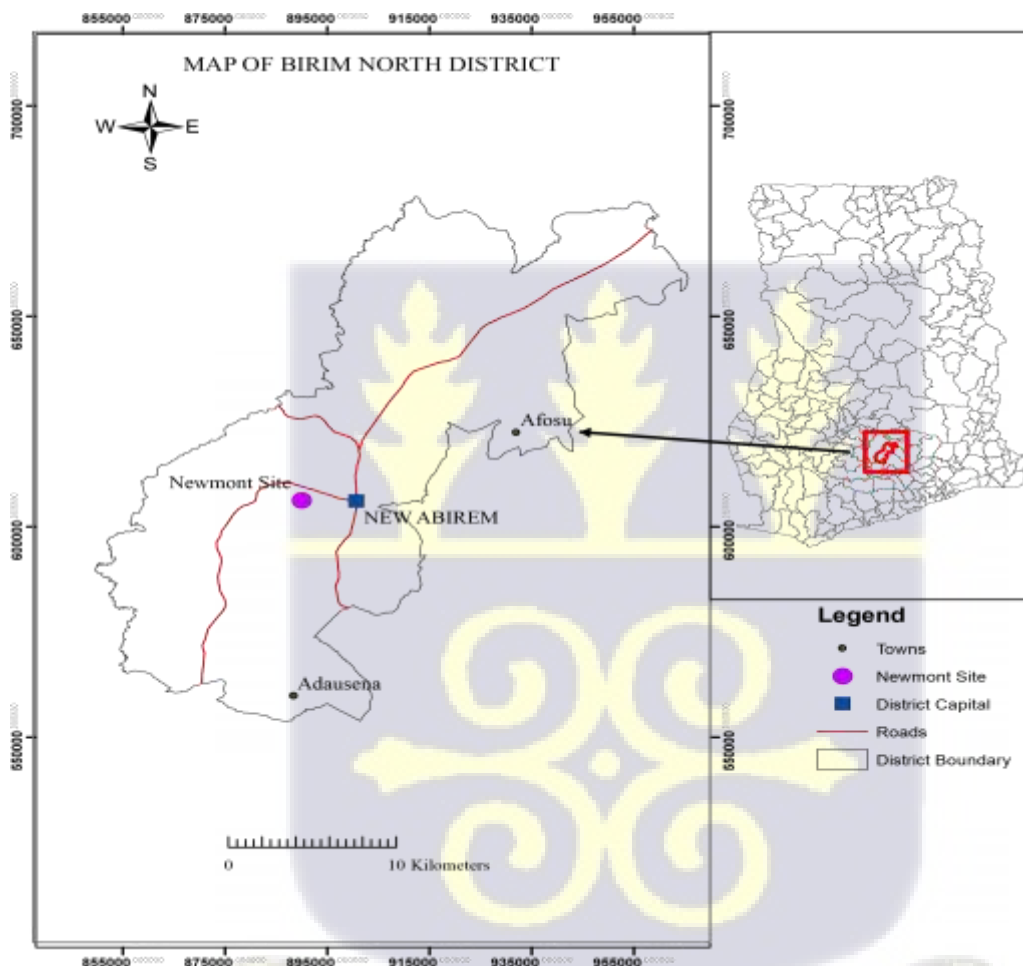


Figure 3.1: A map of Birim North District showing the location of Newmont and sampling sites

3.2.1 Location and Size

The Newmont Akyem mine is located in Birim North district, Eastern Region of Ghana at latitude $6^{\circ}18'N$ and longitude $0^{\circ}59'W$. The population of Birim North is 78,907 people. The total land area of the district is 566.48 square kilometers. The Newmont is located adjacent to thick forest and surrounded with water where both terrestrial and aquatic habitats reside. It is near communities where major farming activities are carried out. The major operation of the company is mining of gold ore deposit for processing purposes. This includes activities like drilling and blasting using blasting agents and explosive materials for rock fragmentation. Approximately 74 hectares of the mining overall pit is located in the Ajenjua Bepo Forest Reserve.



Figure 3.2: Newmont Akyem Mine Pit and Waste Dump

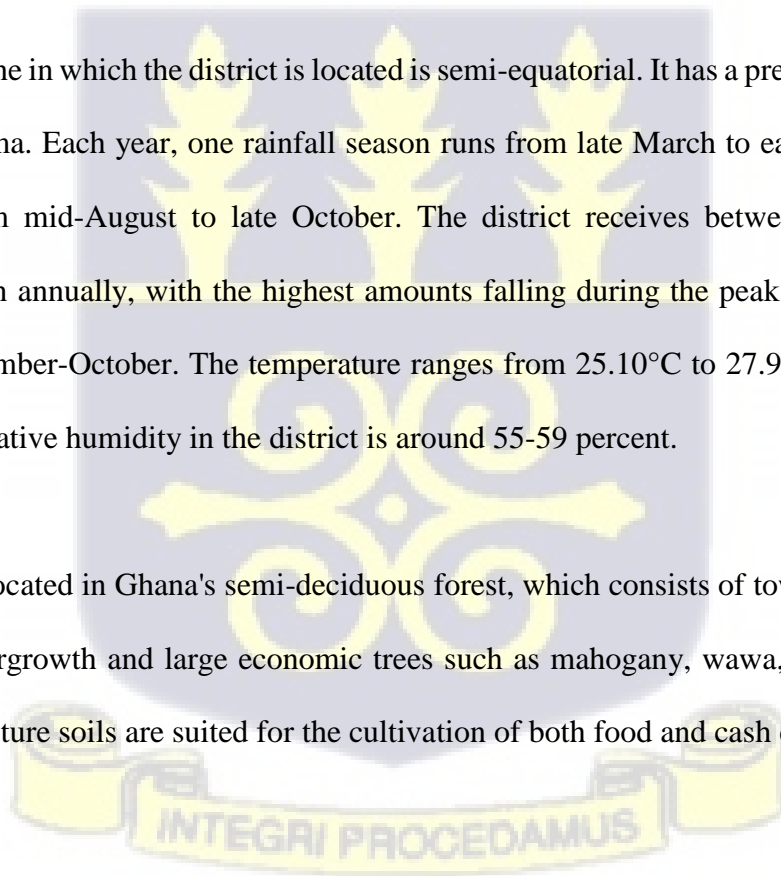
3.2.2 Physical Features

The Birim North District's geography is generally undulating and mountainous in nature (GSS, 2012). The average annual rainfall in these locations is around 170mm, with a low of 80mm. In comparison to the hilly sections, the low areas of the district are made up of phyllite and greywacke, which receive very little rainfall.

The Pra and Birim Rivers are the two main rivers in the district. The Pra River runs between two Districts in the Ashanti area and another District, while the Birim River runs across the district's southern border. The Afosu River is a tributary of the Birim River that runs beside it through Newmont Akyem. This river is a key supply of water for agriculture and domestic usage in the district's neighboring cities and villages (GSS, 2012).

The climatic zone in which the district is located is semi-equatorial. It has a precipitation pattern with two maxima. Each year, one rainfall season runs from late March to early July, and the other runs from mid-August to late October. The district receives between 1500mm and 2000mm of rain annually, with the highest amounts falling during the peak months of May-June and September-October. The temperature ranges from 25.10°C to 27.90°C. Throughout the year, the relative humidity in the district is around 55-59 percent.

The district is located in Ghana's semi-deciduous forest, which consists of towering trees with evergreen undergrowth and large economic trees such as mahogany, wawa, and sapele. The district's agriculture soils are suited for the cultivation of both food and cash crops.



3.2.3 Population

According to GSS, 2010 data shows that the total population of the district is 78,907 representing 3 percent of the regional population. The male population is 39,572 and that of females is 39,335, an indication that there are slightly more males (50.2%) than females (49.8%) in the district. The population distribution of persons in the district shows that about 48% of the populations were between 0-14 years. Between 15 and 49, the potential labour force in the district constitutes about 47% and 60 and above also making about 14%.

Table 3.1: Age and Sex Distribution of the Population

AGE GROUP	MALE	FEMALE	TOTAL	PERCENTAGE
Under 5 years	5974	5586	11560	14.65%
5-9 years	5134	4985	10119	12.82%
10-14 years	5084	4688	9772	12.38%
15-49 years	18189	18533	36722	46.56%
50-60	2514	2504	5018	6.35%
60 +	2677	3039	5716	7.24%
TOTAL	39,572	39,335	78,907	100%

Source: Ghana Statistical Service, 2010 Population and Housing Census

3.2.4 Occupational Distribution

In the Birim north District, agriculture is the dominant occupation, followed by mining and lastly the service and commerce sectors. Mining support activities employ around 10% of the working population, whereas mining/industry employs about 38% of the district's workforce. Males dominate the agricultural and fisheries occupations (56.3% and 43.7% respectively), whereas females dominate the sales 36.1% and services occupations (63.9%) (GSS, 2012).

3.2.5 The Structure of the Local Economy

The mainstay of the local economy in the Birim north district comprised of mining and agriculture. Agriculture dominates local economy forming about 55% and this is followed by the mining sector also constituting 30%. There is also the service sector which includes trading, transport, banking and telecommunication. These constituted about 15% (GSS, 2012).

3.2.6 Health Care Systems and Delivery in the District

Mining activities in the Birim north district necessitate the provision of specialized services, such as health care, to address health issues. The majority of those who participate in these activities are at risk of respiratory and hearing problems. There are various health facilities which are established to take care of these needs of the peoples.

In the Birim North district, they have a total of 15 health facilities scattered in towns and villages and consist of hospital, clinics, health posts and maternity homes owned by the government and private entities. These health facilities have qualified personnel to address the health concern of the people. In cases where health issues reported are not resolved at health facilities in the district, patients are referred to regional hospital, a referral facility for special attention.

3.3 Research Methodology

3.3.1 Methods of Data Collection

The data on the environmental impact of Newmont's actions was gathered for examination. Data on the company's interventional measures, such as safety and health, were also collected and analyzed.

3.3.2 Sources of Data Collection

The data were collected for six months for the purpose of the study. Primary data included three months data on air overpressures and ground vibrations measured by the researcher on daily basis were also utilized. The Newmont, Akyem mine pit holes are drilled by automatically operated drilling machines and the blasting drills were designed in benches of 8m whilst drilling depth of 9.2 or 10m based on the nature of the ground to a diameter of 0.02m drill holes were normally drilled on a staggered pattern. The spacing and burden for ore deposit areas were averaged at 4.8m by 4.8m while waste deposit locations were 5.5m by 5.5m. The Site mixed emulsion explosives known as Fortis advantage or extra were used for blasting. Charged holes are primed by Cast booster and the firing sequence was Such that there was hole to hole initiation. The ground vibrations and the noise were recorded by using the digital monitory systems make up of Seismograph.

Residents of Newmont's surrounding settlements, Akyem mine workers, and officials from governmental institutions such as the Birim North District Assembly and the Environmental Protection Agency were given questionnaires (E.P.A). For pertinent information, interviews were held with authorities from the Birim North District Assembly, the Environmental Protection Agency (EPA), and health center personnel. Interviews with chiefs and other opinion leaders were also conducted.

To establish the consequences of mining operations on the environment, field observations were conducted at mine sites and also gathered secondary data from books, pertinent articles from journals, and research reports. Newmont Company limited, Akyem also provided three months of data on air blast and ground vibration, which were utilized in the study.

3.3.3 Research or Sampling Design

Both simple random and purposive sampling methods were used in this study. This is because the expected data to be collected focuses on several factors of the target population in connection to work place, distance from mines, interviewees' socioeconomic status, and differences in perceptions of mining activities and their consequences on the location.

In addition, 300 persons were chosen at random for the thorough questionnaire administration using the interview approach in order to ensure a 100% completion rate. As shown in Table 3.1, three towns were chosen based on their relative proximity to mine sites or control points. Due to the large populations of these towns in comparison to the others, 100 participants were randomly picked for questionnaire administration in two communities each located 0.5 - 2.0 km apart from mine sites. Sixty (60) respondents were chosen from a village 1.5 to 2.5 kilometers from the mining site, and twenty (20) respondents were chosen from health centers and Newmont's workplaces, respectively. Because the three settlements considered for this study were spread out over the Newmont, as a result, the data collected from the whole sample of 300 respondents effectively represented the views of the entire community. The sample is described in full in Table 3.2.

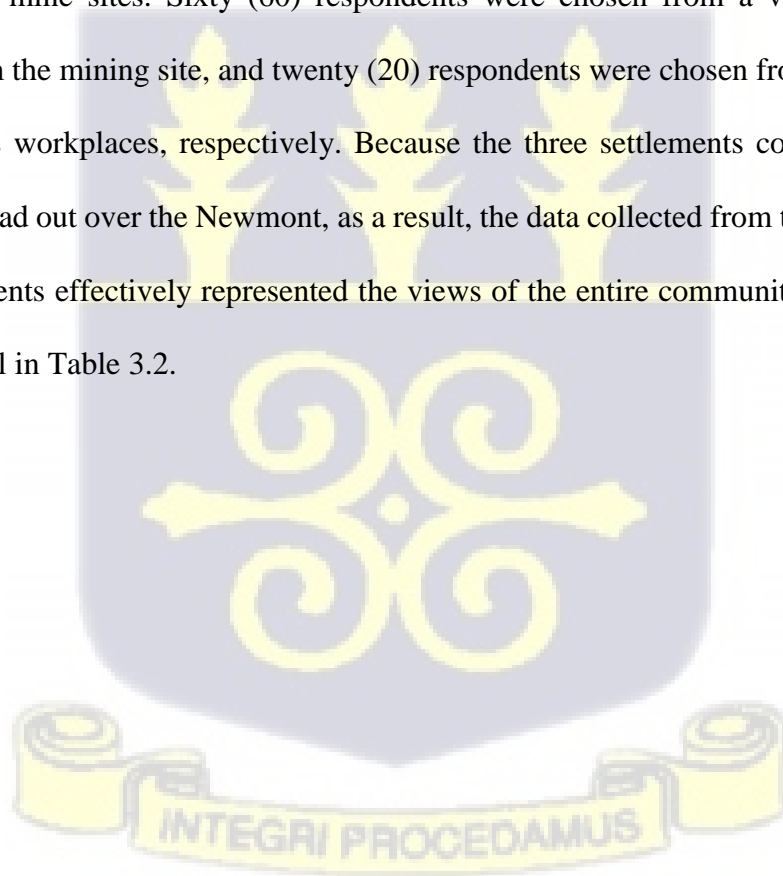


Table 3.2: Distribution of Sample

Community/ Workplace	Distance From The Mine Site	Number of Respondents	Percentage (%)
New Abirem	0.5 - 1.5km	100	33.33
Afosu	1.5 - 2.0km	100	33.33
Adausena	1.5 -2.5km	60	20
Health Centre	2.0 – 3.0km	20	6.67
Newmont Staff	0.5 – 1.0km	20	6.67
TOTAL		300	100

Table 3.1 that stated samples were purposely taken from New Abirem (100) and Afosu (100) while the least was picked from Adausena (60) based on the population size of the three communities. The scientists did this on purpose because these villages are closer to the Newmont location, with distances ranging from 0.5 to 3.0 kilometers. In addition, two (2) officials from the Ghana Minerals Commission and the Environmental Protection Agency, as well as five (5) officials from Newmont Company Ltd, Akyem, and the Akyem District Assembly, were interviewed. For this study, ten (10) health personnel from the New Abirem Government Hospital were interviewed. A set of fifteen (15) mine workers from various mine departments were also interviewed for detailed information on their health problems.

3.3.4 Sampling

During the field investigation (September, 2020), two sampling sites were identified from the tributary of Birim River, one from Newmont site and two from Adausena streams as water bodies that could be polluted by mining activities based on their proximity to the Newmont, Akyem mine. The high and lower parts of the tributary of the Birim River segment were split.

The upper and lower regions each had one sampling site, Afosu and Holy Child, New Abirem, respectively, while the Ahausena stream had two (Aboabo and Adenkyensu). To better understand the impact of natural and human activities on the environment, Newmont was chosen as the fifth sampling site to reflect the region of illuviation of blasting chemicals from a waste dump. Table 3.2 shows the geographic position of each selected sampling site surrounding the Newmont. Water samples were taken once a month at all sampling sites in the Afosu River, Newmont pit, and two Ahausena streams for five months (February 2021 – June 2021).

3.3.5 Sampling and Storage of Surface Water

The samples were then taken by immersing the sampling bottle directly into the water. To prevent metals from sticking to the walls of the plastic bottles, 2 mL nitric acid was added to the water samples that would be used for metals analyses right after they were taken, while those that would be used for blasting chemicals were not. The labelled samples were transported to the laboratory in an icebox and stored in a fridge at 4°C till analysis.

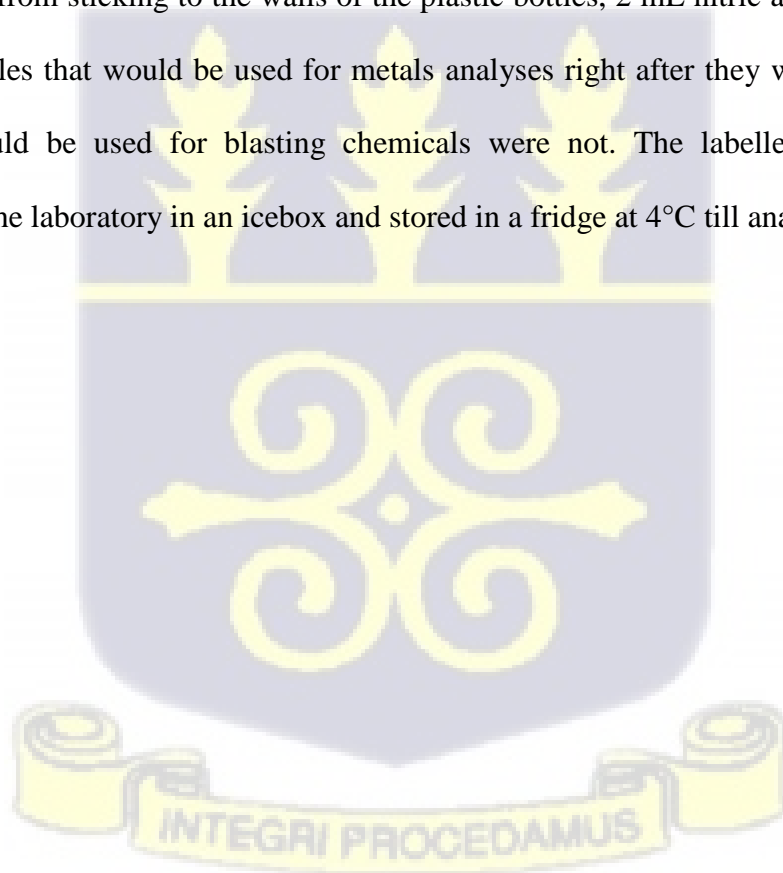


Table 3.3 Location coordinates and height of locations in Afosu River and Adausena streams.

Sampling Site	Latitude	Longitude	Height (ft)
Holy Child (S1)	06 ^o 20.925N	01 ^o 00.029W	501
Afosu (S2)	06 ^o 21.067N	0 ^o 05.816W	546
Aboabo (S3)	06 ^o 22.307N	01 ^o 00.035W	575
Adenkyensu (S4)	06 ^o 21.018N	01 ^o 03.195W	601
Newmont (S5)	06 ^o 21.090N	01 ^o 02.786W	618

3.3.6 Collection and Preparation of Samples for Analysis

In all 108 water samples with 18 from the blasting pit and 24 each from four sites of the three communities namely- New Abirem, Afosu and Adausena were collected from nearby river and two streams adjacent to the blasting pit and dumping sites within five months period. The water samples were collected into washed and rinsed plastic containers in accordance with APHA (1998) standard methods before taken to laboratory for analysis. The samples were stored in the fridge at about 4^oC temperature for analyses in the laboratory at Ecolab in university of Ghana, Legon.

3.3.7 Analysis of Water samples for Physicochemical Parameters

3.3.7.1 Dissolved Oxygen

Dissolved oxygen was measured by using Ascorbic Acid Method 4500 – PE. The sample was collected in a 300 ml BOD bottle using the stopper to avoid bubbling and air trapping in the bottle. 2 ml manganese sulphate and 2 ml Sodium azide solution were added to the 50 ml sample put into the conical flask and allowed to precipitate in the bottle. The stopper was then tightened, and the bottle was shaken frequently by inverting it to ensure thorough mixing of

the contents. After allowing the precipitation to settle, 2 mL of concentrated H₂SO₄ or ascorbic acid was added to the bottle and thoroughly shaken to dissolve all of the precipitate.

Then, using starch as an indicator, 50 ml of material was placed in a conical flask and titrated against sodium thiosulphate (Na₂S₂O₃) of 0.025 M. The original blue color faded to a faint green at the end.

3.3.7.2 Electrical Conductivity

Conductivity was measured using ALPHA 4500 – H⁺ B Method. A reference of 12880 μS/cm was used to calibrate the conductivity meter. The meter's electrode was cleaned and immersed in distilled water. The electrode was rinsed with distilled water before being dropped into the sample water, and a sample of water was placed in a beaker. The observed conductivity was recorded in μS/cm.

3.3.7.3 pH

Buffer solutions of pH was measured using Probe Method (WTW). pH 4.00 and pH 7.00 buffer solutions were used to calibrate the pH meter. A beaker was filled with around 100 ml of sample water, and the tip of the electrode was dipped into it. After the values were stabilized, the pH readings were recorded. Before determining other samples, the electrode was removed and cleaned with distilled water.

3.3.7.4 Temperature

A thermometer was used to measure the temperatures of water samples on the spot. A 100 mL water sample was taken and transferred to a 250 mL beaker. The thermometer had been

immersed in the water for quite some time. After a few minutes, the thermometer's reading was recorded.

3.3.7.5 Ammonia

Salicylate Method 8155 was used to quantify ammonia. 5mL of prepared solution was weighed and put to a 250mL Erlenmeyer flask. The sodium chloride solution was added, and it was shaken for 30 minutes before settling. The output of the photometer was adjusted to 5v and turn on the reference detector to 0.2v after adding 2.5M H₂SO₄ to the Set-up manifold. Then, to create precipitate, a salicylate solution was added to the sample. Two cups were filled with a solution, which was then evaluated. When the peak appears on the recorder, adjust the STD CAL control until it reaches 95% of the whole scale.

3.3.7.6 Nitrate

The AOAC Official Method 973.50 was used to quantify nitrate. A ten-milliliter sample solution was pipette into a beaker, along with two grams of Zn/NaCl granular mixture and five milliliters of Conc. HCl, and let to stand for thirty minutes while stirring irregularly to create a nitrite. The solution was filtered using filter paper into a 100 mL standard flask and diluted to the desired concentration. A stock solution of reduced nitrite containing 0.2 - 10.0 gm/L was put into a series of 10 ml flasks. For the reaction to complete, 1 ml of sulphuric acid and 1 ml of 2 M HCl solution were added and vigorously agitated for about five minutes. The mixture was then diluted to 10 ml with water by adding 1 ml of 5 percent methyl anthranilate and 2 ml of 2 M sodium hydroxide solution. With a UV - Visible spectrophotometer set to wavelength 493 nm, the absorbance of the produced red dye was measured. The calibration curve was created, and the concentrations of the samples were extrapolated from it (Ensafi et al., 2004).

3.3.8 Digestion Protocol of Water Samples for Heavy Metals

A total volume of 5.0ml of the water sample was measured using class A 10ml measuring cylinder into 100ml polytetrafluoroethylene (PTFE) Teflon bombs that had previously been acid cleaned. Then, in a fume chamber, 6ml of concentrated nitric acid (HNO₃, 65%), 3ml of concentrated hydrochloric acid (HCl, 35%), and 0.25ml of hydrogen peroxide (H₂O₂, 30%) were added to each sample. After that, the samples were placed on the microwave carousel. A wrench was used to tighten the vessel tops to avoid leakage. Using the milestone microwave lab station ETHOS 900, INSTR: MLS-1200 MEGA and the microwave program, the entire assembly was microwave irradiated for 26 minutes.

The Teflon bombs on the microwave carousel were cooled in a water bath after digestion to reduce internal pressure and allow the volatilized components to re-stabilize. The digest was produced up to 20mL with double distilled water and tested for Copper (Cu), Iron (Fe), Zinc (Zn), Chromium (Cr), and Manganese (Mn) in an acetylene – air flame using an Atomic Absorption Spectrometer (VARIAN AA 240FS). The manufacturer's instructions were followed when it came to instrument settings and operational conditions. Analytical grade standard metal solutions (1 mg/dm³) were used to calibrate the device in duplicates.

3.3.9 The Method for the Policy Assessment

Officials from Newmont Akyem Gold Ridge Limited and the Ghana Environmental Protection Agency were interviewed as important actors in a case study research design. With permission, some primary data was acquired from focus group discussions and interviews held in the Birim North district's New Abirem, Afosu, and Ahausena. The five Newmont Akyem mine officials were questioned about all relevant laws, rules, and commitments, including the Environmental Assessment Regulations 1999 (L.I. 1652) and the Mining and Mineral Act (2006).

3.3.10 Data Processing and Statistical Analysis

Data on questionnaire involving the perception of people on the effect of blasting were summarized using spreadsheet in Microsoft excel and stored in statistical tables, charts and graphs using SPSS software. Associations between physicochemical parameters of waters and explosive chemicals were analyzed and both qualitative and quantitative methods were also used for the explanation.

Standard analytical statistics was conducted on the data using Statistical Package for Social Science (SPSS) by applying one-way Analysis of Variance (ANOVA) to find possible differences in air blast, ground vibration, heavy metal, nitrate (NO_3) and ammonia (NH_3) concentrations among sampling stations. A significance level of less than or equal to 0.05 was considered (Zar, 2001). The mean values were separated using the post-hoc Turkey's (HSD) test when significant differences were discovered. Statistical software was also used to generate descriptive and inferential statistics for all of the data collected.

3.3.11 Pollution indices of Water

In this study, the computing method for two pollution indices, the degree of Pollution Index (Pd) was proposed by Backman in 1998 and the Heavy Metal Pollution Index proposed by Prasad and Bose, was also examined (2001).

3.3.11.1 Degree of Pollution Index (Pd)

The Pollution Index (Pd) is a method utilized to assess the water quality by calculating the degree of pollution, the Pd of surface water. The computation method of two pollution indices, the degree of Pollution Index (Pd) proposed by Backman et al. (1998) and the Heavy Metal

Pollution Index proposed by Prasad and Bose (2001), was also studied in this work. $Pd =$

$$\sum_{i=1}^n Pfi$$

But $Pfi = \frac{PAi}{PNI} - 1$

Where Pfi denotes the pollution factor for the ith component, PAi denotes the analytical value for the ith component, and PNI is the ith component's upper allowable concentration.

Table 3.4 Standard Used for the Calculation of Pollution Indices

Parameter	W	S	I	UPC	RV
Cu	0.001	1.0	2.0	1000	0.003
Fe	0.005	0.2	0.3	200	0.05
Zn	0.0002	3.0	5.0	5000	0.005
Cr	0.02	0.01	0.05	50	0.001
Mn	0.02	0.1	0.5	50	0.005

Where W means Weightage which is calculated using the formula $W = (1/UPC)$, S is the Standard permissible in mg/L, I is the Highest permissible limit in mg/L, UPC is upper permissible concentration mg/L and RV Reference value in mg/L.

All analytical data were considered in this analysis, regardless of whether they were above or below the highest allowed concentration limit (PNI) as shown in Table 3.4. Cu, Fe, Zn, Cr, and Mn are among the elements considered.

3.3.10.2 Heavy Metal Contamination Index (HCI)

The HCI is a method for calculating total water pollution due to heavy metals that was created.

The HCI is derived from a predetermined sample mean technique that employs a rating system in which values are inversely proportional to the suggested standard (Si) for the respective

parameter (Mohan et al., 1996; Horton, 1995). Prasad and Bose (2001) calculated the HPI using unit weightage (W_i), which was defined as a number inversely proportional to the suggested standard (S_i) of the associated parameter, as proposed by Reddy (1995).

The HCI model (Mohan et al., 1996) is giving by

$$HCI = \frac{\sum_{i=1}^n W_i Q_i}{\sum_{i=1}^n W_i}$$

Where D_i is the i th parameter's dependent-index. The i th parameter's unit 'weightage' is W_i , and the number of parameters examined is n . The parameter's dependent-index (D_i) is determined as follows:

$$D_i = \sum_{i=1}^n \frac{\{M_i(-)I_i\}}{(S_i - I_i)} \times 100$$

Where M_i is the i th parameter's monitored heavy metal value, I_i is the i th parameter's ideal value, and S_i is the i th parameter's standard value. The symbol (-) denotes the numerical difference between the two numbers, but the algebraic sign is ignored. According to Prasad and Bose (2001), the critical pollution index of HCI value for drinking water is 100 mg/L.

Cu, Fe, Zn, Cr, and Mn were used to calculate the HCI for this investigation. The 'weightage' (W_i) was calculated as the inverse of UPL, with S_i being the WHO drinking water standard and I_i representing the element's guidance value (Table 3.4).

CHAPTER FOUR

4.0 RESULTS

The results on the findings of opinion of respondents and results on air overpressure and ground vibration measured at three compliance locations are presented. Physicochemical characteristics (temperature, dissolved oxygen, pH, electric conductivity, nitrate, and ammonia) as well as heavy metal concentrations (Cu, Fe, Zn, Cr, and Mn) in surface water near the Newmont site are also reported.

4.1 Perception of the community towards mine blasting and its impact

Finding on perceptions of communities towards mine blasting and its impact on people and structures are reported in this section.

Table 4.1: Perception on Effects of Mine Blasting on the communities

Years of staying in town	Do method of mining affect the environment			PERCENTAGE	
	NUMBER OF COUNTS			YES	NO
	YES	NO	TOTAL		
1 – 10	48	0	48	16	0
11 - 20	28	4	32	9.33	1.33
21 - 30	74	10	84	24.67	3.33
31 – 40	85	0	85	28.33	0
41 – 50	21	8	29	7	2.68
51 – 60	12	0	12	4	0
61 years +	9	1	10	3	0.33
Total	277	23	300	92.33	7.67

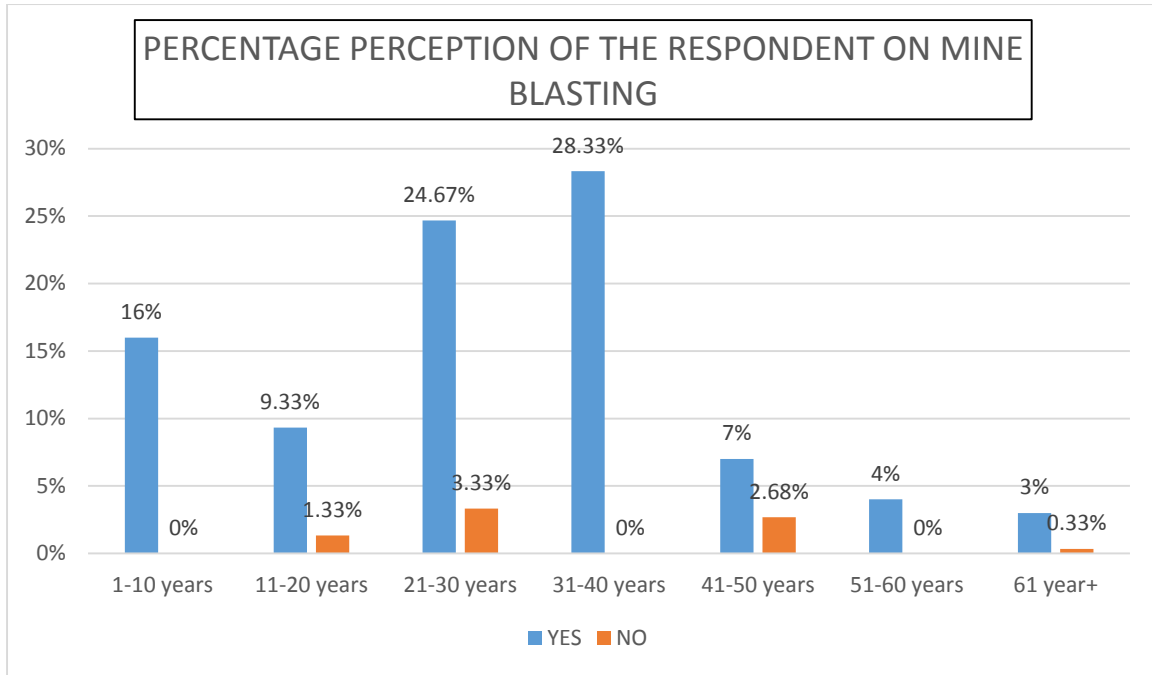


Figure 4.1: Comparison of percentage perception of the respondents on mine blasting at three different communities.

Approximately, 92% of the respondents asserted that the air overpressure and ground vibration effects in their communities were due to the mining activities whilst 8% however claimed otherwise. Those with a mid-year stay ranging from 25.5 to 35.5 years led the respondents, accounting for 56.33% of the total. Out of this, 53% said that mining activity in the region had generated air blast and ground vibration, whereas 3.33% disagreed. Furthermore, those who had stayed for more than 41 years comprised the minority of total respondents, with 51 (representing 14%) attesting to the fact that mining activities had produced the air blast and ground vibration in the area. As a result, respondents' perceptions of mining's effects on the environment and health were positively connected with proximity to the site, but not with the number of years spent there. The air blast and ground tremor in their vicinities were attributed to mining activities by the respondents from 1 to 20, comprising 25.33% of the respondents, with 1.33% of the respondents disproving this allegation.

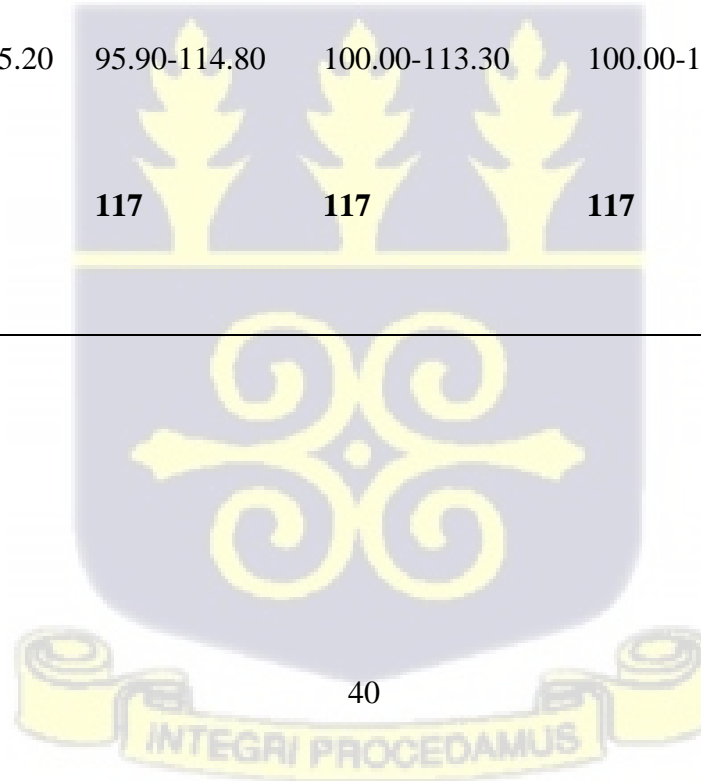
4.2 Air Overpressure from Three Blast Monitory Points (BMP)

The twenty (20) blast shots were carried out at the mine pit in the data collecting month each, starting from October, 2020 to March, 2021. The average blast air overpressure measured at AF-BMP (Afosu), NAB-BMP (New Abirem) and AD-BMP (Ahausena) were also compared with 117 dBL Explosives Regulations, 2012 (L.I. 2177), Section 199. The mean, minimum and maximum blast on air overpressure for each monitoring point are presented in the table 4.2 below:



Table 4.2: Mean and range values for air blast.

AIR BLAST						
SITE\ MONTH	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
AFOSU	103.32 ± 4.05	104.50 ± 5.15	105.35 ± 3.30	105.26 ± 4.65	103.04 ± 3.81	100.51 ± 2.11
	98.80-112.00	98.80-114.80	101.00-113.30	97.50-117.60	98.80-115.50	95.90-106.50
NEW ABIREM	100.08±0.69	100.20 ± 1.44	98.28 ± 3.46	101.14 ±3.23	100.18 ± 1.85	103.50± 2.94
	98.80-102.80	95.90-104.20	94.00-102.80	95.90-107.00	95.90-104.90	100.00-108.40
ADAUSENA	105.33±4.15	101.91 ± 4.11	105.52 ± 4.33	100.66 ±1.78	102.32 ± 2.63	103.28 ± 3.24
	100.00-115.20	95.90-114.80	100.00-113.30	100.00-107.00	100.00-108.40	100.00-109.90.
MINERALS AND MINING						
REGULATION	117	117	117	117	117	117
LIMIT						



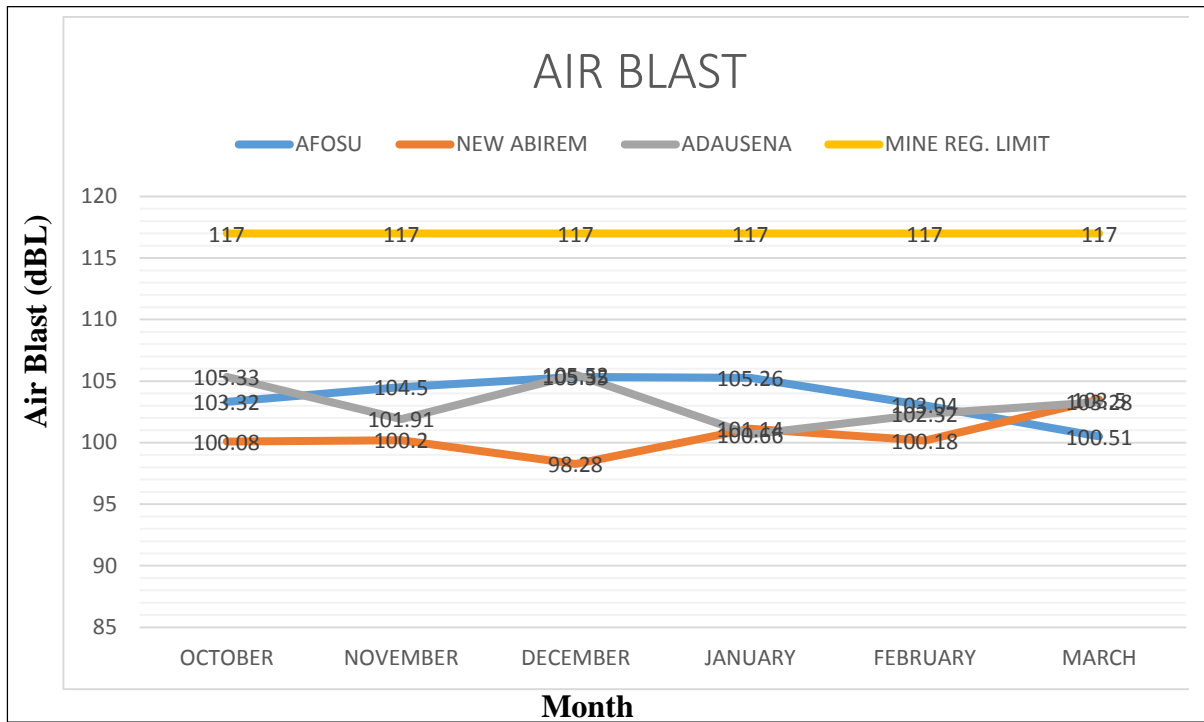


Figure 4.2: Graph of noise (dB) at three different blast monitory locations.

The mean air blast levels measured at BMP- Afosu ranged between 100.51 and 105.35 dBL. The highest value was observed in December while the minimum air blast level was recorded in March, 2021.

At the New Abirem blast monitory location, the air blast levels ranged from 98.28 to 103.50 dBL. The highest value was recorded in March (2021) and the lowest level was observed in December, 2020.

The monitory location in Adausena, recorded a mean air overpressure between 100.66 and 105.52 dBL. The highest value of 105.52 dBL was recorded in December, 2020 while the lowest air blast level (100.66 dBL) observed in January, 2021.

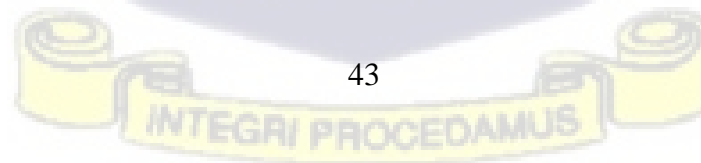
4.3 Ground Vibration from Three Blast Monitory Points (BMP)

The twenty (20) blast shot were carried out at the mine pit in the data collecting month each, starting from October, 2020 to March, 2021. The average blast vibration measured at the compliance locations AF-BMP (Afosu), NAB-BMP (New Abirem) and AD-BMP (Ahausena) were compared with 2mm/s of Explosives Regulations, 2012 (L.I. 2177), Section 199. The mean, minimum and maximum blast on ground vibration for each monitoring point are presented in the table 4.1.3 below:



Table 4.3: Mean, standard deviation and range values for ground vibration at the locations.

GROUND VIBRATION						
SITE\ MONTH	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
AFOSU	0.33 ± 0.19	0.46 ± 0.31	0.29 ± 0.22	0.38 ± 0.26	0.32 ± 0.18	0.41 ± 0.20
	0.08-0.67	0.03-1.31	0.00 - 0.77	0.08 - 0.77	0.08 - 0.67	0.08 - 1.09
NEW ABIREM	0.31 ± 0.04	0.29 ± 0.10	0.32 ± 0.16	0.26 ± 0.08	0.32 ± 0.08	0.30 ± 0.12
	0.30 - 0.45	0.07 - 0.41	0.07 - 0.55	0.08 - 0.46	0.08 - 0.46	0.07 - 0.55
ADAUSENA	0.35 ± 0.14	0.32 ± 0.02	0.16 ± 0.15	0.22 ± 0.16	0.35 ± 0.10	0.32 ± 0.23
	0.08 - 0.62	0.10 - 0.51	0.09 - 0.54	0.09 - 0.48	0.19 - 0.58	0.11 - 0.94
MINERALS AND MINING REGULATION LIMIT	2	2	2	2	2	2



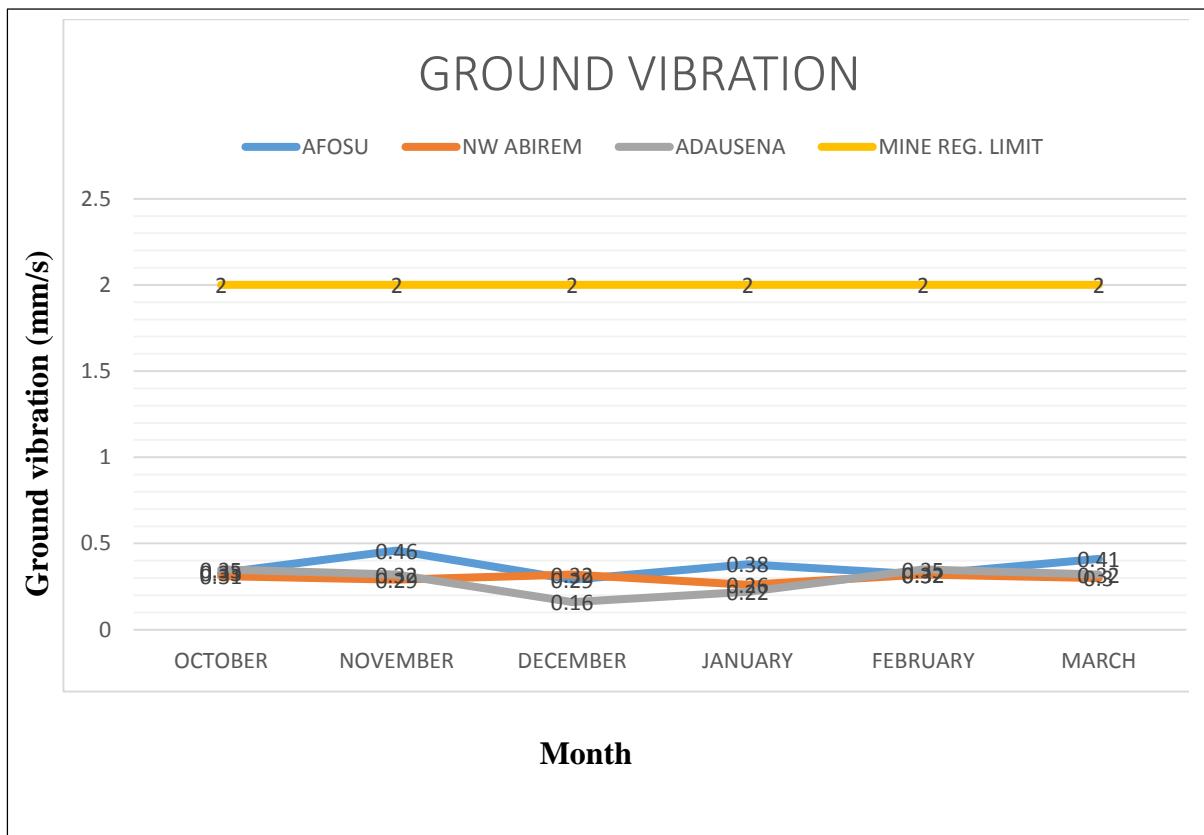


Figure 4.3: Graph of Ground vibration (mm/s) at three different monitory locations

The ground vibration means values measured at BMP – Afosu ranged from 0.29 to 0.46 mm/s. The highest value of 0.46 mm/s has recorded in November 2020 while the lowest level was found in December, 2020.

A mean level measured ranged from 0.21 to 0.38 mm/s was recorded at the monitory location in New Abirem. The highest value was observed in December, 2020 and February, 2021 while the lowest level was recorded in January.

At the Adausena blast monitory location, the mean ground vibration levels ranged from 0.16 to 0.35 mm/s. The highest value was observed in October, 2020 and February, 2021 while the

lowest was recorded in December 2020. The second highest value was observed in November, 2020 and March, 2021.



4.4 Physicochemical Parameters

Table 4.4: Mean, standard deviation and range values for physicochemical parameters at locations.

ND – Below detectable limit

Parameter/Site	Holy Child	Afosu	Aboabo	Adenkyensu	Newmont
Water temp ($^{\circ}\text{C}$)	27.20 ± 0.17	26.70 ± 0.10	26.80 ± 0.10	26.77 ± 0.15	26.73 ± 0.06
Range	27.00–27.30	26.60 -26.80	26.70 -26.90	26.60 -26.90	26.70 – 26.80
DO (mg L^{-1})	3.75 ± 0.13	3.65 ± 0.08	3.62 ± 0.30	3.65 ± 0.01	4.05 ± 0.01
Range	3.65 – 3.80	3.60 – 3.74	3.60 – 3.65	0.00 – 3.65	3.00 – 3.05
EC ($\mu\text{S cm}^{-1}$)	427.33 ± 5.86	316.00 ± 20.22	420.00 ± 26.46	486.67 ± 5.77	937.67 ± 95.01
Range	423.00 – 434.00	293.00 – 331.00	400.00 - 450.00	480.00 - 490.00	828.00 – 995.00
pH	6.33 ± 0.15	6.50 ± 0.10	7.57 ± 0.06	7.30 ± 0.17	8.10 ± 0.17
Range	6.20 – 6.50	6.40 – 6.60	7.50 – 7.60	7.20 – 7.50	8.00 – 8.30
NH_3 (mgL^{-1})	0.01 ± 0.01	0.01 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.52 ± 0.01
Range	0.00 – 0.01	0.01 – 0.20	0.03 – 0.04	0.02 – 0.03	0.52 – 0.53
NO_3 (mgL^{-1})	0.25 ± 0.01	0.22 ± 0.01	0.25 ± 0.01	0.26 ± 0.01	0.34 ± 0.04
Range	0.25 – 0.26	0.22 – 0.23	0.25 – 0.26	0.25 – 0.26	0.36 – 0.42

4.4.1 Dissolved Oxygen (DO)

The dissolved oxygen at Holy Child ranged from 3.65 to 3.80 mg/L and a mean concentration of 3.75 ± 0.13 mg/L. At Afosu dissolved ranged from 3.60 to 3.74 mg/L and with a mean of 3.65 ± 0.08 mg/L. Aboabo and Adenkyensu had a mean dissolved oxygen concentration of 3.62 ± 0.30 mg/L and 3.65 ± 0.01 mg/L respectively. The dissolved oxygen concentration for Newmont was 4.05 ± 0.01 mg/L and it ranged between 4.04 – 4.06 mg/L.

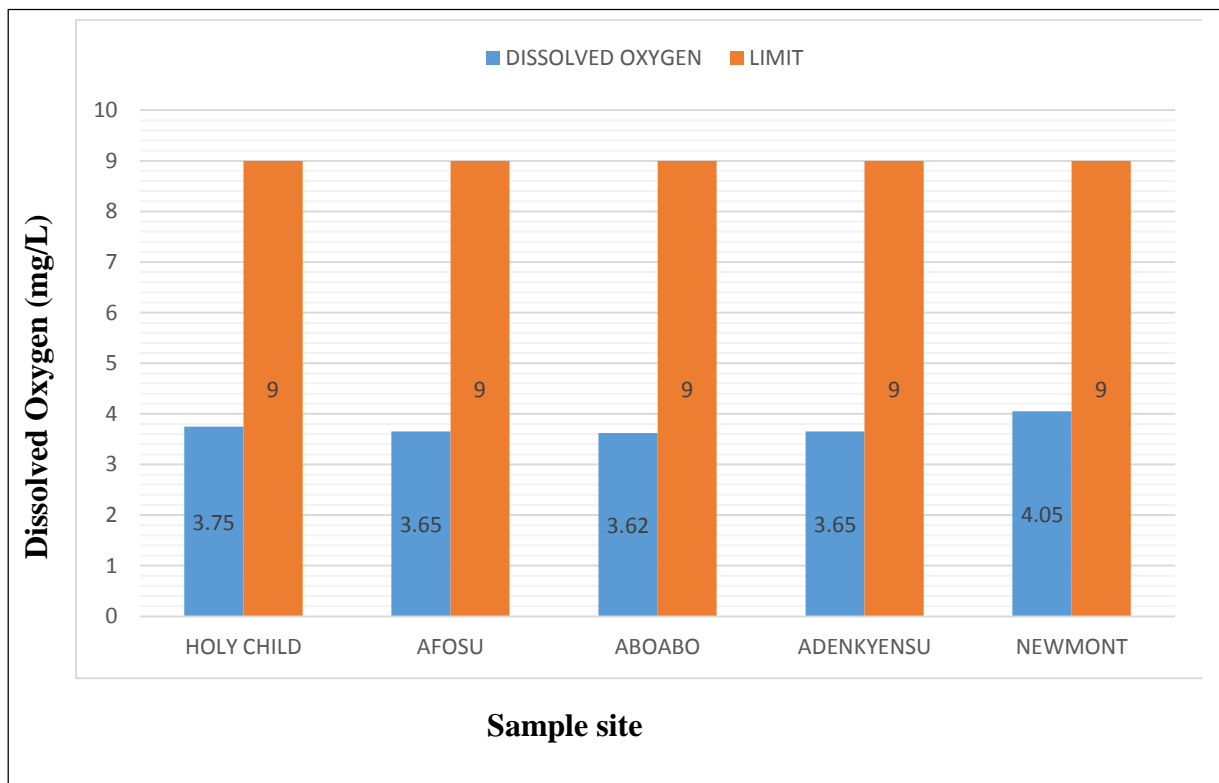


Figure 4.4: Variations in DO (mgL^{-1}) between January and December 2021 in different locations.

4.4.2 Electrical Conductivity (EC)

The mean electrical conductivity at Holy Child was 427.33 ± 5.86 $\mu\text{S/cm}$, Afosu recorded 316.00 ± 20.22 $\mu\text{S/cm}$, Aboabo obtained 420.00 ± 26.46 $\mu\text{S/cm}$, Adenkyensu recorded 486.67 ± 5.77 $\mu\text{S/cm}$, and Newmont obtained 937.67 ± 95.01 $\mu\text{S/cm}$. The highest EC value was

observed at Newmont ($937.67 \pm 95.01 \mu\text{S}/\text{cm}$) in February, 2021 and the lowest was Afosu ($316.00 \pm 20.22 \mu\text{S}/\text{cm}$) in June 2021.

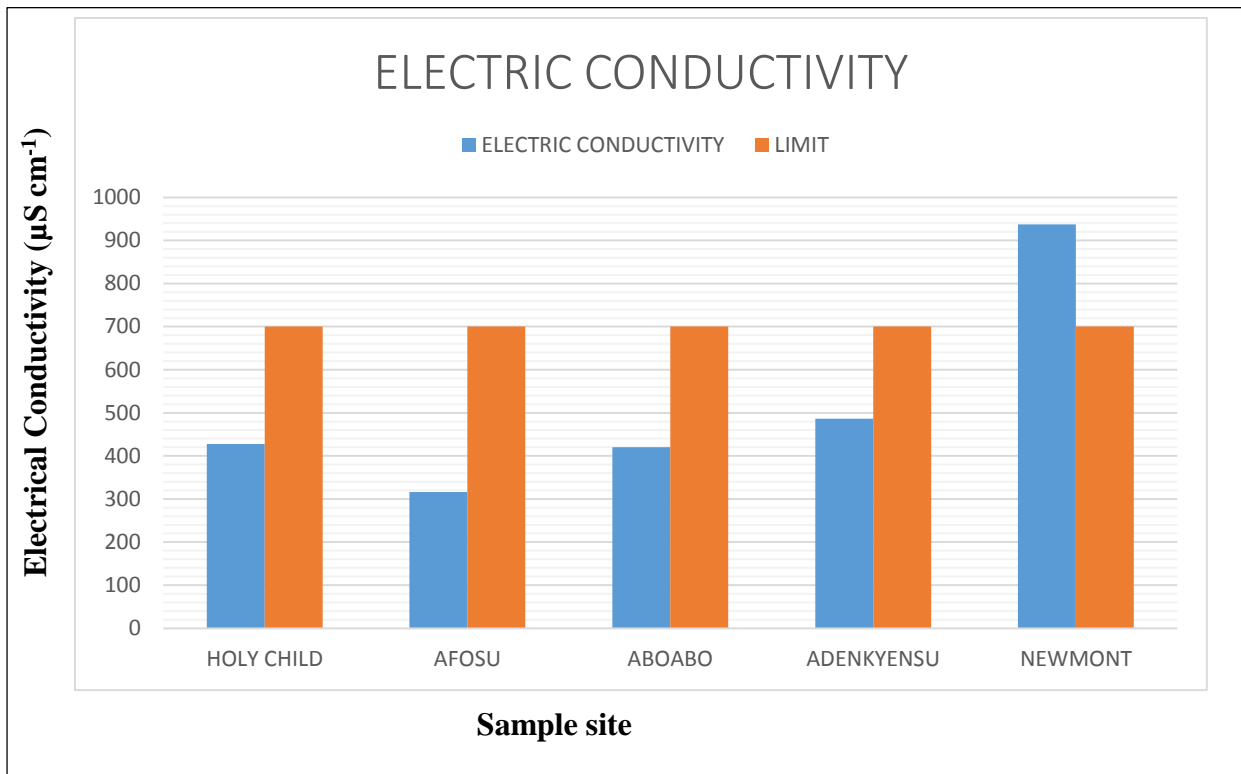
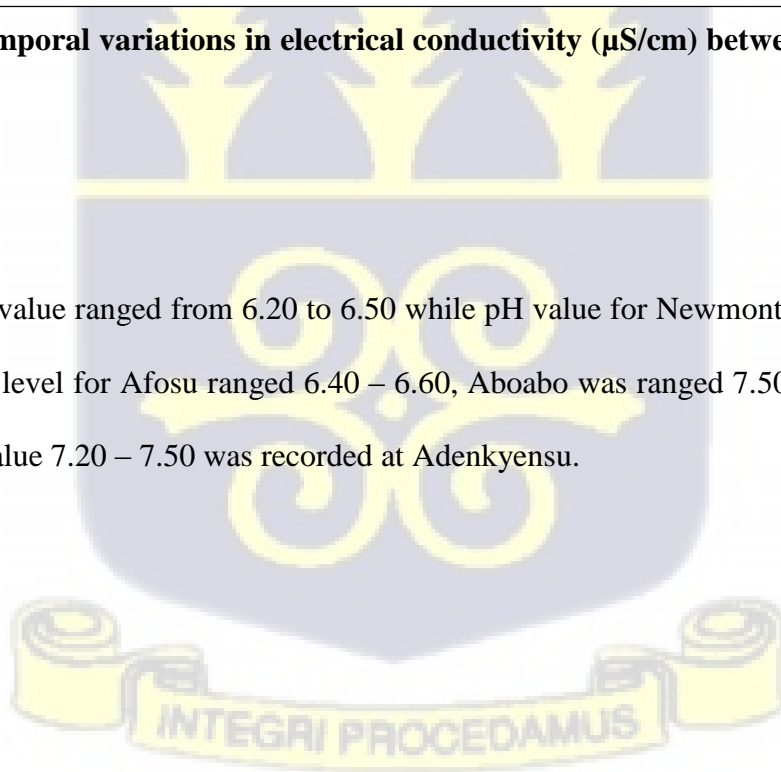


Figure 4.5: Temporal variations in electrical conductivity ($\mu\text{S}/\text{cm}$) between January and June 2021.

4.4.3 pH

Holy Child pH value ranged from 6.20 to 6.50 while pH value for Newmont was ranged 8.00 – 8.30. The pH level for Afosu ranged 6.40 – 6.60, Aboabo was ranged 7.50 – 7.60 and the ranged of pH value 7.20 – 7.50 was recorded at Adenkyensu.



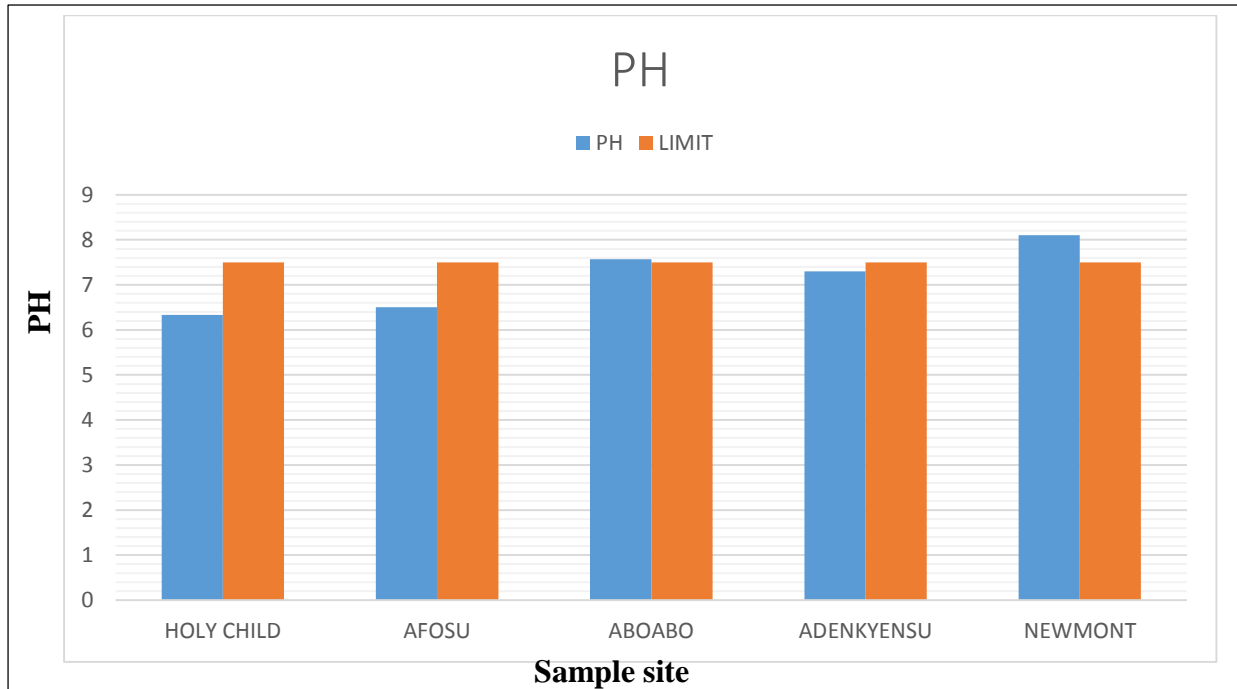


Figure 4.6: Variations in pH between January and June 2021 in different sampling sites.

4.4.4 Water Temperature

The mean temperature ($^{\circ}\text{C}$) for all the sites is shown in Table 4.3. The highest mean value of temperature, $27.2 \pm 0.2^{\circ}\text{C}$ was recorded at the Holy child (S1) while the lowest of $26.7 \pm 0.1^{\circ}\text{C}$ was recorded at Newmont (S5). The monthly water temperature for Afosu (S2) ranged between 26.6 and 26.8°C and Newmont (S5) recorded a monthly water temperature range of 26.7 to 26.8°C . At Aboabo (S3) the mean water temperature was $26.8 \pm 0.1^{\circ}\text{C}$, while the monthly temperature varied from 26.7 to 26.9°C . The monthly water temperature for Adenkyensu (S4) ranged from 26.60 to 26.90°C and the mean water temperature was 26.8 ± 0.2 .



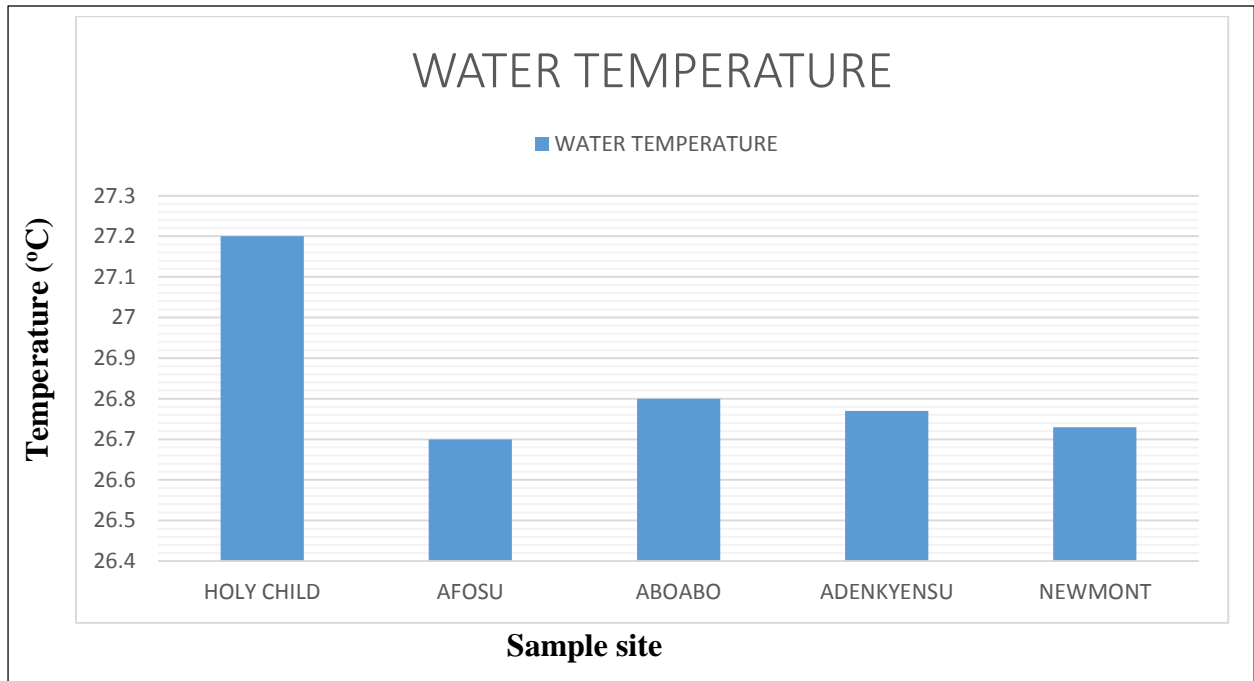


Figure 4.7: Variations in surface water temperature ($^{\circ}\text{C}$) between January and June 2021 at different sampling sites

4.4.5 Nitrate (NH_3)

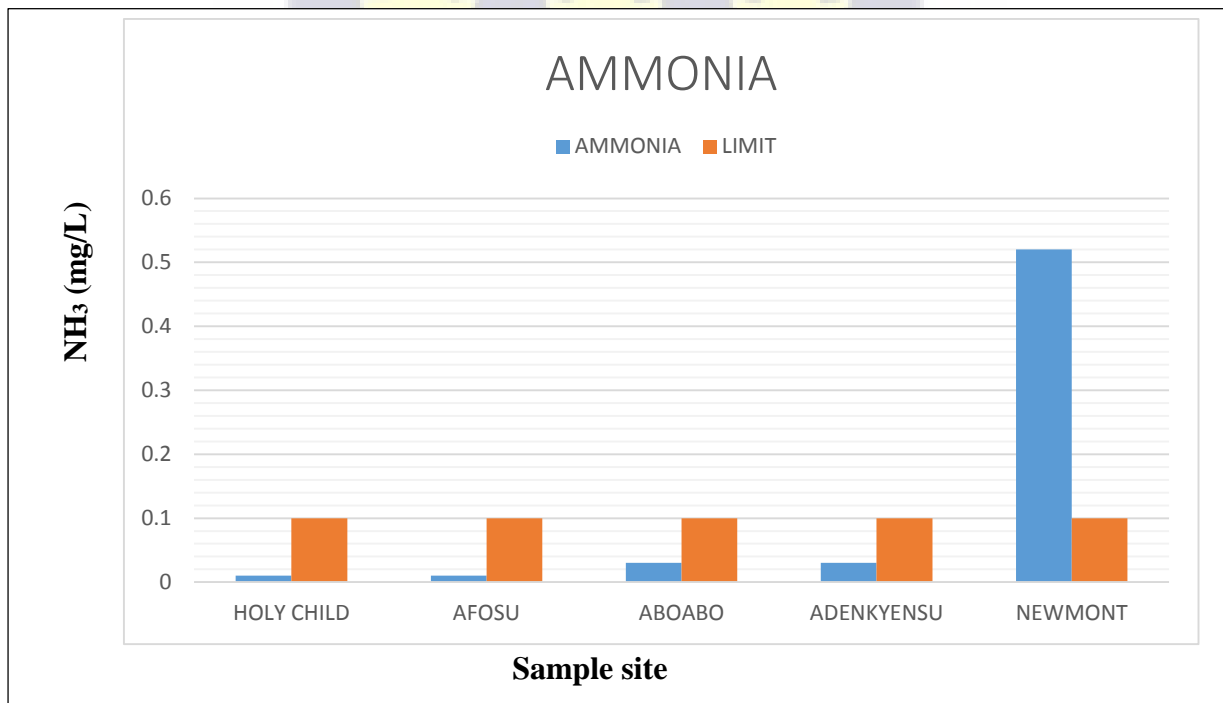


Figure 4.8: Variations in NH_3 between January and June 2021 at Afosu River and Adausena streams sites.

The mean NH_3 concentrations in the water ranged from 0.01mg/L to 0.52 mg/L. The highest value was recorded in Newmont (0.52 mg/L) while the lowest (0.01 mg/L) was observed from Holy Child and Afosu water sample sites. The second highest value (0.03 mg/L) was recorded in Aboabo and Adenkyensu.

4.4.6 NO_3

The mean NO_3 levels in the water sample ranged from 0.22 mg/L to 0.34 mg/L. The highest value (0.34 mg/L) was found in Newmont and had ranged between 0.36 mg/L and 0.42 mg/L. The lowest level was recorded in Afosu. The second highest concentration was obtained in Adenkyensu while 0.25 mg/L was recorded in both Holy Child and Aboabo water samples.

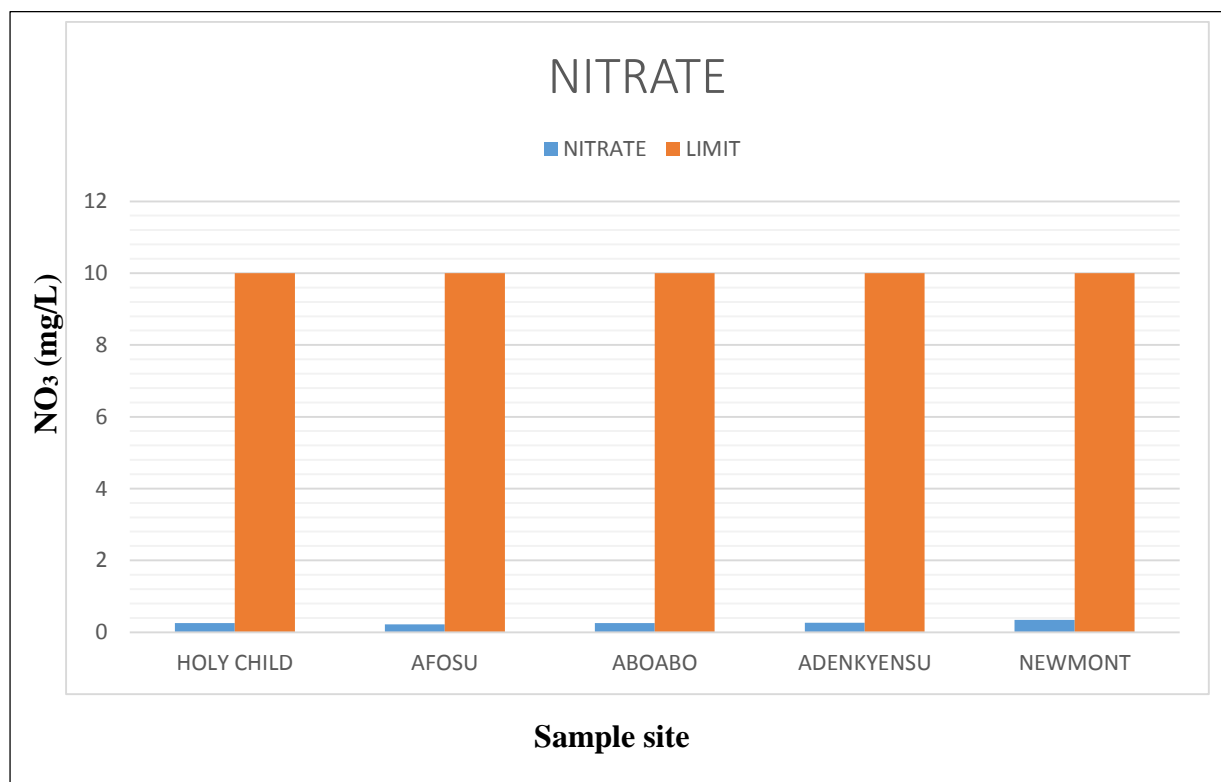
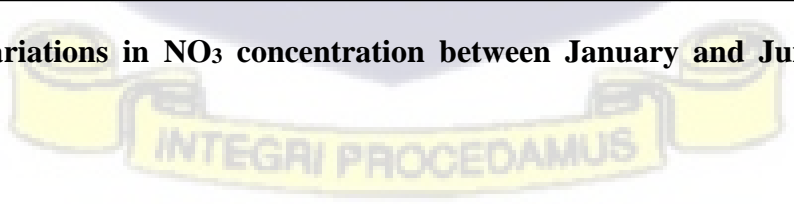


Figure 4.9: Variations in NO_3 concentration between January and June in different sampling sites.



4.5 Heavy Metal Concentrations in Surface Water

Table 4.1.3 shows the mean concentrations (mg/L) of selected heavy metals measured in Newmont pit water and other water bodies running through villages such as New Abirem, Afosu, and Adausena, as well as results from a control site at the Newmont site where actual mining activities take place. Figures 4.10 to 4.14, on the other hand, indicate the general patterns in terms of concentration ranges for each heavy metal in the water.

Table 4.5: Mean, standard deviation and range values for heavy metal concentration (mg L-1) in surface water of Afosu River and Adausena streams recorded from February to June 2021.

Means in same row with significantly different at $p < 0.05$ levels. ND – Below detectable limit

Element/Site	Holy Child	Afosu	Aboabo	Adenkyensu	Newmont
Cu (mg L-1)	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.02 ± 0.01
Range	0.00 – 0.01	0.00 – 0.01	0.00 – 0.01	0.00 – 0.01	0.01 – 0.03
Fe (mg/L)	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.33 ± 0.01
Range	0.02 – 0.04	0.00 – 0.04	0.00 – 0.03	0.02 – 0.03	0.04 – 0.05
Zn (mg/L)	0.91 ± 0.06	0.24 ± 0.10	0.09 ± 0.01	0.08 ± 0.01	0.93 ± 0.06
Range	0.86 – 0.99	0.09 – 0.31	0.08 – 0.10	0.07 – 0.09	0.88 – 1.00
Cr (mg/L)	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
Range	0.00 – 0.01	0.00 – 0.01	0.00 – 0.01	0.00 – 0.01	0.01 – 0.03
Mn (mg/L)	0.10 ± 0.02	0.12 ± 0.02	0.02 ± 0.050	0.03 ± 0.03	0.07 ± 0.02
Range	0.08 – 0.12	0.09 – 0.14	0.01 – 0.07	0.06 – 0.09	0.06 – 0.09

4.5.1 Copper (Cu) Concentration (mg L⁻¹)

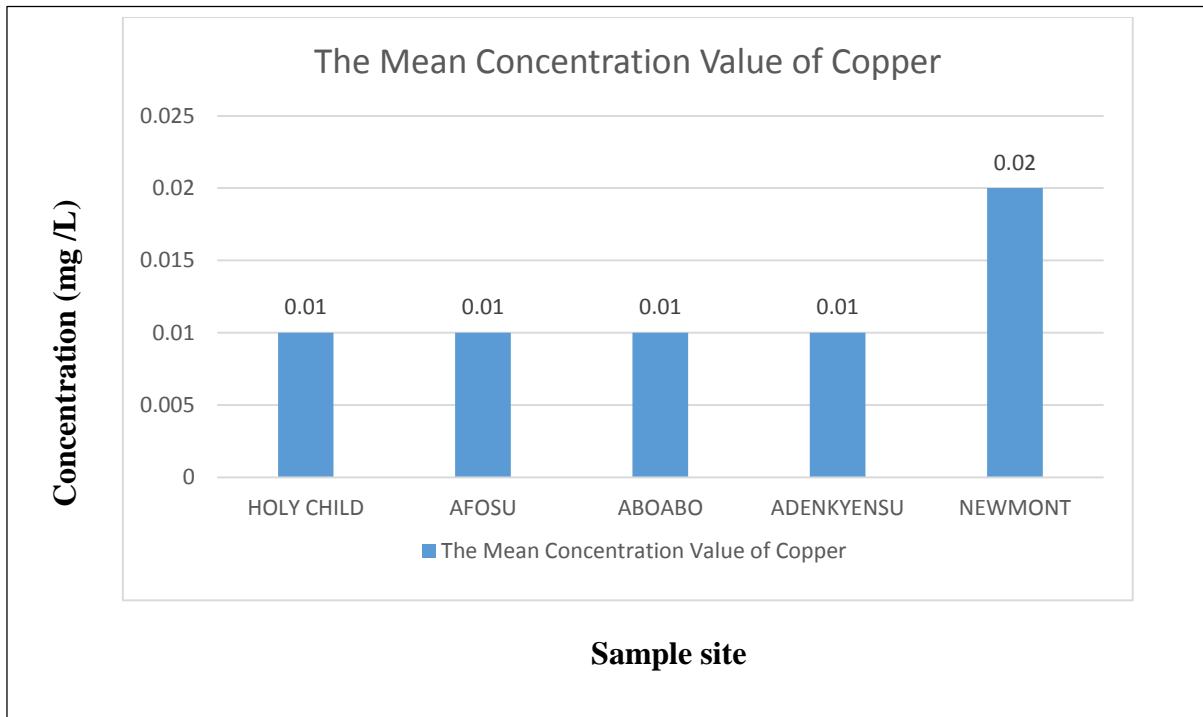
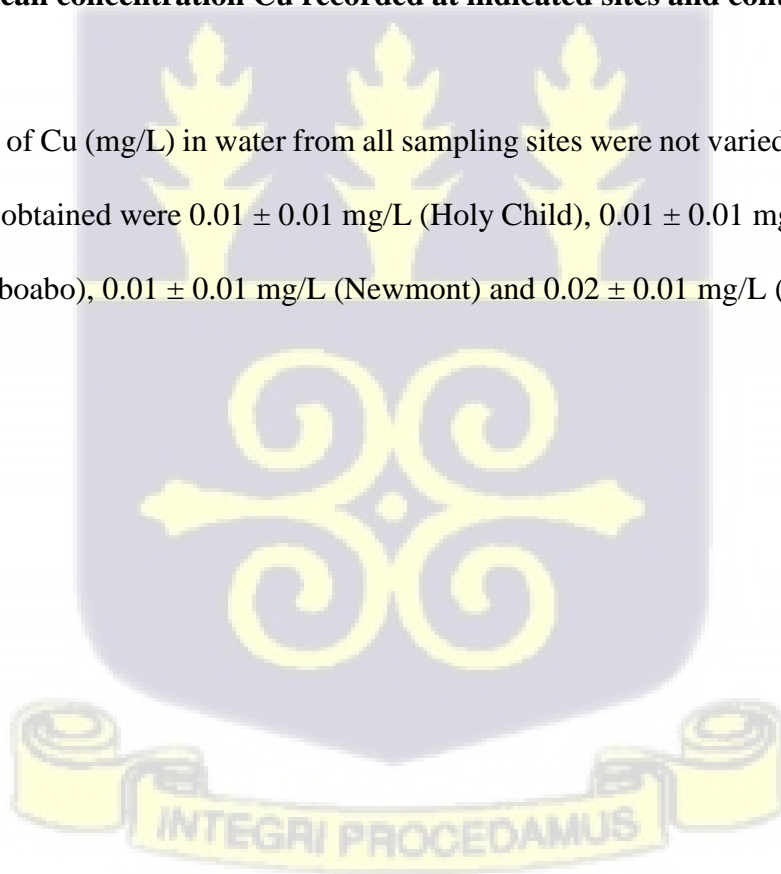


Figure 4.10: Mean concentration Cu recorded at indicated sites and control

The mean value of Cu (mg/L) in water from all sampling sites were not varied (Table 4.4). The mean Cu levels obtained were 0.01 ± 0.01 mg/L (Holy Child), 0.01 ± 0.01 mg/L (Afosu), 0.01 ± 0.01 mg/L (Aboabo), 0.01 ± 0.01 mg/L (Newmont) and 0.02 ± 0.01 mg/L (Adenkyensu).



4.5.2 Iron (Fe) Concentration (mg L⁻¹)

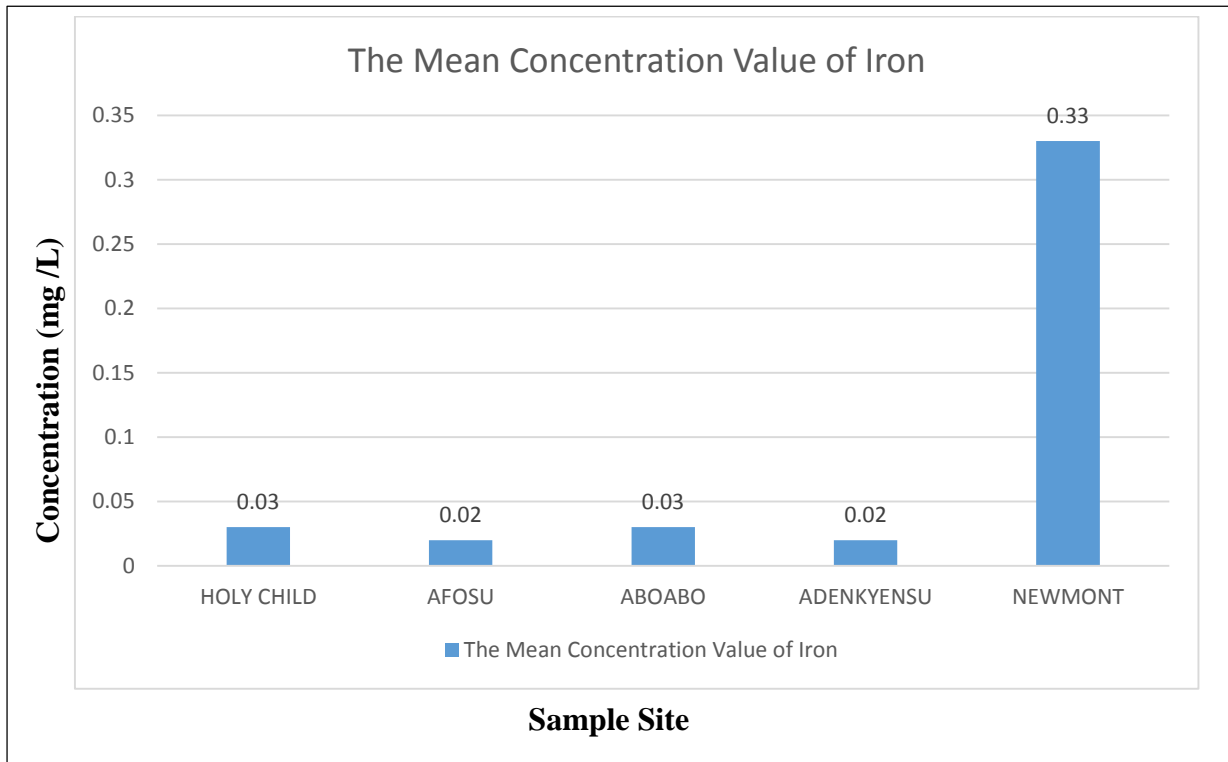
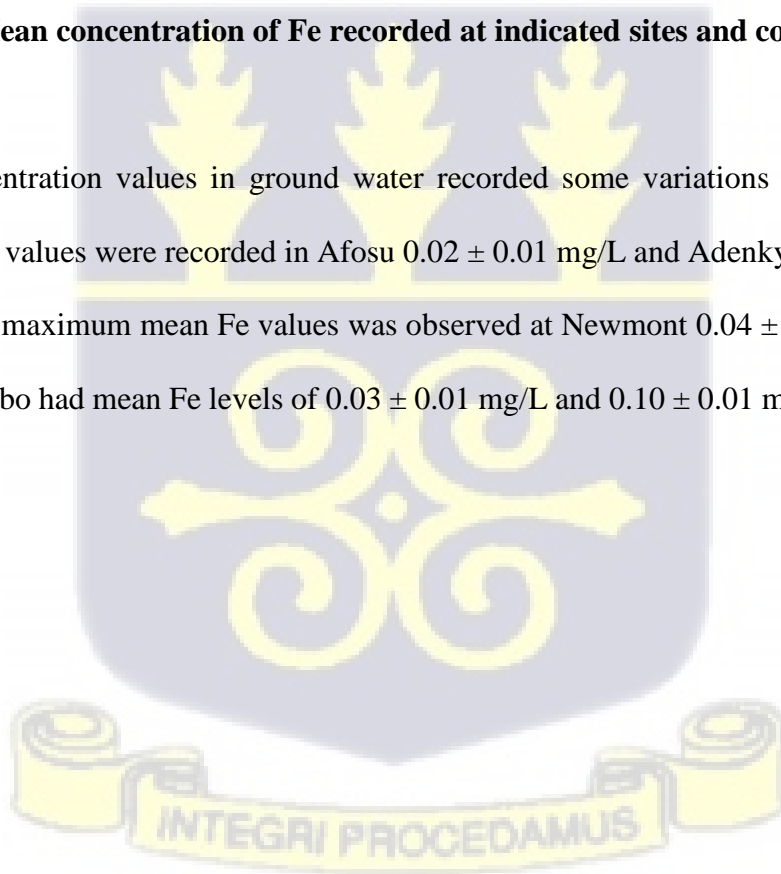


Figure 4.11: Mean concentration of Fe recorded at indicated sites and control

Mean Fe concentration values in ground water recorded some variations (Table 4.4). The lowest mean Fe values were recorded in Afosu 0.02 ± 0.01 mg/L and Adenkyensu 0.02 ± 0.01 mg/L while the maximum mean Fe values was observed at Newmont 0.04 ± 0.01 mg/L. Holy Child and Aboabo had mean Fe levels of 0.03 ± 0.01 mg/L and 0.10 ± 0.01 mg/L respectively.



4.5.3 Zinc (Zn) Concentration (mg/L)

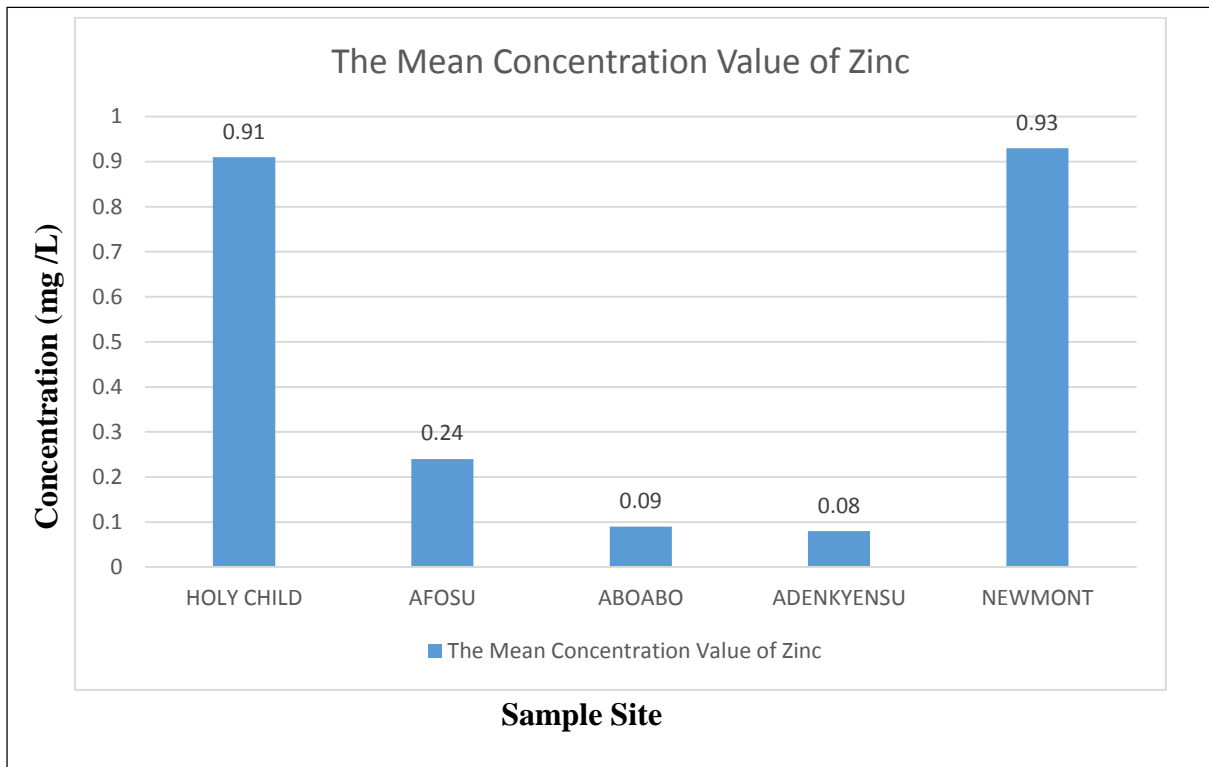
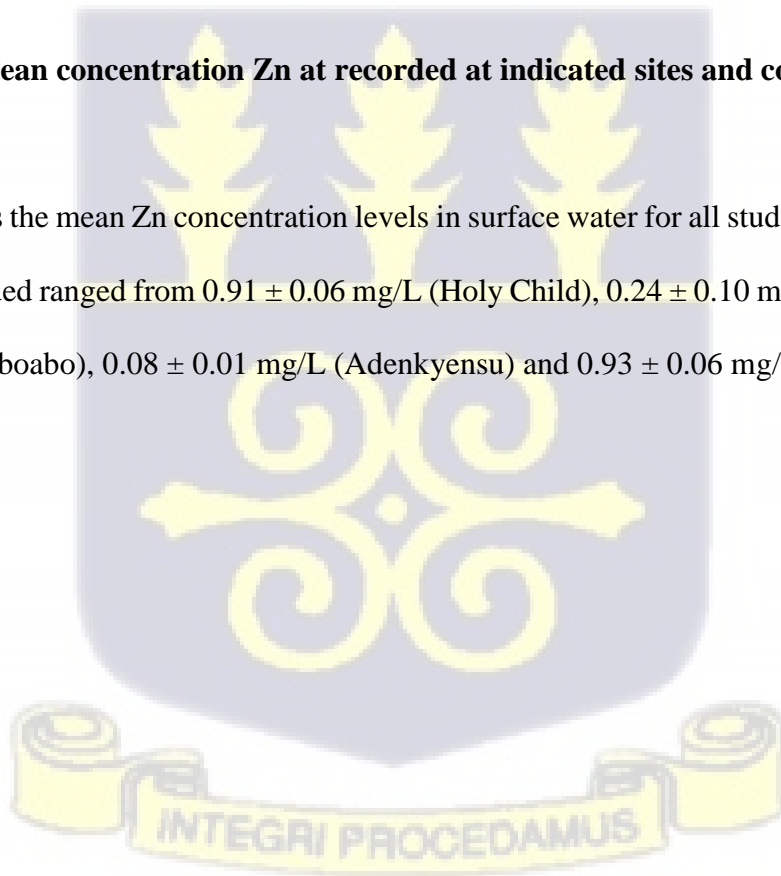


Figure 4.12: Mean concentration Zn at recorded at indicated sites and control

Table 4.4 shows the mean Zn concentration levels in surface water for all study sites. The mean Zn levels recorded ranged from 0.91 ± 0.06 mg/L (Holy Child), 0.24 ± 0.10 mg/L (Afosu), 0.09 ± 0.01 mg/L (Aboabo), 0.08 ± 0.01 mg/L (Adenkyensu) and 0.93 ± 0.06 mg/L (Newmont).



4.5.4 Chromium (Cr) Concentration (mg L⁻¹)

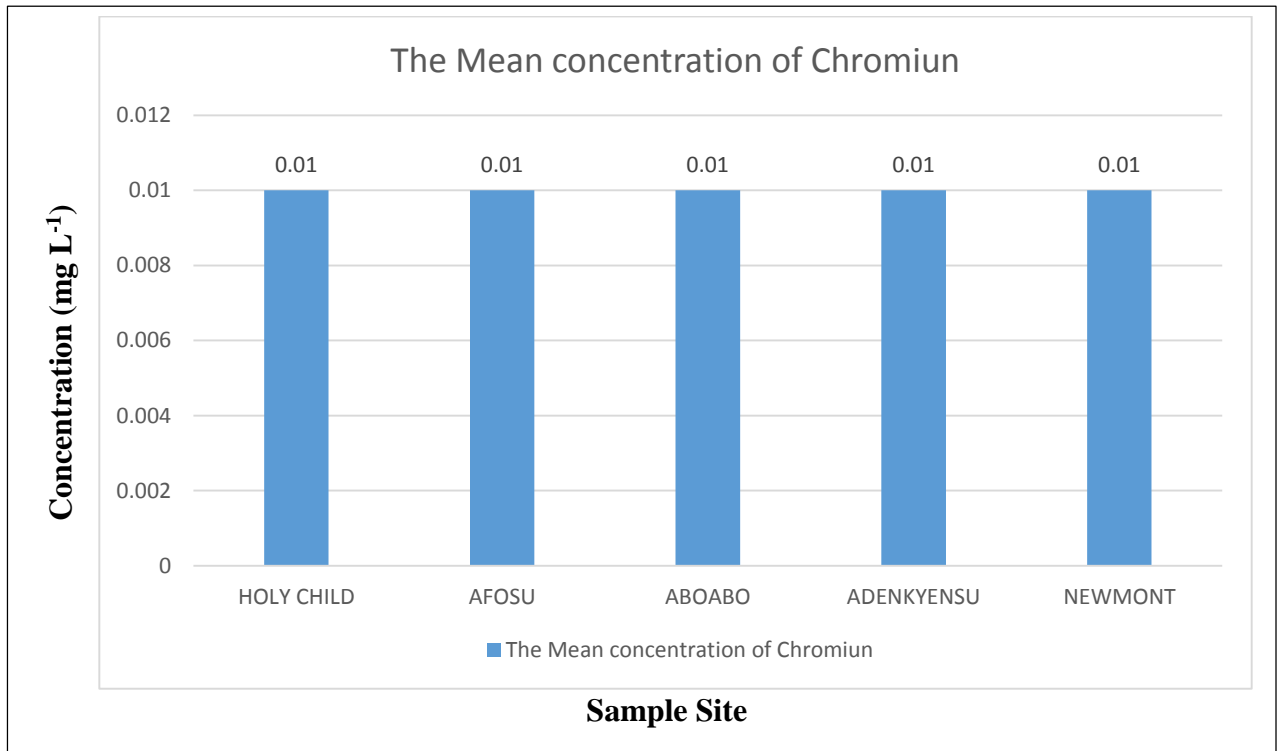
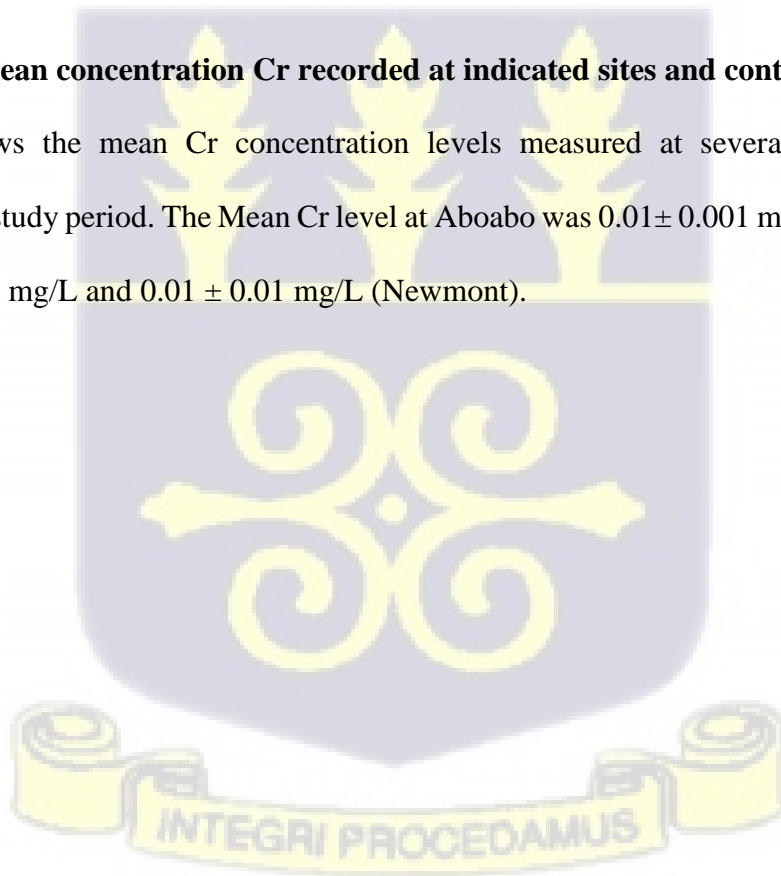


Figure 4.13: Mean concentration Cr recorded at indicated sites and control

Table 4.4 shows the mean Cr concentration levels measured at several sampling sites throughout the study period. The Mean Cr level at Aboabo was 0.01 ± 0.001 mg/L, Adenkyensu was 0.01 ± 0.01 mg/L and 0.01 ± 0.01 mg/L (Newmont).



4.5.5 Manganese (Mn) Concentration (mg L⁻¹)

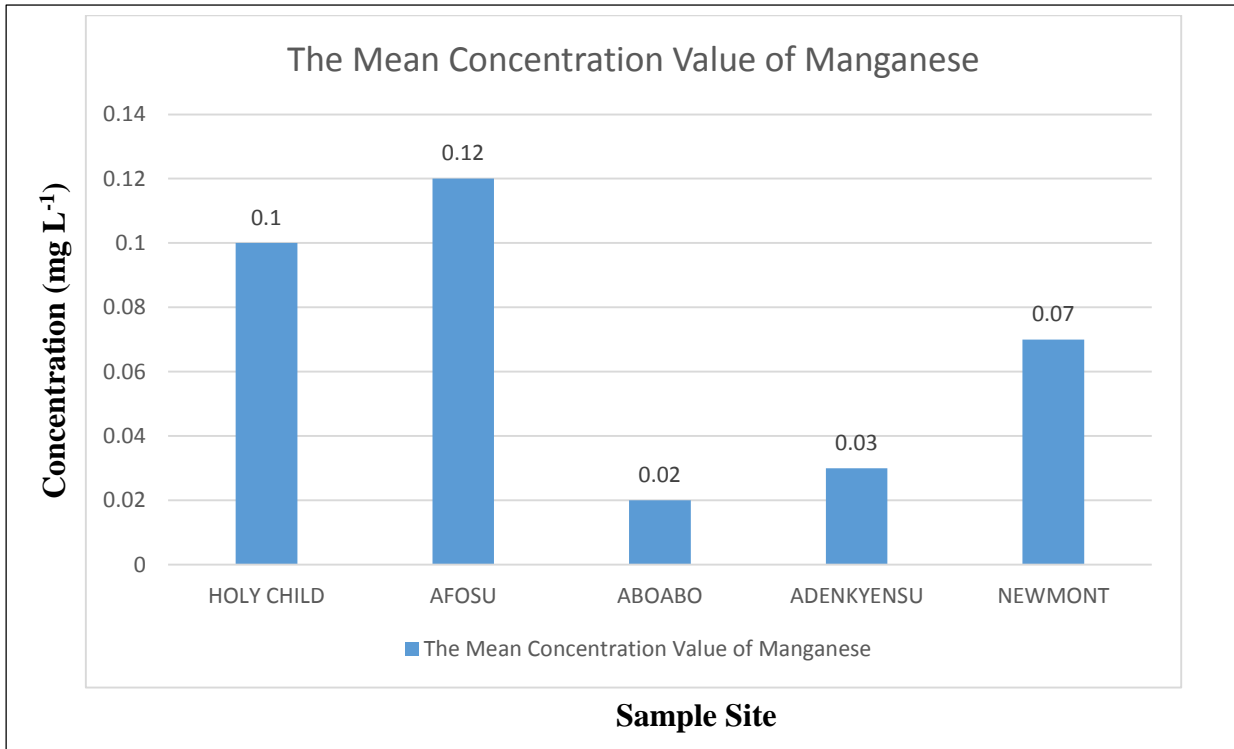
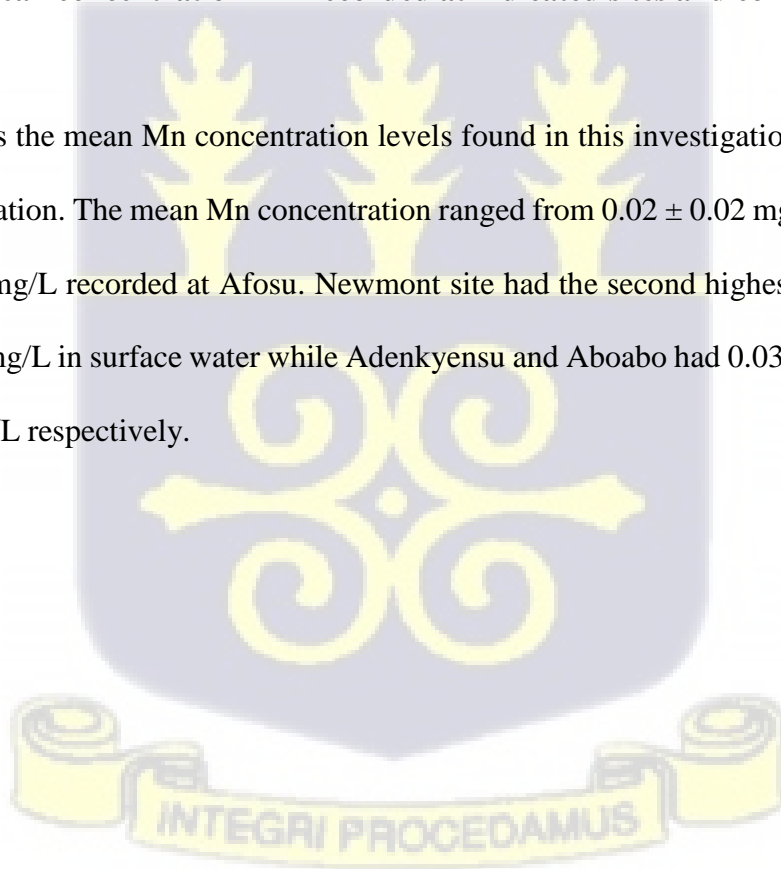


Figure 4.14: Mean concentration Mn recorded at indicated sites and control

Table 4.4 shows the mean Mn concentration levels found in this investigation, which showed only minor variation. The mean Mn concentration ranged from 0.02 ± 0.02 mg/L at Holy Child to 0.12 ± 0.02 mg/L recorded at Afosu. Newmont site had the second highest mean Mn level of 0.07 ± 0.02 mg/L in surface water while Adenkyensu and Aboabo had 0.03 ± 0.03 mg/L and 0.02 ± 0.01 mg/L respectively.



4.6 The Pollution Indices of Locations

Table 4.6: Two different pollution indices result of the sample sites

SAMPLE SITE	Cd	HPI
Holy Child	3.39	128.96
Afosu	2.84	120.06
Aboabo	4.39	110.35
Adenkyensu	4.09	125.50
Newmont	2.67	93.91
Maximum	4.39	128.96
Minimum	2.67	93.91
Mean	3.48	115.76

The calculated Pd values for each location or sample site is presented in Table 4.6. These values ranged from 2.67 – 4.39 (mean =3.48). The calculated HCI values are also given in Table 4.6. The values vary between 93.91 and 128.96 (mean = 115.76).

4.7 Results on Policy Assessment

Newmont Gold Ridge Limited (NGRL) had demonstrated a commitment to environmental protection and management. The organization completed its duty by adhering to the laws and regulations that protect the environment in New Abirem and its surrounding areas. Newmont Akyem Mine was committed to including all stakeholders in environmental decision-making in New Abirem and its environs, particularly the Environmental Protection Agency (EPA).

Newmont Gold Ridge Limited planned to follow environmental policy, offer strong environmental performance based on corporate standards, and establish targets for ongoing improvement, according to the officials. The Newmont Corporate Sustainability and

Stakeholder Engagement Policy was used as standard operating procedure by NGRL to achieve this approach. The following are key parts of the policy related to environmental stewardship:

- Seek to preserve overall ecosystem health and resiliency in the places where businesses operate, as healthy and functional ecosystems are essential to their operations.
- Value water as a valuable resource and want to leave a legacy of water management in their host countries and communities.
- Using concepts of minimization, characterization, recycling and reuse, innovation, and application of best practices, manage mining residuals from cradle to grave.



CHAPTER FIVE

5.0 DISCUSSION

Discussions of results includes opinion of perception of air blast and ground vibration effects on the people and the structures, physicochemical parameters and heavy metals as well as comparison with other variables and guidelines are given in this chapter.

5.1 The Air overpressure

The modest variations in the mean air blast values at the three blast monitory locations are mainly due to the differences among the distances in their blast monitory locations. The globally permissible levels of air blast for human discomfort and onset of structure damage are 120 dBL and 130 dBL respectively. It was discovered that the levels of air blast were also not above the maximum permissible limits of Explosive Regulation, 2012 (L.I. 2177) of Ghana.

5.3 Ground Vibration

The essence of assessing the blasting effects of ground vibration on the ecosystem was to determine how safe the mine environment would be for the structures. The results obtained from the three communities monitored on the perception of the people and measuring of ground vibration were presented in figure 1 and 3. From the table 4.3, it was found that the levels of ground vibration recorded during this study were below the worldwide safe damage limits of 13 mm/s. The results obtained were compared with Explosive Regulation, 2012 (L.I. 2177) and they were recorded within the Mining and Mineral Regulation of Ghana.

5.4.0 Physicochemical Parameters

The main objective of monitoring physicochemical parameters of water was to maintain standard water of aquatic ecosystems needed. The findings of physicochemical parameters

such as, dissolved oxygen, electrical conductivity, PH, water temperature, ammonia and nitrate at various locations in the four water sampling sites around the Newmont are shown in (Table 4.4 and Figures 4 - 9).

5.4.1 Dissolved Oxygen

Dissolved oxygen is required for the survival of all aquatic organisms, and its existence in greater quantities in a water body provides a broad indication of water quality. The amount of dissolved oxygen in water bodies is strongly influenced by temperature. When the water is coldest, high dissolved oxygen values are obtained, according to Taseli (2006). Dissolved oxygen in water bodies is mostly created by photosynthetic phytoplankton and other aquatic plants, or it comes from the atmosphere.

The lowest average mean dissolved oxygen levels were found in May 2021, and the greatest mean dissolved oxygen concentrations were found in February 2021, according to the chronological fluctuations in dissolved oxygen values in the sampling locations. Low amounts of dissolved oxygen in the River Afosu and Adausena streams around May 2021 could be due to turbidity in the water during the long rainy season. Turbidity reduces light penetration, resulting in low photosynthetic rates in phytoplankton.

The most common cause of dissolved oxygen depletion in aquatic bodies is certain types of water contamination (Srivastava et al., 2009). Dissolved oxygen concentrations in unpolluted waters are normally in the range of 8 to 10 mg/L, according to Taseli (2006), with readings below 5 mg/L recognized to be harmful to aquatic life. This could be attributable to the rising effect of anthropogenic activities within the Newmont region, as all sampling locations were below 5 mg/L as well as 8 to 10 mg/L. The Vicinity includes the communities of New Abirem, Afosu, and Adausena, which are closer to the mining site, and mining waste flowing into the

Birim River and Ahausena streams could be a contributing factor to low dissolved oxygen levels at all sampling sites. In this study, the mean dissolved oxygen concentration is below the Taseli dissolved oxygen concentration safe limit in unpolluted waterways, which has a negative impact on aquatic life.

5.4.2 Electrical Conductivity

Water's ability to conduct electricity is measured and used to calculate the number of dissolved solids in the liquid (Mushatq et al., 2013). The electrical conductivity of a water sample is a good indicator of mineralization (Jain et al., 2005). The standard for electrical conductivity in drinking and drinkable water is 700 $\mu\text{S}/\text{cm}$, according to the World Health Organization (2003).

In relation to the electrical conductivity reported in this study, all sampling sites water is safe for home use, with the exception of the Newmont pit water sample, which were above 700 $\mu\text{S}/\text{cm}$. This signifies that the water in the Newmont pit is unfit for human consumption since it has been contaminated by the conductivity level.

5.4.3 pH

The pH scale is used to determine whether water is acidic or alkaline. The pH of naturally occurring fresh water ranges between 6.0 to 8.0, according to Osman and Kloas (2010). The pH of water is critical because it influences the solubility, availability, and consumption of nutrients by aquatic species (Osman and Kloas, 2010). Except for the Holy Child and Afosu sites, the pH measured in this investigation was slightly alkaline water. The decreased pH values in the Holy Child and Afosu sampling sites could be due to rainwater, which has a slightly acidic pH, as well as a dilution effect. The leaching of waste rocks from garbage discharged by acidic rainwater causes the acidic nature of the surface water in New Abirem

and Afosu (Edet et al, 2002). The pH range discovered in the study region was judged to be appropriate for fishing (EPA, 2002).

The pH scale is used to assess whether water is acidic or alkaline. The reported mean pH values at all test sites were within acceptable levels for water used for human (6.5–8.5) and livestock consumption. Environmental Protection Agency (EPA), 2002. In general, the pH was within the range of standard values (APHA, 2005) and the WHO drinking water quality recommendation of 6.0–8.5. (De, 2002 and Bbosa et al., 2009). This pH range also signifies a water body's productivity (Garg et al., 2010).

5.4.4 Temperature

Due to daily weather circumstances, the monthly water temperature in all of the locations varied, with the lowest value (26.60 – 26.80⁰C) recorded in May 2021. The seasonal differences in weather within the research area could be to blame for the periodic shifts in water temperature. The biggest difference could be due to a change in vegetative cover around Holy Child against the Newmont, where afforestation had been implemented. During the study period, Afosu, which is located at the upper end of the river Afosu, had the lowest mean surface water temperature of 26.70.

Surface water temperature differed significantly between locations ($p = 0.03$; $df = 10$) according to a one-way analysis of variance. Tukey's HSD test for separation of means in table 4.3 revealed that the mean water temperature at Holy Child differed from the mean water temperature at Newmont.

5.4.5 Ammonia (NH₃)

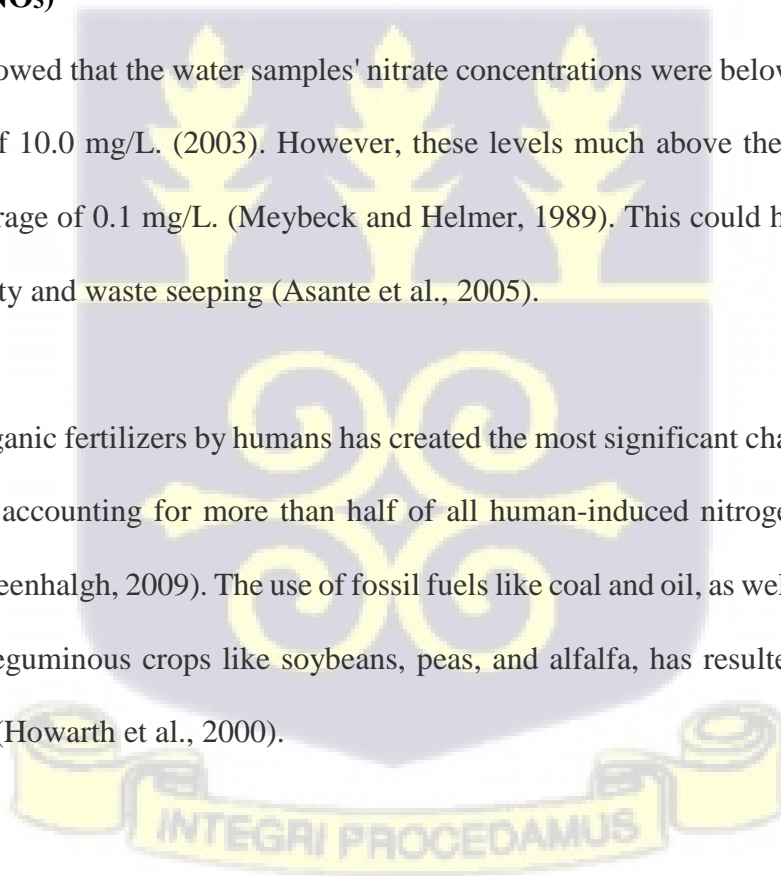
Ammonia has toxicological effects only at concentrations greater than 200 mg/kg of body weight. Ammonia in drinking water has no direct health implications, hence no health-based recommendation value is provided. However, the Guidelines said that ammonia concentrations exceeding 35 and 1.5 mg/l could produce taste and odour concerns, respectively (WHO, 2003).

In contrast, ammonia can diminish disinfection efficiency, because nitrite generation in distribution systems, accelerate manganese filter failure, and cause taste and odor problems in water. As a result of metabolic, agricultural, and industrial processes, as well as chloramine disinfection, ammonia is released into the environment. The presence of ammonia in water indicates bacterial, sewage, and animal waste pollution.

5.4.6 Nitrate (NO₃)

The analysis showed that the water samples' nitrate concentrations were below WHO's highest allowed level of 10.0 mg/L. (2003). However, these levels much above the global nitrate in fresh water average of 0.1 mg/L. (Meybeck and Helmer, 1989). This could happen as a result of human activity and waste seeping (Asante et al., 2005).

The use of inorganic fertilizers by humans has created the most significant change in the global nitrogen cycle, accounting for more than half of all human-induced nitrogen cycle changes (Selman and Greenhalgh, 2009). The use of fossil fuels like coal and oil, as well as the increased cultivation of leguminous crops like soybeans, peas, and alfalfa, has resulted in high nitrate levels in rivers (Howarth et al., 2000).



5.5.0 Heavy Metals

The purpose of monitoring the concentrations of these trace metals in the water body was to identify their pollution levels and consequences for Ghana's long-term aquatic resource management in terms of health and the environment. The results of resident heavy metal distribution, particularly Cu, Fe, Zn, Cr, and Mn, at various places in the four water sample sites around the Newmont are presented in the graph (Table 4.5 and Figures 10 - 14).

5.5.1 Copper (Cu)

Copper concentrations ranging from 0.01 to 0.02 mg/L were discovered at all test sites when compared to WHO, EPA, WPCL, and CIW guidelines/standards (Figure 4.10). Cu concentrations in drinking water in any of the sampling sites did not exceed the WHO (2003) limit of 1.00 mg/L. Copper is released into water as a result of natural soil weathering and industrial and sewage treatment plant emissions (Romo-Kroger et al., 1994 and Hutchinson, 2002).

According to Al-Weher (2008), copper in surface water results from the widespread use of pesticide sprays containing Cu compounds for agricultural purposes. Cu is hazardous to aquatic species and plants in its dissolved form, especially young life stages like fish. The toxicity of river water is considerably reduced when Cu is mixed with particle matter in the water and the water is cleansed.

5.5.2 Iron (Fe)

Iron (Fe) is a necessary component of many proteins and enzymes that keep us healthy (IOM, 2001). Newmont (control site) (0.33 mg/L) > Holy Child = Aboabo (0.03 mg/L) > Afosu = Adenkyensu (0.02 mg/L) > Afosu = Adenkyensu (0.02 mg/L) > Afosu = Adenkyensu (0.02

mg/L) > Afosu = Adenkyensu (0.02 mg/L) > Afosu (Figure 4.11). The value found at Newmont was higher than the WHO, EPA, and WPCL maximum permitted level of iron, but lower than the CIW maximum permissible limit of iron.

Iron deficiency impairs oxygen delivery to cells, resulting in fatigue, decreased work performance, and weakened immunity. Toxicity, a quick increase in heart rate and blood coagulation in blood vessels, hypertension, drowsiness, and even death are all possible side effects (Bhaskaram, 2001; Corbett, 1995). When present in suspended form as Fe²⁺ or Fe³⁺, excess iron can influence the presence of germs in dam water, stain garments, and provide a harsh taste. The main sources of iron include natural geological sources, industrial wastes, and residential and industrial discharge by-products; when present in suspended form as Fe²⁺ or Fe³⁺, excess iron can influence the presence of bacteria in dam water, stain garments, and impart a harsh taste (Ansari et al., 2004).

Except for the one from the blasting pit, Newmont, which recorded 0.33mg/L, all of the Fe levels observed were below the WHO recommended limit of 0.3mg/L in drinking water (WHO, 2003) and Ghana Standard Authority (G.S.A), with the exception of the one from the blasting pit, Newmont, which recorded 0.33mg/L, which is slightly above the permissible limit. This signifies that the water in the Birim River and the Adausena streams is free of Fe contamination.

5.5.3 Zinc (Zn)

Zinc is commonly present in water as a result of industrial waste, metal plating, and plumbing. It is an essential nutrient in man's diet, according to Hotz et al. (2003), because it functions as a catalytic or structural component in many enzymes involved in energy metabolism, RNA

transcription and translation, determining the outcome of pregnancies, and supporting neurobehavioral development.

High quantities of Zn compounds, on the other hand, are caustic and irritating to the skin, eyes, mucous membranes, and digestive tract, resulting in nausea, vomiting, and a kind of dermatitis known as "zinc pox" (Lagadic et al., 2000).

However, the mean Zn concentrations in this study, varied from 0.08 to 0.93 mg/L discovered were below the stipulated recommendations or requirements and may not exhibit the associative toxicity symptoms claimed on the individuals who consume the water resources in the short term. The content of zinc in surface water in this investigation did not surpass the suggested limit of 3 mg/L for Zn levels in drinking water (WHO, 2003).

5.5.4 Chromium (Cr)

The mean Cr values of 0.01 obtained in this investigation were determined to be within the recommended limit for Cr in drinking water of 0.05 mg/ L. (WHO, 2003). The mean Cr concentration of 0.01 mg/L recorded at Holy Child, Afosu, Aboabo, and Adenkyensu, as well as the control site at Newmont, as shown in Figure 4.13, was below the WHO, EPA, and WPCL suggested specific guideline or criteria. In terms of chromium pollution, this means that the Afosu River and Adausena streams were safe for home chores, agriculture, and industry use.

Hexavalent chromium (Cr⁶⁺) is quickly absorbed in the human body and can induce toxic effects within cells, including irritation of the eyes, skin, and mucous membranes, as well as damage to the kidneys and liver, according to ATSDR (2008). This suggests that the amount of chromium in the various water samples examined could not have caused any harm.

5.5.5 Manganese (Mn)

The order of Mn concentration at all sampling sites revealed that levels detected at Afosu (0.12 mg/L) > Holy Child (0.1 mg/L) > Newmont (control site) (0.07 mg/L) > Adenkyensu (0.03 mg/L) > Aboabo (0.02 mg/L) were all lower than WHO, EPA, WPCL, and CIW guidelines/standards, and all sites recorded comparatively lower Mn values than WHO, EPA (Figure 4.14). Manganese contamination can also occur as a result of the metal's presence in the leachate of burned waste (WHO, 1981).

The mean Mn content level in the Holy Child sample site was equivalent to the WHO's (2003) permitted limit of 0.10 mg/L for Mn in drinking water, as well as above the EPA's guideline of 0.10 mg/L. (2002). In Afosu, the mean Mn content in surface water exceeded the EPA's suggested limit of 0.02 mg/L and the WHO's permissible limit of 0.10 mg/L in drinking water (WHO, 2003). The high Mn levels in Afosu could be linked to the area's significant use of agricultural fertilizers as well as soil erosion.

5.6 The Evaluation of Pollution Indices

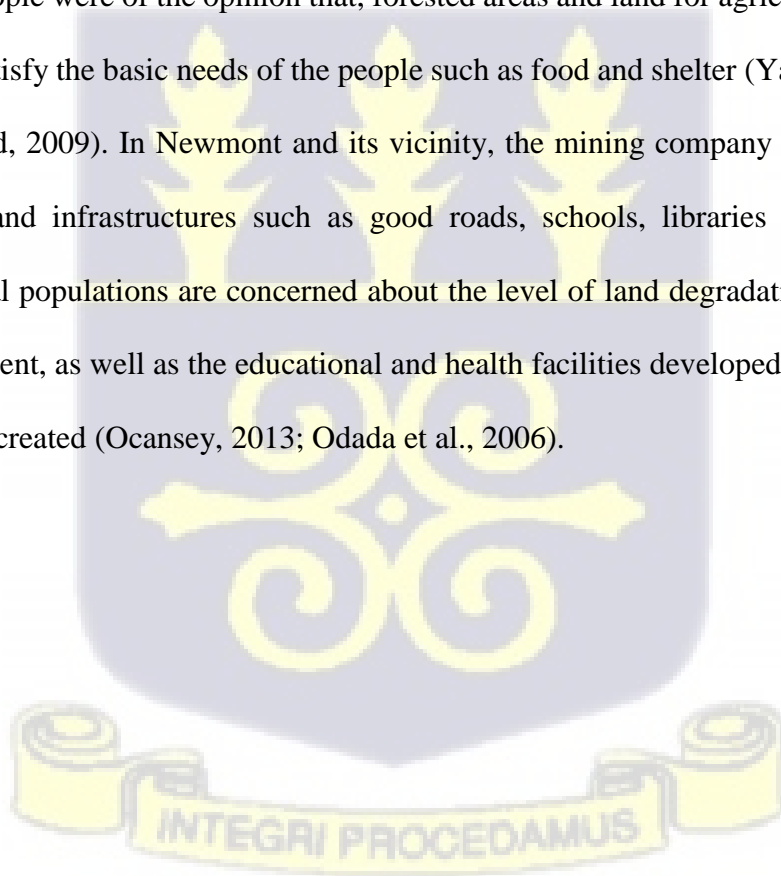
Heavy metal concentrations below 3 mg/L, the limit, pose no risk to groundwater quality. The total Pd value identify area of contamination levels are categorized as follows: weakly polluted ($Pd < 1$), moderately polluted ($Pd = 1 - 3$) and strongly polluted ($Pd > 3$).

When neglecting the algebraic sign as reported by Prasad and Bose (2001), the heavy metal pollution index in all of the water samples tested was larger than 100 mg/L, the critical value for drinking water, with the exception of the Newmont site sample.

5.7 Environmental Stewardship Policy

Based on the environmental strategy and the ways in which the EPA monitored activities, Newmont officials were interviewed. According to the EPA, the numerous ways include Newmont Company's frequent site inspections and the mining communities' complaints were addressed as planned. The environmental element of mining, according to officials, is directly governed by the environmental protection agency Act 490 and the mining and mineral law 2006, both of which provide for environmental protection and pollution prevention. The 1994 mining and mineral regulation was enacted to prevent mining from causing long-term environmental damage and to encourage good environmental stewardship (Boocock, 2002). This was also stated in Newmont's Akyem mine's environmental stewardship program.

Though, the people were of the opinion that, forested areas and land for agriculture remain the medium that satisfy the basic needs of the people such as food and shelter (Yaro, 2010; Hilson and Mohammed, 2009). In Newmont and its vicinity, the mining company had provided for developments and infrastructures such as good roads, schools, libraries and other social amenities. Local populations are concerned about the level of land degradation and pollution in the environment, as well as the educational and health facilities developed for them and the additional jobs created (Ocansey, 2013; Odada et al., 2006).



CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In view of the results obtained in this study with respect to study objectives, the conclusions are:

- The levels of air blast were within 117 dB of Explosives Regulations, 2012 (L.I. 2177) or the safe limits of the globally maximum damage levels quoted AS 2187.2 – 1993 for human discomfort and onset of structure damage 120 dB and 130 dB respectively.
- The ground vibration levels measured at the three compliance locations in Birim North District were within 2mm/s of Explosives Regulations, 2012 (L.I. 2177), Section 199 of Ghana.
- The Dissolved Oxygen concentrations at all the five sampling sites of Birim North District were below 5 mg/L which indicated that the water was polluted and adversely affected aquatic life.
- Water from Birim North District is not appropriate for home use without additional treatment.
- The results of ground water from New Abirem and Afosu sample sites were slightly acidic.
- The two pollution indices, the degree of contamination, Cd values for Holy Child, Aboabo and Adenkyensu were above the criteria limit and the heavy metal pollution index provide strong results compared with the limit, 100 mg/L whilst the Newmont value was below the criteria limits.
- The mean of the heavy metals analyzed (Cu, Fe, Zn, Cr, and Mn) was lower than the WHO recommended drinking water limit and the EPA acceptable pollution threshold.

6.2 Recommendations

The following are to be considered to prevent future environmental negative effects of mine blasting in New Abirem and its vicinity:

- There is the need for continuous engagement of the stakeholder with technical background to complement the Governmental organizations that monitored the air blast, Particulate matter and ground vibration.
- Stakeholders shall monitor, control, or cease avoidable anthropogenic activities that result in the addition of heavy metals to the water bodies investigated on a continuous basis.
- An integrated management plan for Afosu River and streams in the locality involving reduction water contamination emanating from anthropogenic activities.
- It is recommended that water used for drinking, domestic chores, agricultural (irrigation) or industrial use by communities along the tributaries of the Birim River must be treated before use.

Further Research

Further Research into the following is also recommended:

- Determine the relationship between particulate matter that affects soil quality and its origin.
- Determine levels of heavy metals in surface and underground water, sediments and fish in New Abirem and its vicinity.
- Assess levels of other heavy metals not covered in this study in sediments, water, and fish species within the water bodies Birim North District.



REFERENCES

- Abubakar S., Alzubi J., Alzubi Y. and Alzyoud A., (2011). Potato (*Solanum tuberosum* L.) Production under Phosphate Waste in Jordan. *Journal of Agronomy, Asian Network for Scientific Information*. Pp. 1-2.
- Adam, P., Bertness, M. D., Davy, A. J. & Zedler, J. B. (2008). Saltmarsh. Pp. 157–171, In: N. V. C. Polunin (ed.), *Aquatic ecosystems: Trends and global prospects*. Cambridge: Cambridge University Press.
- Alloway, B. J. (1995) (ed.) *Heavy Metals in Soils*. 2nd edition. Blackie Academic & Professional.
- Alloway B.J. and Ayres D.C. (1998). *Chemical principles of environmental pollution*. Pub. Stanley Thorens Ltd.
- Akabzaa T. and Darimani A., (2001). *Impact of Mining Sector Investment in Ghana: A case study of the Tarkwa Mining Region, A Draft Report*, www.saprin.org/ghana/research/gha_mining.pdf.
- Akan J. C., Abbagambo M. T. and Chellube Z. M., (2012). Assessment of Pollutants in Water and Sediment Samples. *Journal of Environmental Protection*, 3: 1428–1441.
- Akande J. M. and Awojobi D., (2005). Assessment of Environmental Impact of Exploitation of Granitw Deposit in Iiorin, Nigeria. *Journal of Science*, vol. 10, no. 2, pp. 4888-4900.
- Akoto O., Bruce T. N and Darko G (2008). Heavy metals pollution profiles in streams serving the Owabi reservoir. *African Journal of Environmental Science and Technology Vol. 2(11)*. Pp. 354 – 359.
- Al-Weher, S. M (2008). Levels of heavy metal Cd, Cu and Zn in three fish species collected from the northern Jordan valley. *Jordan Journal of Biological Sciences*, 1(1), 41 – 46.

- American Conference of Governmental Industrial Hygienist (ACGIH) (2010). Threshold limit values for chemical substances and physical agents and biological exposure indices. ACGIH. Cincinnati OH.
- Andrews N.C. (1986) Disorders of iron metabolism. *New England Journal of Medicine*; 341:1986-95.
- Ansari T.M., Marr I.L., Tariq N., (2004). Heavy Metals in Marine Pollution Perspective - A Mini Review. *J. Appl. Sci.* 4(1): 1-20.
- American Public Health Association (APHA), (1998). *Standard Methods for the Examination of Water and Waste Water (Standard Methods)*. 20th Edition, APHA-AWWA-WEF.
- APHA (2005). *Standards methods for the examination of water and waste-water* 21st edition. Washington, D. C (2005).
- Asante, K. A., Quarcoopome T. and Amevenku F. Y. K., (2005). Water Quality of the Weija Reservoir after 28 years of Impoundment. *West African Journal of Applied Ecology*, **13**: 171-180.
- Agency for Toxic Substances and Disease Registry, ATSDR (2008a). Chromium (TP-7) In: *Toxicological Profile*. US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, pp. 610. Retrieved August 12, 2012 from <http://www.atsdr.cdc.gov/toxprofiles/tp7>.
- Awudi B. K. (2002). The Role of Foreign Direct Investment (FDI) in the Mining Sector of Ghana and the Environment. A Paper Presented at the Conference on Foreign Direct Investment and the Environment 7 – 8 February 2002, OECD, Paris – France by George B. K. Awudi, Friends of the Earth –Ghana, Accra, www.oecd.org/dataoecd/44/12/1819492.pdf.

- Backman B., Bodis D., Lahermo P., Rapant S. and Tarvainen (1998). Application of a ground water contamination index in Finland and Slovakia. *Environmental Geology* **36**(1-2) 55 – 64.
- Bbosa, B. N., Wandiga, S.O., Madadi, O.V and Abongo, D.A (2009). Physicochemical parameters and magnetic speciation of Iron in Nakivubo Channel and Lake Victoria waters. *Lakes & Reservoirs: Research and Management* 2009 14: 127 – 137.
- Best E. P. H., Geter K. N., Tatem H. E. and Lane B. K., (2006). Effects, transfer, and fate of RDX from aged soil in plants and worms. *Chemosphere*, 62:616–625.
- Best A. A., Wither A. W. and Coates S., (2007). Dissolved oxygen as a physicochemical supporting element in the water framework directive. *Marine Pollution Bulletin*, 55: 53-64.
- Bhaskaram P., (2001). Immunobiology of mild micronutrient deficiencies. *Bri. J. Nutri.* 85: S75-80.
- Boocock C. N (2002). Organization for Economic Corporation and Development (OECD) global forum on international investment: Environmental impact of Foreign Direct Investment (FDI) in the mining sector in Sub-Saharan Africa, 7–8 February 2002, Paris, France.
- Bradi, B.H (2005). Heavy metals in the environment. *Interface Science and Technology*, ed. Hubbard, A., Vol.6. Elsevier Academic Press: Neubrucke.
- Camara V., Filhote M. I., Lima, M.I., Alheira F. V., Martins M. S., Dantas T. O., Luiz R. R., (1997). “Strategies for preventing adolescent mercury exposure in Brazilian gold mining areas.” *Toxicol and Health* **13**(2-3): 285-297.

- Carolyn S., Bentivegna J. A., Sean M. B. and Katarzyna C., (2004). Influence of sediment characteristics on heavy metal toxicity in an urban marsh department of biology, Seton Hall University, South Orange, NJ 07079.
- Chapman D., (1992). Water quality assessment, A guide to the use of biota, sediments, and water in environmental monitoring, University Press, Cambridge, p 585.
- Chapman, D and Chapman, D.E (Ed). (1996). Water quality assessments. A guide to the use of biota, sediments and water in environmental Monitoring. 2nd Edition, Chapman and Hall, London, 1996.
- Corbett J. V., (1995). Accidental poisoning with iron supplements. MCN American J. Maternal and Child Nursing. 20:234.
- Dallman P.R. (1986). Biochemical basis for the manifestations of iron deficiency. Annual Review of Nutrition; 6:13-40.
- Damodharan U., (2013). Bioaccumulation of heavy metals in contaminated river water – Uppanar, Cuddalore South East Coast of India. <http://dx.doi.org/10.5772/5334>.
- De A.K., (2002). Environmental chemistry (4th Edn). New Delhi, India: New Age.
- Drasch G., Bose-O'Reilly, S., Beinhoff, C., Roider, G., Maydl, S. (2001). “The Mt. Diwata study on the Philippines 1999-- assessing mercury intoxication of the population by small scale gold mining.” Science of Total Environment **267**(1-3): 151-68.
- Duffus J. H. (2002). “Heavy Metals” – A meaningless term. Pure and Applied Chemistry 74, 793 – 807. Electronic version 3/1996.
- DWAF (Department of Water Affairs and Forestry) (1996) *South African. water quality guidelines. Volume 7: Aquatic ecosystems*, DWAF, Pretoria.
- Edet A. E., Merkel B. J. and Offlong O. E., (2002). Trace element hydrochemical assessment of the Calabar coastal plain sand aquifer, southeastern Nigeria using statistical methods. Environmental Geology online DOI 10.1007/s 00254-0738-1.

- Environmental Protection Agency (EPA), (2005). <http://www.epa.gov.gh/mining/index.html>
- EPA, (1997). Current Drinking Water Standards (Human): Office of ground water and drinking water. US Environmental Protection Agency, Washington, DC, EPA 815-k-97-002.
- EPA, (2002). Current drinking water standards. Office of ground water and drinking water. US Environmental Protection Agency, Government Printing Office, Washington, 2002.
- Fatoki, O.S and Awofolu, O.R (2003). Levels of Cd, Hg and Zn in some surface water from the Eastern Cape Province, South Africa. *Water South Africa*, 29: 375 -380.
- Gadzala-Kopciuch R., Berecka B., Bartoszewicz J. and Buszewski B., (2004). Some Considerations about Bioindicators in Environmental Monitoring. In Polish Journal of Environmental Studies Vol. 13, No. 5 (2004), 453 – 462.
- Garg, R.K., Rao, R.J., Uchchariya, D., Shukla, G and Saksena, D. N(2010). Seasonal variations in water quality and major threats to Ramsagar reservoir, India. *Africa Journal of Science and Technology*. 4(2): 061-076.
- Ghana Statistical Service (2012). 2010 Population and Housing Census: Regional Analytical Report- Eastern Region.
- Grouse, R. G., Pories, W. J., Bray, J. T., and Mauger, R. I., (1983). Geochemistry and man, health and diseases. In Thorton, I., (1983): Applied Environmental Geochemistry. Academic press, London 267- 303.
- Gueu, S.; Yao, B. Adouby, K., and Ado, G., (2007). International Journal Environmental Science Technology, 4: 11-17.
- Harada M (1995). Minamata disease: methylmercury poisoning in Japan caused by environmental pollution. *Crit Rev Toxicol* 25(1):1–24.
- Heath M. J., Merefield J. R., Paithankar A.G. (1993). “Environmental impact of mining in tropical forest”, Mining Environmental Management, September 1993.

- Helen, P., Neal, M., Alison, J., Linda, H. and Wickham, H., (2005). Water Quality of Treated Sewage Effluent in a Rural Area of the Upper Thames Basin, Southern England, and the Impacts of Such Effluents on Riverrine Phosphorus Concentrations, *Journal of Hydrology*, **304**: 103-117.
- Hilson G. and Mohammed S. (2009). Are alternative livelihood projects alleviating poverty in mining communities? Evidence from Ghana. *Journal of Development Studies*, 45(02), 172–196.
- Horton R. K. (1965). An index system for rating water quality. *Journal water pollution control federation* 3: 300 - ?.
- Hotz C., Lowe N. M., Araya M. and Brown K. H., (2003). Assessment of the trace element status of individuals and populations: The example of zinc and copper. *The American society of nutritional science*. 133 (5):1563-1560.
- Howarth, R., D. Anderson, J. Cloern, C. Elfring, C. Hopkinson, B. Lapointe, T. Malone, N. Marcus, K. McGlathery, A. Sharpley and Walker, D. (2000): Nutrient Pollution of Coastal Rivers, Bays and Seas. *Issues in Ecology*. Published by the Ecological Society of America. Number 7.
- Hutchinson, T. H (2002). Reproductive and developmental effects of endocrine disruptors in invertebrates: in vitro and in vivo approaches. *Toxicology Letters* 2002; 131: 75–81.
- Jain P, Sharma JD, Sohu D, Sharma P (2005). Chemical analysis of drinking water of villages of Sanganer Tehsil, Jaipur District. *Int. J. Environ. Sci. Tech.* 2 (4): 373-379.
- Jennings, G. D.; Sneed, R. E.; Clair, M. B.; St., (1996). *Metals in drinking water* published by North Carolina Cooperative Extension service publication number: AG-473-1, electronic version 3/1996.

- Juhasz A. L. and Naidu R., (2007). Explosives fate, dynamics, and ecological impact in terrestrial and marine environments. *Rev Environ Contam Toxicol*, **191**:163– 215.
- Koren D.W., Gould W.D., Bedard, P. (2000). Biological removal of ammonia and nitrate from simulated mine and mill effluents. *Water, Air, and Soil Pollution* 56: 127-144.
- Krishnamurthy C.R and Pushpa V (1995). Toxic metals in the Indian Environment Tata McGraw Hill Publishing Co. Ltd., New Delhi. Pp 280.
- Kumar, B., Mukherjee, D.P., Kumar, S., Mishra, M., Prakash, D., Singh, S.K and Sharma, C.S (2011). Bioaccumulation of heavy metals in muscle tissue of fisheries from selected aquaculture ponds in east Kolkata wetlands. *Annals of Biological Research*, 2011, 2(5): 125 – 134.
- Lagadic L., Caquet T., Amiard J.C. and Ramade F., (2000). Use of biomarkers for environmental quality assessment. *Technique et documentation* pp 55-157. Lavoisier: Paris.
- Lee, C. L.; Li, X. D.; Zhang, G.; Li, J.; Ding, A. J.; Wang, T., (2007). Heavy metals and Pb isotopic composition of aerosols in urban and suburban areas of Hong Kong and Guangzhou, South China Evidence of the long-range transport of air contaminants. *Environ. Pollut.*, 41 (2), 432-447 (16 pages).
- L.I.2177 (2012) Minerals and Mining (Explosives) Regulations, 2012. In: M.C.o. Ghana, Ed., Ghana Publishing Company Ltd, Accra.
- Madsen, H., Poulsen, L., and Grandjean, P., (1990). Risk of copper content in drinking water. *Ugeskr. Laeger*, Jun. 18, 152 (25): 1806-90041-5782.
- Malm, O. (1998). "Gold mining as a source of mercury exposure in the Brazilian Amazon." *Environment and Resources* **77**(2): 73-8.

- Mattila, K., Zaitsev, G., Langwaldt, J. (2007). Biological removal of nutrients from mine waters
Biologinen ravinteiden poisto kaivosvedestl Final report – Loppuraportti. Finnish
Forest Research Institute, Rovaniemi.
- Meybeck, M. and Helmer, R., (1989). The quality of rivers: from pristine stage to global
pollution. *Palaeogeography, Palaeoclimatology, Palaeoecology*, (Global Planet
Change Section) **75**:283–309.
- Meyer R, Köhler J. and Homburg A., (2007). Explosives, 6th, Compl. Weinheim: Wiley-VCH
Verlag GmbH, Weinheim.
- Mohan S.V., Nithila P. and Reddy S. J., (1996). Estimation of heavy metal in drinking water
and development of heavy metal pollution index. *Journal Environmental Science and
Health A* 31(2): 283 - ?
- Momtaz, M (2002). Geochemical studies of heavy metals in the seawater along Karachi
Makran Coast. *In Chemistry 2002*, University of Karachi. Karachi. p. 414.
- Mohamed M.T., (2010). Vibration Control, Mining and Metallurgical Department, Faculty of
Engineering, Assiut University, Assiut, 2010.
- Michaud, J. P. (1991). A citizen's guide to understanding and monitoring lakes and streams.
Publ. #94-149. Washington State Department of Ecology, USA.
- Mushatq, B., Raina, R., Yaseen, T., Wanganeo, A and Yousuf, A.R (2013).
Variations in the physicochemical properties of Dal Lake, Srinagar,
Kashmir. *African Journal of Environment Science and Technology* Vol.7
(7): 624 – 633.
- NAS/NRC (1973): Manganese. Washington, DC, National Academy of science of the National
Research Council, pp. 1-191.

- Nicholas, O., Kylie, L., Suzanne M. and Emma B., (1998). Sediment chemistry –macroinvertebrate fauna relationships in urban streams. Project S5: National River Health Program for the Urban Water Research Association of Australia July 1998.
- NCSU, (2006). North Carolina State University/ NCSU Water Quality Group.
- Ocansey I. T., (2013). Mining impacts on agricultural lands and food security — case study of towns in and around Kyebi in the Eastern Region of Ghana. Bachelor’s thesis, Turku University of Applied Sciences, Dept of International Business Management.
- O’Dell, B.L. and Campell B.J. (1971). Trace elements metabolism and metabolic function *Campri. Bioch.* 21.179-266.
- Osman A.G.M and Kloas W. (2010). Water quality and heavy metal monitoring in water, sediments and tissues of the African Catfish *Clarias gariepinus* (Burchell, 1822) from the River Nile, Egypt. *Journal of Environmental Protection, 2010*, Vol. 1. 389 – 400.
- Prasad B. and Bose J.M., (2001). Evaluation of heavy metal pollution index for surface and spring water near a limestone mining area of the lower Himalayas. *Environmental Geology* 41: 183 – 188.
- Prasad B. and Jaiprakas K.C., (1999). Evaluation of heavy metals in groundwater near mining area and development of heavy metal pollution index. *Journal Environmental Science and Health A* 34(1): 91 – 102.
- Rajappa B., Manjappa S., and Puttaiah E. T., (2010). Monitoring of heavy metal concentration in groundwater of Hakinaka Taluk, India. *Contemporary Engineering Sciences*, 3: 183-190.
- Reddy S.J., (1995). *Encyclopedia of environmental pollution and control*. Environmental Media, Karlla, India 1342 p.

- Rocheleau S., Lachance B., Kuperman R.G., Hawari J., Thiboutot S., Ampleman G., Rylott EL., Lorenz A. and Bruce N.C., (2011). Biodegradation and biotransformation of explosives. *Curr Opin Biotechnol*, 22:434–440.
- Romero, F. M.; Armienta, M. A.; and Carrillo-Chavez, A., (2004). Arsenic sorption by carbonaterich aquifer material, a control on arsenic mobility at Zimapan, Mexico. *Archives of Environmental Contamination and Toxicology*, 47: 1-13.
- Romo-Kroger, C. M., Kiley, J.R., Dinator, M.I and Llona, F (1994). Heavy metals in the atmosphere coming from a copper smelter in Chile, *Atmospheric Environment* 1994; 28, 705–711.
- Smith, D. G., (1986). Heavy metals in the New Zealand Aquatic Environment: A review, water Qaulity Centre, Ministry of works and Development, Wellington, New Zealand, 1986.
- Spellman F. R., and Drinan. J., (2000). The drinking water handbook. Lancaster, Pa: Technomic Pub. Co.
- Srivatava, N., harit, G.H and Srivatava, R (2009). A study of physicochemical characteristics of lakes around Jaipur. *Indian J. Environmental Biology* 30(5): 889 – 894.
- Stephens, C. and Ahern, M. (2001). Worker and Community Health Impacts Related to Mining Operations: A Rapid Review of the Literature, http://www.natural-resources.org/minerals/CD/docs/mmsd/topics/worker_community_health.pdf.
- Suresh, B., Steiner, W., Rydlo, M and Taraschewski, H (1999). Concentrations of 17 elements in Zebra mussel (*Dreissena polymorpha*). *Environmental Toxicology and Chemistry*, 18: 2574 – 9.
- Taseli B. K (2006). Influence of influent tributaries on water quality changes in Lake Mogan, Turkey. *Lakes & Reservoirs: Research and Management*, 11: 149 -168.doi:10.1111/j.1440 -1770. 2006.00302.

Tirado, V., Garcia, M. A., Moreno, J., Galeano, L.M., Lopera, F., Franco, A. (2000).

“[Pneuropsychological disorders after occupational exposure to mercury vapors in El Bagre (Antioquia, Colombia)].” *Rev Neurol* **31**(8):712-6.

Tirkey A., Shrivastava, P and Saxena, A. (2012). Bioaccumulation of heavy metals in different components of two Lakes ecosystem. *Current World Environment*. Vol. 7(2), 293-297.

UNECE (1998). To the 1979 Convention on Long-range Transboundary Air Pollution on Heavy Metals. Available from: <http://www.unece.org/env/lrtap/full%20text/1998.Heavy.Metals.e.pdf>. Accessed: 6.3.2008.

United States Environmental Protection Agency (USEPA) (1986): Quality Criteria for Water -1986. United Environmental Protection Agency office of Water Regulations and Standards. Washington DC, 20460.

USEPA, (1999): Drinking water and health. EPA 816-K-99-001.

USGS (2003): Minerals Information. Explosive Web.

US Geological Survey (USGS): December 2006. Nutrients.
<http://toxics.usgs.gov/definitions/nutrients/html>.

Van Straaten, P.(2000a), “Human Exposure to Mercury due to Small-Scale Gold Mining in northern Tanzania.” *Science of Total Environment*, Vol. 259, No. 1-3, 2000a, p. 45-53.

Veiga, M.M., and Beinhoff,C (1997), "UNECA Centers: A Solution to Reduce Mercury Pollution from Artisanal Gold Mining Activities". *UNEP Industry and Environment*, Vol. 20, No. 4, p.49-52.

Vigil K. M., (2003). *Clean water: an introduction to water quality and water pollution control*. Corvallis: Oregon State University Press.

Vinodhini, R.; Narayanan, M., (2008). Bioaccumulation of heavy metals in organs of fresh water fish *Cyprinus carpio* (Common carp). *Int. J. Environ. Sci. Tech.*, 5 (2), 179-182 (4 pages).

Warhurst, A. (1999), *Mining and the Environment: Case-Studies from the Americas*. Stylus Publishing, VA: May.

Winfield L. E., Rodgers J. H. and D'Surney S. J., (2004). The responses of selected terrestrial plants to short (<12 days) and long term (2, 4 and 6 weeks) hexahydro- 1,3,5-trinitro-1,3,5-triazine (RDX) exposure Part I: growth and developmental effects. *Ecotoxicology*, 13: 335 – 347.

World Health Organization (WHO), (1981). *Environmental Health Criteria 17: Manganese*. World Health Organization, Geneva.

World Health Organization (WHO), (2003). *Environmental Health Criteria No. 221, Zinc*. Geneva, Switzerland.

World Health Organization (WHO), (2003). *Guidelines for drinking water quality*. Geneva, 249p.

World Health Organisation (2005),

http://www.rbm.who.int/cmc_upload/0/000/015/370/RBMInfosheet_3.htm

World Health Organization, (WHO), (2011). *Guidelines for drinking water quality*, 4th edn. Geneva, p. 564.

Yaro, I. J (2010). *The Impact of mining on livelihoods of local communities: A case study of Newmont Ahafo South Mining Project of Brong-Ahafo Region of Ghana*. Unpublished Masters' Thesis, ISS, Erasmus University, Dept of Development Studies.

Yelpaala K., (2004). *Mining, Sustainable Development and Health in Ghana: The Akwatia Case-Study*, Brown University, U.S.A, and March 2004.

Zar J. H. (2001). *Biostatistical analysis*. Printice –Hall, Englewood Cliffs, N.J

APPENDICES

Appendix A: Questionnaire on environmental impact of mine blasting and perception of the community.

A. 'PERSONAL INFORMATION'

1. Residence.....
2. Sex:.... Male [] Female []
3. Age.....
4. Occupation'.....
5. Marital status: a. 'Married' [] b. 'Unmarried' [] c. 'Divorced' []
6. Highest level of educational attainment'
a. 'Illiterate' [] b. 'Basic' [] c. 'Secondary' (S.H.S, Vocational) [] d. 'Tertiary' []
7. For how long have you been staying in this town/village?'

B. 'IMPACTS OF MINING ACTIVITIES ON THE ENVIRONMENT'

8. Do you have any knowledge of mining operations in this town/village?
[] Yes [] No
9. 'If so, what extraction method(s) does/does the company use?' (Please check all that apply.)
A. Surface Mining, B. Underground Mining C. Dredging, D. Gallamsey Method,
E. Other, please specify.....
10. 'Do you believe the mining company's methods of operation have any negative effects on the natural environment?'
[] Yes [] No

11. 11. 'If so, what are some of the consequences?' (Please check all that apply.)
A. Land and vegetation degradation B. Water contamination, C. Pollution of the air
D. Noise pollution, E. Vibrations in the ground

12. 12. 'What is the true cause(s) of land degradation?' (Please check all that apply.)
A. The presence of tailing dams B. Toxic materials use C. Heavy machine usage
D. Vegetation Clearing E. Extraction for a long time
Other, Specify.....

13. 'How does pollution (of any kind, as determined in Q11) affect the environment?'
(Please check all that apply.)
A. The presence of tailing dams B. Toxic materials use C. Heavy machine usage
D. Vegetation Clearing E. Extraction over a long period of time
Other, Specify.....

14. Has Newmont taken any efforts to mitigate or mitigate the negative environmental effects of mining activities? Yes No

15. If so, what are some of the measures that are being taken?
A. Aforestation B. Building of Hospitals C. Resettlement D. Construction of Portable Water

16. Reforestation is a term used to describe the process of replace.

C. IMPACT MINING ON HEALTH OF THE PEOPLE

17. Which of the following diseases do you frequently get or suffer from?
A. Malaria B. Diarrhoea C. Skin disorders D. Fever E. Colds and catarrh,
F. Other disease(s).....

18. What diseases do members of your family tend to contract frequently?
A. Malaria B. Diarrhoea C. Skin disorders D. Fever E. Colds and catarrh,
F. 'Other disease(s).....
19. Would you consider the disease(s) mentioned above are linked to mining activities?
 Yes No
20. Where can you get medicine to help you with your health problems?'
A. Clinics B. Hospitals C. Traditional (herbal) medicine D. Drug stores
E. Other, please specify.....
21. 'Is Newmont doing anything to meet the community's health needs?' Yes No
22. 'If so, what are a few of these activities?'
.....
23. 'Has Newmont constructed any health facilities in this community for the benefit of both workers and residents?' Yes No
24. Does Newmont run a health-awareness campaign to educate the public?
 Yes No
25. If yes, explain an example of a campaign like this that you are aware of.
.....

D. IN THE MINING SECTOR, THE ROLES OF LEGAL REGULATING AGENCIES AND OTHER STAKEHOLDER ORGANIZATIONS'

26. 'Do you know of any agencies or organizations that are involved in monitoring?'
Yes No
27. 'Regulating and handling the mining sector's activities in the country?'
Yes No

28. 'If so, what are some of them?' (Please check all that apply.)

- A. Environmental Protection Agency B. Mining Chamber C. Ghana Minerals Commission D. NGO's (Non-Governmental Organizations)

29. 'Are you aware of any of the above organization's mining-related activities?'

Yes [] No []

30. 'If so, which of those are you most familiar with?' (Please check all that apply.)

- A. Environmental Protection Agency B. Mining Chamber
C. Ghana Minerals Commission
D. Non-Governmental Organizations (Name.....).



APPENDIX B

AIR BLAST

Table BI: Descriptive Statistics for Air Blast

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean			
						Lower Bound	Upper Bound	Minimum	Maximum
October_2020	Afosu	20	103.3250	4.05591	.90693	101.4268	105.2232	98.80	112.00
	New Abirem	20	100.0800	.69403	.15519	99.7552	100.4048	98.80	102.80
	Adausena	20	105.3300	4.67548	1.04547	103.1418	107.5182	100.00	115.20
	Total	60	102.9117	4.15342	.53620	101.8387	103.9846	98.80	115.20
November_2020	Afosu	20	104.5000	5.12157	1.14522	102.1030	106.8970	98.80	114.80
	New Abirem	20	100.2000	1.43747	.32143	99.5272	100.8728	95.90	104.20
	Adausena	20	101.9100	4.11325	.91975	99.9849	103.8351	95.90	114.80
	Total	60	102.2033	4.21173	.54373	101.1153	103.2913	95.90	114.80
December_2020	Afosu	20	105.3500	3.29489	.73676	103.8079	106.8921	101.00	112.30
	New Abirem	20	98.2750	3.45602	.77279	96.6575	99.8925	94.00	102.80
	Adausena	20	105.5150	4.32609	.96734	103.4903	107.5397	100.00	113.30
	Total	60	103.0467	4.99513	.64487	101.7563	104.3370	94.00	113.30
January_2021	Afosu	20	105.2550	4.65171	1.04015	103.0779	107.4321	97.50	117.60
	New Abirem	20	101.1400	3.29775	.73740	99.5966	102.6834	95.90	107.00
	Adausena	20	100.6600	1.77598	.39712	99.8288	101.4912	100.00	107.00
	Total	60	102.3517	3.97635	.51334	101.3245	103.3789	95.90	117.60

	Afosu	20	103.0350	3.81110	.85219	101.2513	104.8187	98.80	115.50
February_2021	New Abirem	20	100.1750	1.84616	.41281	99.3110	101.0390	95.90	104.90
	Adausena	20	102.3150	2.62524	.58702	101.0864	103.5436	100.00	108.40
	Total	60	101.8417	3.08134	.39780	101.0457	102.6377	95.90	115.50
	Afosu	20	100.5050	2.10625	.47097	99.5192	101.4908	95.90	106.50
March_2021	New Abirem	20	103.4950	2.94395	.65829	102.1172	104.8728	100.00	108.40
	Adausena	20	103.2750	3.23629	.72366	101.7604	104.7896	100.00	109.90
	Total	60	102.4250	3.07817	.39739	101.6298	103.2202	95.90	109.90



Table BII: ANOVA FOR AIR BLAST

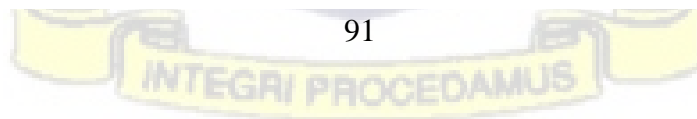
		Sum of Squares	df	Mean Square	F	Sig.
October_2020	Between Groups	280.750	2	140.375	10.856	.000
	Within Groups	737.052	57	12.931		
	Total	1017.802	59			
November_2020	Between Groups	187.481	2	93.741	6.220	.004
	Within Groups	859.098	57	15.072		
	Total	1046.579	59			
December_2020	Between Groups	683.336	2	341.668	24.690	.000
	Within Groups	788.793	57	13.838		
	Total	1472.129	59			
January_2021	Between Groups	255.184	2	127.592	10.732	.000
	Within Groups	677.685	57	11.889		
	Total	932.870	59			
February_2021	Between Groups	88.517	2	44.259	5.349	.007
	Within Groups	471.669	57	8.275		
	Total	560.186	59			
March_2021	Between Groups	111.076	2	55.538	7.067	.002
	Within Groups	447.957	57	7.859		



Table BIII: Multiple Comparisons for Air Blast

Tukey HSD

Dependent Variable	(I) AIR BLAST	(J) AIR BLAST	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
October_2020	Afosu	New Abirem	3.24500*	1.13713	.016	.5086	5.9814
		Adausena	-2.00500	1.13713	.191	-4.7414	.7314
	New Abirem	Afosu	-3.24500*	1.13713	.016	-5.9814	-.5086
		Adausena	-5.25000*	1.13713	.000	-7.9864	-2.5136
	Adausena	Afosu	2.00500	1.13713	.191	-.7314	4.7414
		New Abirem	5.25000*	1.13713	.000	2.5136	7.9864
November_2020	Afosu	New Abirem	4.30000*	1.22768	.003	1.3457	7.2543
		Adausena	2.59000	1.22768	.097	-.3643	5.5443
	New Abirem	Afosu	-4.30000*	1.22768	.003	-7.2543	-1.3457
		Adausena	-1.71000	1.22768	.351	-4.6643	1.2443
	Adausena	Afosu	-2.59000	1.22768	.097	-5.5443	.3643
		New Abirem	1.71000	1.22768	.351	-1.2443	4.6643
December_2020	Afosu	New Abirem	7.07500*	1.17637	.000	4.2442	9.9058
		Adausena	-1.16500	1.17637	.989	-2.9958	2.6658
	New Abirem	Afosu	-7.07500*	1.17637	.000	-9.9058	-4.2442



	Adausena	-7.24000*	1.17637	.000	-10.0708	-4.4092
	Afosu	.16500	1.17637	.989	-2.6658	2.9958
	New Abirem	7.24000*	1.17637	.000	4.4092	10.0708
	New Abirem	4.11500*	1.09038	.001	1.4911	6.7389
	Adausena	4.59500*	1.09038	.000	1.9711	7.2189
January_2021	Afosu	-4.11500*	1.09038	.001	-6.7389	-1.4911
	New Abirem					
	Adausena	.48000	1.09038	.899	-2.1439	3.1039
	Afosu	-4.59500*	1.09038	.000	-7.2189	-1.9711
	New Abirem	-.48000	1.09038	.899	-3.1039	2.1439
	New Abirem	2.86000*	.90966	.007	.6710	5.0490
	Afosu					
	Adausena	.72000	.90966	.710	-1.4690	2.9090
February_2021	Afosu	-2.86000*	.90966	.007	-5.0490	-.6710
	New Abirem					
	Adausena	-2.14000	.90966	.057	-4.3290	.0490
	Afosu	-.72000	.90966	.710	-2.9090	1.4690
	New Abirem	2.14000	.90966	.057	-.0490	4.3290
	New Abirem	-2.99000*	.88650	.004	-5.1233	-.8567
	Afosu					
	Adausena	-2.77000*	.88650	.008	-4.9033	-.6367
March_2021	Afosu	2.99000*	.88650	.004	.8567	5.1233
	New Abirem					
	Adausena	.22000	.88650	.967	-1.9133	2.3533
	Afosu	2.77000*	.88650	.008	.6367	4.9033
	Adausena					
	New Abirem	-.22000	.88650	.967	-2.3533	1.9133

*. The mean difference is significant at the 0.05 level.

APPENDIX C

GROUND VIBRATION

Table CI: Descriptive Statistics for Ground Vibration

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
October_2020	Afosu	20	2.1110	7.97883	1.78412	-1.6232	5.8452	.08	36.00
	New ABIREM	20	.3145	.04058	.00907	.2955	.3335	.30	.45
	Adausena	20	.3465	.13720	.03068	.2823	.4107	.08	.62
	Total	60	.9240	4.60700	.59476	-.2661	2.1141	.08	36.00
November_2020	Afosu	20	.4615	.30737	.06873	.3176	.6054	.03	1.31
	New ABIREM	20	.2895	.09918	.02218	.2431	.3359	.07	.41
	Adausena	20	.3155	.10364	.02318	.2670	.3640	.10	.51
	Total	60	.3555	.20707	.02673	.3020	.4090	.03	1.31
December_2020	Afosu	20	.2875	.21971	.04913	.1847	.3903	.08	.77
	New ABIREM	20	.3220	.15703	.03511	.2485	.3955	.07	.55
	Adausena	20	.1570	.14643	.03274	.0885	.2255	.09	.54



	Total	60	.2555	.18849	.02433	.2068	.3042	.07	.77
January_2021	Afosu	20	.3815	.25621	.05729	.2616	.5014	.07	.77
	New ABIREM	20	.2645	.07564	.01691	.2291	.2999	.09	.34
	Adausena	20	.2225	.15532	.03473	.1498	.2952	.09	.48
	Total	60	.2895	.18803	.02427	.2409	.3381	.07	.77
February_2021	Afosu	20	.3240	.17727	.03964	.2410	.4070	.08	.67
	New ABIREM	19	.3205	.07835	.01797	.2828	.3583	.08	.46
	Adausena	20	.3530	.09728	.02175	.3075	.3985	.19	.58
	Total	59	.3327	.12457	.01622	.3002	.3652	.08	.67
March_2021	Afosu	20	.4075	.20209	.04519	.3129	.5021	.08	1.09
	New ABIREM	20	.2985	.11988	.02681	.2424	.3546	.07	.55
	Adausena	20	.3190	.22799	.05098	.2123	.4257	.11	.94
	Total	60	.3417	.19182	.02476	.2921	.3912	.07	1.09



Table CII: ANOVA FOR GROUND VIBRATION

		Sum of Squares	df	Mean Square	F	Sig.
October_2020	Between Groups	42.279	2	21.140	.996	.376
	Within Groups	1209.963	57	21.227		
	Total	1252.242	59			
November_2020	Between Groups	.344	2	.172	4.483	.016
	Within Groups	2.186	57	.038		
	Total	2.530	59			
December_2020	Between Groups	.303	2	.151	4.815	.012
	Within Groups	1.793	57	.031		
	Total	2.096	59			
January_2021	Between Groups	.272	2	.136	4.266	.019
	Within Groups	1.814	57	.032		
	Total	2.086	59			
February_2021	Between Groups	.013	2	.006	.397	.674
	Within Groups	.887	56	.016		
	Total	.900	58			
March_2021	Between Groups	.134	2	.067	1.878	.162
	Within Groups	2.037	57	.036		
	Total	2.171	59			

Table CIII: Multiple Comparisons for Ground Vibration

Tukey HSD

Dependent Variable	(I) Ground Vibration	(J) Ground Vibration	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
October_2020	Afosu	New ABIREM	1.79650	1.45696	.439	-1.7096	5.3026
		Adausena	1.76450	1.45696	.452	-1.7416	5.2706
	New ABIREM	Afosu	-1.79650	1.45696	.439	-5.3026	1.7096
		Adausena	-.03200	1.45696	1.000	-3.5381	3.4741
	Adausena	Afosu	-1.76450	1.45696	.452	-5.2706	1.7416
		New ABIREM	.03200	1.45696	1.000	-3.4741	3.5381
November_2020	Afosu	New ABIREM	.17200*	.06193	.020	.0230	.3210
		Adausena	.14600	.06193	.056	-.0030	.2950
	New ABIREM	Afosu	-.17200*	.06193	.020	-.3210	-.0230
		Adausena	-.02600	.06193	.908	-.1750	.1230
	Adausena	Afosu	-.14600	.06193	.056	-.2950	.0030
		New ABIREM	.02600	.06193	.908	-.1230	.1750
December_2020	Afosu	New ABIREM	-.03450	.05609	.812	-.1695	.1005
		Adausena	.13050	.05609	.060	-.0045	.2655
	New ABIREM	Afosu	.03450	.05609	.812	-.1005	.1695
		Adausena	.16500*	.05609	.013	.0300	.3000
	Adausena	Afosu	-.13050	.05609	.060	-.2655	.0045

		New ABIREM	-.16500*	.05609	.013	-.3000	-.0300
	Afosu	New ABIREM	.11700	.05642	.104	-.0188	.2528
		Adausena	.15900*	.05642	.018	.0232	.2948
January_2021	New ABIREM	Afosu	-.11700	.05642	.104	-.2528	.0188
		Adausena	.04200	.05642	.738	-.0938	.1778
	Adausena	Afosu	-.15900*	.05642	.018	-.2948	-.0232
		New ABIREM	-.04200	.05642	.738	-.1778	.0938
	Afosu	New ABIREM	.00347	.04033	.996	-.0936	.1006
		Adausena	-.02900	.03981	.748	-.1248	.0668
February_2021	New ABIREM	Afosu	-.00347	.04033	.996	-.1006	.0936
		Adausena	-.03247	.04033	.701	-.1296	.0646
	Adausena	Afosu	.02900	.03981	.748	-.0668	.1248
		New ABIREM	.03247	.04033	.701	-.0646	.1296
	Afosu	New ABIREM	.10900	.05977	.171	-.0348	.2528
		Adausena	.08850	.05977	.308	-.0553	.2323
March_2021	New ABIREM	Afosu	-.10900	.05977	.171	-.2528	.0348
		Adausena	-.02050	.05977	.937	-.1643	.1233
	Adausena	Afosu	-.08850	.05977	.308	-.2323	.0553
		New ABIREM	.02050	.05977	.937	-.1233	.1643

*. The mean difference is significant at the 0.05 level.

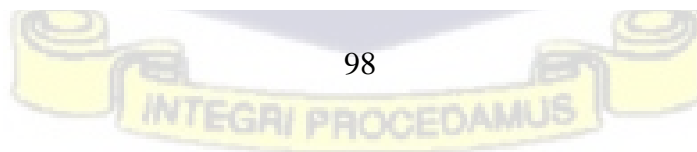


APPENDIX D

PHYSICOCHEMICAL

Table DI: Descriptive Statistics for Physicochemical

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	
					Lower Bound	Upper Bound			
Temp	Holy Child	3	27.2000	.17321	.10000	26.7697	27.6303	27.00	27.30
	Afosu	3	26.7000	.10000	.05774	26.4516	26.9484	26.60	26.80
	Aboabo	3	26.8000	.10000	.05774	26.5516	27.0484	26.70	26.90
	Adenkyensu	3	26.7667	.15275	.08819	26.3872	27.1461	26.60	26.90
	Newmont	3	26.7333	.05774	.03333	26.5899	26.8768	26.70	26.80
	Total	15	26.8400	.21647	.05589	26.7201	26.9599	26.60	27.30
DO	Holy Child	3	3.7500	.13229	.07638	3.4214	4.0786	3.60	3.85
	Afosu	3	3.6467	.08083	.04667	3.4459	3.8475	3.60	3.74
	Aboabo	3	3.6167	.02887	.01667	3.5450	3.6884	3.60	3.65
	Adenkyensu	3	3.6500	.00000	.00000	3.6500	3.6500	3.65	3.65
	Newmont	3	4.0500	.01000	.00577	4.0252	4.0748	4.04	4.06
	Total	15	3.7427	.17617	.04549	3.6451	3.8402	3.60	4.06
EC	Holy Child	3	427.3333	5.85947	3.38296	412.7776	441.8891	423.00	434.00
	Afosu	3	316.0000	20.22375	11.67619	265.7614	366.2386	293.00	331.00
	Aboabo	3	420.0000	26.45751	15.27525	354.2759	485.7241	400.00	450.00
	Adenkyensu	3	486.6667	5.77350	3.33333	472.3245	501.0088	480.00	490.00
	Newmont	3	937.6667	95.00702	54.85233	701.6562	1173.6772	828.00	995.00



	Total	15	517.5333	227.97145	58.86197	391.2870	643.7797	293.00	995.00
PH	Holy Child	3	6.3333	.15275	.08819	5.9539	6.7128	6.20	6.50
	Afosu	3	6.5000	.10000	.05774	6.2516	6.7484	6.40	6.60
	Aboabo	3	7.5667	.05774	.03333	7.4232	7.7101	7.50	7.60
	Adenkyensu	3	7.3000	.17321	.10000	6.8697	7.7303	7.20	7.50
	Newmont	3	8.1000	.17321	.10000	7.6697	8.5303	8.00	8.30
	Total	15	7.1600	.69467	.17936	6.7753	7.5447	6.20	8.30
NH3	Holy Child	3	.0097	.00153	.00088	.0059	.0135	.01	.01
	Afosu	3	.0110	.00361	.00208	.0020	.0200	.01	.02
	Aboabo	3	.0333	.00577	.00333	.0190	.0477	.03	.04
	Adenkyensu	3	.0267	.00577	.00333	.0123	.0410	.02	.03
	Newmont	3	.5217	.00289	.00167	.5145	.5288	.52	.53
	Total	15	.1205	.20788	.05368	.0053	.2356	.01	.53
NO3	Holy Child	3	.2533	.00577	.00333	.2390	.2677	.25	.26
	Afosu	3	.2240	.00173	.00100	.2197	.2283	.22	.23
	Aboabo	3	.2533	.00577	.00333	.2390	.2677	.25	.26
	Adenkyensu	3	.2567	.00577	.00333	.2423	.2710	.25	.26
	Newmont	3	.3983	.03753	.02167	.3051	.4916	.36	.42
	Total	15	.2771	.06558	.01693	.2408	.3135	.22	.42



Table DII: ANOVA FOR PHYSICOCHEMICAL

		Sum of Squares	df	Mean Square	F	Sig.
Temp	Between Groups	.503	4	.126	8.196	.003
	Within Groups	.153	10	.015		
	Total	.656	14			
DO	Between Groups	.385	4	.096	19.254	.000
	Within Groups	.050	10	.005		
	Total	.434	14			
EC	Between Groups	707187.733	4	176796.933	86.640	.000
	Within Groups	20406.000	10	2040.600		
	Total	727593.733	14			
PH	Between Groups	6.563	4	1.641	84.862	.000
	Within Groups	.193	10	.019		
	Total	6.756	14			
NH3	Between Groups	.605	4	.151	8369.489	.000
	Within Groups	.000	10	.000		
	Total	.605	14			
NO3	Between Groups	.057	4	.014	47.303	.000
	Within Groups	.003	10	.000		
	Total	.060	14			

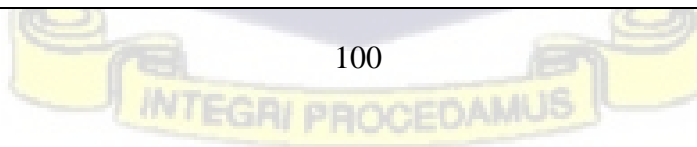
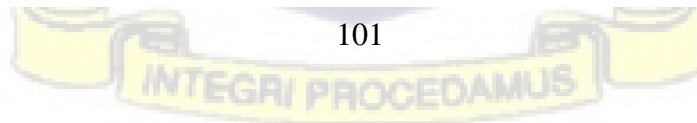


Table DIII: Multiple Comparisons for Physicochemical

Tukey HSD

Dependent Variable	(I) Physiochemical	(J) Physiochemical	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Temp	Holy Child	Afosu	.50000*	.10111	.004	.1673	.8327
		Aboabo	.40000*	.10111	.018	.0673	.7327
		Adenkyensu	.43333*	.10111	.011	.1006	.7661
		Newmont	.46667*	.10111	.007	.1339	.7994
	Afosu	Holy Child	-.50000*	.10111	.004	-.8327	-.1673
		Aboabo	-.10000	.10111	.854	-.4327	.2327
		Adenkyensu	-.06667	.10111	.961	-.3994	.2661
		Newmont	-.03333	.10111	.997	-.3661	.2994
	Aboabo	Holy Child	-.40000*	.10111	.018	-.7327	-.0673
		Afosu	.10000	.10111	.854	-.2327	.4327
		Adenkyensu	.03333	.10111	.997	-.2994	.3661
		Newmont	.06667	.10111	.961	-.2661	.3994
	Adenkyensu	Holy Child	-.43333*	.10111	.011	-.7661	-.1006
		Afosu	.06667	.10111	.961	-.2661	.3994
		Aboabo	-.03333	.10111	.997	-.3661	.2994
		Newmont	.03333	.10111	.997	-.2994	.3661



		Holy Child	-.46667*	.10111	.007	-.7994	-.1339
	Newmont	Afosu	.03333	.10111	.997	-.2994	.3661
		Aboabo	-.06667	.10111	.961	-.3994	.2661
		Adenkyensu	-.03333	.10111	.997	-.3661	.2994
		Afosu	.10333	.05770	.428	-.0866	.2932
	Holy Child	Aboabo	.13333	.05770	.218	-.0566	.3232
		Adenkyensu	.10000	.05770	.458	-.0899	.2899
		Newmont	-.30000*	.05770	.003	-.4899	-.1101
		Holy Child	-.10333	.05770	.428	-.2932	.0866
	Afosu	Aboabo	.03000	.05770	.983	-.1599	.2199
		Adenkyensu	-.00333	.05770	1.000	-.1932	.1866
		Newmont	-.40333*	.05770	.000	-.5932	-.2134
		Holy Child	-.13333	.05770	.218	-.3232	.0566
DO	Aboabo	Afosu	-.03000	.05770	.983	-.2199	.1599
		Adenkyensu	-.03333	.05770	.975	-.2232	.1566
		Newmont	-.43333*	.05770	.000	-.6232	-.2434
		Holy Child	-.10000	.05770	.458	-.2899	.0899
	Adenkyensu	Afosu	.00333	.05770	1.000	-.1866	.1932
		Aboabo	.03333	.05770	.975	-.1566	.2232
		Newmont	-.40000*	.05770	.000	-.5899	-.2101
		Holy Child	.30000*	.05770	.003	.1101	.4899
	Newmont	Afosu	.40333*	.05770	.000	.2134	.5932
		Aboabo	.43333*	.05770	.000	.2434	.6232

		Adenkyensu	.40000*	.05770	.000	.2101	.5899
		Afosu	111.33333	36.88360	.076	-10.0536	232.7203
	Holy Child	Aboabo	7.33333	36.88360	1.000	-114.0536	128.7203
		Adenkyensu	-59.33333	36.88360	.524	-180.7203	62.0536
		Newmont	-510.33333*	36.88360	.000	-631.7203	-388.9464
		Holy Child	-111.33333	36.88360	.076	-232.7203	10.0536
	Afosu	Aboabo	-104.00000	36.88360	.103	-225.3870	17.3870
		Adenkyensu	-170.66667*	36.88360	.007	-292.0536	-49.2797
		Newmont	-621.66667*	36.88360	.000	-743.0536	-500.2797
		Holy Child	-7.33333	36.88360	1.000	-128.7203	114.0536
EC	Aboabo	Afosu	104.00000	36.88360	.103	-17.3870	225.3870
		Adenkyensu	-66.66667	36.88360	.420	-188.0536	54.7203
		Newmont	-517.66667*	36.88360	.000	-639.0536	-396.2797
		Holy Child	59.33333	36.88360	.524	-62.0536	180.7203
	Adenkyensu	Afosu	170.66667*	36.88360	.007	49.2797	292.0536
		Aboabo	66.66667	36.88360	.420	-54.7203	188.0536
		Newmont	-451.00000*	36.88360	.000	-572.3870	-329.6130
		Holy Child	510.33333*	36.88360	.000	388.9464	631.7203
	Newmont	Afosu	621.66667*	36.88360	.000	500.2797	743.0536
		Aboabo	517.66667*	36.88360	.000	396.2797	639.0536
		Adenkyensu	451.00000*	36.88360	.000	329.6130	572.3870
PH	Holy Child	Afosu	-.16667	.11353	.603	-.5403	.2070
		Aboabo	-1.23333*	.11353	.000	-1.6070	-.8597

	Adenkyensu	-.96667*	.11353	.000	-1.3403	-.5930
	Newmont	-1.76667*	.11353	.000	-2.1403	-1.3930
	Holy Child	.16667	.11353	.603	-.2070	.5403
Afosu	Aboabo	-1.06667*	.11353	.000	-1.4403	-.6930
	Adenkyensu	-.80000*	.11353	.000	-1.1736	-.4264
	Newmont	-1.60000*	.11353	.000	-1.9736	-1.2264
	Holy Child	1.23333*	.11353	.000	.8597	1.6070
Aboabo	Afosu	1.06667*	.11353	.000	.6930	1.4403
	Adenkyensu	.26667	.11353	.207	-.1070	.6403
	Newmont	-.53333*	.11353	.006	-.9070	-.1597
	Holy Child	.96667*	.11353	.000	.5930	1.3403
Adenkyensu	Afosu	.80000*	.11353	.000	.4264	1.1736
	Aboabo	-.26667	.11353	.207	-.6403	.1070
	Newmont	-.80000*	.11353	.000	-1.1736	-.4264
	Holy Child	1.76667*	.11353	.000	1.3930	2.1403
Newmont	Afosu	1.60000*	.11353	.000	1.2264	1.9736
	Aboabo	.53333*	.11353	.006	.1597	.9070
	Adenkyensu	.80000*	.11353	.000	.4264	1.1736
NH3	Afosu	-.00133	.00347	.995	-.0128	.0101
	Aboabo	-.02367*	.00347	.000	-.0351	-.0122
	Adenkyensu	-.01700*	.00347	.004	-.0284	-.0056
	Newmont	-.51200*	.00347	.000	-.5234	-.5006
Afosu	Holy Child	.00133	.00347	.995	-.0101	.0128



	Aboabo	-.02233*	.00347	.001	-.0338	-.0109
	Adenkyensu	-.01567*	.00347	.008	-.0271	-.0042
	Newmont	-.51067*	.00347	.000	-.5221	-.4992
	Holy Child	.02367*	.00347	.000	.0122	.0351
Aboabo	Afosu	.02233*	.00347	.001	.0109	.0338
	Adenkyensu	.00667	.00347	.366	-.0048	.0181
	Newmont	-.48833*	.00347	.000	-.4998	-.4769
	Holy Child	.01700*	.00347	.004	.0056	.0284
Adenkyensu	Afosu	.01567*	.00347	.008	.0042	.0271
	Aboabo	-.00667	.00347	.366	-.0181	.0048
	Newmont	-.49500*	.00347	.000	-.5064	-.4836
	Holy Child	.51200*	.00347	.000	.5006	.5234
Newmont	Afosu	.51067*	.00347	.000	.4992	.5221
	Aboabo	.48833*	.00347	.000	.4769	.4998
	Adenkyensu	.49500*	.00347	.000	.4836	.5064
	Afosu	.02933	.01420	.304	-.0174	.0761
Holy Child	Aboabo	.00000	.01420	1.000	-.0467	.0467
	Adenkyensu	-.00333	.01420	.999	-.0501	.0434
NO3	Newmont	-.14500*	.01420	.000	-.1917	-.0983
	Holy Child	-.02933	.01420	.304	-.0761	.0174
Afosu	Aboabo	-.02933	.01420	.304	-.0761	.0174
	Adenkyensu	-.03267	.01420	.221	-.0794	.0141



	Newmont	-.17433*	.01420	.000	-.2211	-.1276
	Holy Child	.00000	.01420	1.000	-.0467	.0467
Aboabo	Afosu	.02933	.01420	.304	-.0174	.0761
	Adenkyensu	-.00333	.01420	.999	-.0501	.0434
	Newmont	-.14500*	.01420	.000	-.1917	-.0983
	Holy Child	.00333	.01420	.999	-.0434	.0501
Adenkyensu	Afosu	.03267	.01420	.221	-.0141	.0794
	Aboabo	.00333	.01420	.999	-.0434	.0501
	Newmont	-.14167*	.01420	.000	-.1884	-.0949
	Holy Child	.14500*	.01420	.000	.0983	.1917
Newmont	Afosu	.17433*	.01420	.000	.1276	.2211
	Aboabo	.14500*	.01420	.000	.0983	.1917
	Adenkyensu	.14167*	.01420	.000	.0949	.1884

*. The mean difference is significant at the 0.05 level.



APPENDIX E: HEAVY METALS

Table EI: Descriptive Statistics for Heavy Metals

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	
					Lower Bound	Upper Bound			
Cu	Holy Child	4	.0073	.00096	.00048	.0057	.0088	.01	.01
	Afosu	4	.0133	.00171	.00085	.0105	.0160	.01	.02
	Aboabo	4	.0063	.00330	.00165	.0010	.0115	.00	.01
	Adenkyensu	4	.0093	.00096	.00048	.0077	.0108	.01	.01
	Newmont	4	.0168	.00789	.00394	.0042	.0293	.01	.03
	Total	20	.0106	.00534	.00119	.0081	.0130	.00	.03
Fe	Holy Child	4	.0295	.00985	.00492	.0138	.0452	.02	.04
	Afosu	4	.0193	.01576	.00788	-.0058	.0443	.00	.04
	Aboabo	4	.0292	.00222	.00111	.0257	.0328	.03	.03
	Adenkyensu	4	.0195	.00574	.00287	.0104	.0286	.02	.03
	Newmont	4	.0425	.00500	.00250	.0345	.0505	.04	.05
	Total	20	.0280	.01187	.00265	.0224	.0336	.00	.05
Zn	Holy Child	4	.9045	.05968	.02984	.8095	.9995	.86	.99

	Afosu	4	.2423	.10433	.05217	.0762	.4083	.09	.31
	Aboabo	4	.0890	.00779	.00389	.0766	.1014	.08	.10
	Adenkyensu	4	.0808	.00763	.00382	.0686	.0929	.07	.09
	Newmont	4	.9282	.05524	.02762	.8403	1.0162	.88	1.00
	Total	20	.4489	.39956	.08934	.2620	.6359	.07	1.00
	Holy Child	4	.0080	.00082	.00041	.0067	.0093	.01	.01
Cr	Afosu	4	.0052	.00313	.00156	.0002	.0102	.00	.01
	Aboabo	4	.0055	.00238	.00119	.0017	.0093	.00	.01
	Adenkyensu	4	.0078	.00096	.00048	.0062	.0093	.01	.01
	Newmont	4	.0142	.00854	.00427	.0007	.0278	.01	.03
	Total	20	.0081	.00504	.00113	.0058	.0105	.00	.03
	Holy Child	4	.1033	.01884	.00942	.0733	.1332	.08	.12
Mn	Afosu	4	.1055	.02158	.01079	.0712	.1398	.09	.14
	Aboabo	4	.0198	.00450	.00225	.0126	.0269	.01	.03
	Adenkyensu	4	.0268	.02934	.01467	-.0199	.0734	.01	.07
	Newmont	4	.0705	.01658	.00829	.0441	.0969	.06	.09



Total **20** **.0652** **.04136** **.00925** **.0458** **.0845** **.01** **.14**

Table EII: ANOVA FOR HEAVY METALS

		Sum of Squares	df	Mean Square	F	Sig.
Cu	Between Groups	.000	4	.000	4.928	.010
	Within Groups	.000	15	.000		
	Total	.001	19			
Fe	Between Groups	.001	4	.000	4.445	.014
	Within Groups	.001	15	.000		
	Total	.003	19			
Zn	Between Groups	2.980	4	.745	211.467	.000
	Within Groups	.053	15	.004		
	Total	3.033	19			
Cr	Between Groups	.000	4	.000	2.961	.055
	Within Groups	.000	15	.000		
	Total	.000	19			
Mn	Between Groups	.027	4	.007	16.806	.000
	Within Groups	.006	15	.000		
	Total	.033	19			

Table EIII: Multiple Comparisons for Heavy Metals

Tukey HSD

Dependent Variable	(I) Heavy Metals	(J) Heavy Metals	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Cu	Holy Child	Afosu	-.00600	.00279	.251	-.0146	.0026
		Aboabo	.00100	.00279	.996	-.0076	.0096
		Adenkyensu	-.00200	.00279	.949	-.0106	.0066
		Newmont	-.00950*	.00279	.028	-.0181	-.0009
	Afosu	Holy Child	.00600	.00279	.251	-.0026	.0146
		Aboabo	.00700	.00279	.141	-.0016	.0156
		Adenkyensu	.00400	.00279	.617	-.0046	.0126
		Newmont	-.00350	.00279	.722	-.0121	.0051
	Aboabo	Holy Child	-.00100	.00279	.996	-.0096	.0076
		Afosu	-.00700	.00279	.141	-.0156	.0016
		Adenkyensu	-.00300	.00279	.816	-.0116	.0056
		Newmont	-.01050*	.00279	.014	-.0191	-.0019
	Adenkyensu	Holy Child	.00200	.00279	.949	-.0066	.0106
		Afosu	-.00400	.00279	.617	-.0126	.0046

	Aboabo	.00300	.00279	.816	-.0056	.0116
	Newmont	-.00750	.00279	.104	-.0161	.0011
	Holy Child	.00950*	.00279	.028	.0009	.0181
Newmont	Afosu	.00350	.00279	.722	-.0051	.0121
	Aboabo	.01050*	.00279	.014	.0019	.0191
Holy Child	Adenkyensu	.00750	.00279	.104	-.0011	.0161
	Afosu	.01025	.00639	.517	-.0095	.0300
	Aboabo	.00025	.00639	1.000	-.0195	.0200
	Adenkyensu	.01000	.00639	.539	-.0097	.0297
Afosu	Newmont	-.01300	.00639	.297	-.0327	.0067
	Holy Child	-.01025	.00639	.517	-.0300	.0095
	Aboabo	-.01000	.00639	.539	-.0297	.0097
	Adenkyensu	-.00025	.00639	1.000	-.0200	.0195
Fe	Newmont	-.02325*	.00639	.018	-.0430	-.0035
	Holy Child	-.00025	.00639	1.000	-.0200	.0195
	Afosu	.01000	.00639	.539	-.0097	.0297
	Aboabo	.00975	.00639	.562	-.0100	.0295
Adenkyensu	Newmont	-.01325	.00639	.281	-.0330	.0065
	Holy Child	-.01000	.00639	.539	-.0297	.0097
	Afosu	.00025	.00639	1.000	-.0195	.0200
	Aboabo	-.00975	.00639	.562	-.0295	.0100
Newmont	Newmont	-.02300*	.00639	.019	-.0427	-.0033
	Holy Child	.01300	.00639	.297	-.0067	.0327

	Afosu	.02325*	.00639	.018	.0035	.0430
	Aboabo	.01325	.00639	.281	-.0065	.0330
	Adenkyensu	.02300*	.00639	.019	.0033	.0427
Holy Child	Afosu	.66225*	.04197	.000	.5326	.7919
	Aboabo	.81550*	.04197	.000	.6859	.9451
	Adenkyensu	.82375*	.04197	.000	.6941	.9534
	Newmont	-.02375	.04197	.978	-.1534	.1059
Afosu	Holy Child	-.66225*	.04197	.000	-.7919	-.5326
	Aboabo	.15325*	.04197	.017	.0236	.2829
	Adenkyensu	.16150*	.04197	.012	.0319	.2911
	Newmont	-.68600*	.04197	.000	-.8156	-.5564
Aboabo	Holy Child	-.81550*	.04197	.000	-.9451	-.6859
	Afosu	-.15325*	.04197	.017	-.2829	-.0236
	Adenkyensu	.00825	.04197	1.000	-.1214	.1379
	Newmont	-.83925*	.04197	.000	-.9689	-.7096
Adenkyensu	Holy Child	-.82375*	.04197	.000	-.9534	-.6941
	Afosu	-.16150*	.04197	.012	-.2911	-.0319
	Aboabo	-.00825	.04197	1.000	-.1379	.1214
	Newmont	-.84750*	.04197	.000	-.9771	-.7179
Newmont	Holy Child	.02375	.04197	.978	-.1059	.1534
	Afosu	.68600*	.04197	.000	.5564	.8156
	Aboabo	.83925*	.04197	.000	.7096	.9689
	Adenkyensu	.84750*	.04197	.000	.7179	.9771

		Afosu	.00283	.00300	.876	-.0064	.0121
	Holy Child	Aboabo	.00250	.00300	.916	-.0068	.0118
		Adenkyensu	.00025	.00300	1.000	-.0090	.0095
		Newmont	-.00625	.00300	.277	-.0155	.0030
		Holy Child	-.00283	.00300	.876	-.0121	.0064
	Afosu	Aboabo	-.00032	.00300	1.000	-.0096	.0089
		Adenkyensu	-.00258	.00300	.907	-.0118	.0067
		Newmont	-.00908	.00300	.056	-.0183	.0002
		Holy Child	-.00250	.00300	.916	-.0118	.0068
Cr	Aboabo	Afosu	.00032	.00300	1.000	-.0089	.0096
		Adenkyensu	-.00225	.00300	.941	-.0115	.0070
		Newmont	-.00875	.00300	.068	-.0180	.0005
		Holy Child	-.00025	.00300	1.000	-.0095	.0090
	Adenkyensu	Afosu	.00258	.00300	.907	-.0067	.0118
		Aboabo	.00225	.00300	.941	-.0070	.0115
		Newmont	-.00650	.00300	.244	-.0158	.0028
		Holy Child	.00625	.00300	.277	-.0030	.0155
	Newmont	Afosu	.00908	.00300	.056	-.0002	.0183
		Aboabo	.00875	.00300	.068	-.0005	.0180
		Adenkyensu	.00650	.00300	.244	-.0028	.0158
		Afosu	-.00225	.01406	1.000	-.0457	.0412
Mn	Holy Child	Aboabo	.08350*	.01406	.000	.0401	.1269
		Adenkyensu	.07650*	.01406	.001	.0331	.1199

	Newmont	.03275	.01406	.189	-.0107	.0762
	Holy Child	.00225	.01406	1.000	-.0412	.0457
Afosu	Aboabo	.08575*	.01406	.000	.0423	.1292
	Adenkyensu	.07875*	.01406	.000	.0353	.1222
	Newmont	.03500	.01406	.145	-.0084	.0784
	Holy Child	-.08350*	.01406	.000	-.1269	-.0401
Aboabo	Afosu	-.08575*	.01406	.000	-.1292	-.0423
	Adenkyensu	-.00700	.01406	.986	-.0504	.0364
	Newmont	-.05075*	.01406	.019	-.0942	-.0073
	Holy Child	-.07650*	.01406	.001	-.1199	-.0331
Adenkyensu	Afosu	-.07875*	.01406	.000	-.1222	-.0353
	Aboabo	.00700	.01406	.986	-.0364	.0504
	Newmont	-.04375*	.01406	.048	-.0872	-.0003
	Holy Child	-.03275	.01406	.189	-.0762	.0107
Newmont	Afosu	-.03500	.01406	.145	-.0784	.0084
	Aboabo	.05075*	.01406	.019	.0073	.0942
	Adenkyensu	.04375*	.01406	.048	.0003	.0872

*. The mean difference is significant at the 0.05 level.



APPENDIX F

Evaluation of water quality of study area based on modified categories for Cd and HPI

Index Method	Class	Description
Cd	<20	Low
	20 – 40	Medium
	>40	High
HPI	<15	Low
	15 – 30	Medium
	>30	High

