CADMIUM AND LEAD CONCENTRATION IN RICE GRAIN, WATER AND SOIL FROM THE ANUM VALLEY IRRIGATION PROJECT AT NOBEWAM

BY

JAMES KOJO FENYI FORSON

(BSc. AGRICULTURAL ENGINEERING, KUMASI)

A Thesis submitted to the Department of Agricultural Engineering, Kwame Nkrumah University of Science and Technology in partial fulfillment of the requirement for the degree of MASTER OF SCIENCE IN SOIL AND WATER ENGINEERING

FACULTY OF MECHANICAL AND AGRICULTURAL ENGINEERING

COLLEGE OF ENGINEERING

JUNE 2009

DECLARATION

I hereby declare to the best of my knowledge that this work has not been accepted in any previous application for a degree here or elsewhere. This thesis is original and has been done by myself except where specifically and duly acknowledged. All sources of information and related literature have been acknowledged by means of referencing.

James Kojo Fenyi Forson Signature ……………… Date 27th March, 2009

CERTIFIED BY

Prof. N. Kyei-Baffour Signature ……………… Date 27th March, 2009

(Supervisor)

Dr. Emmanuel Ofori Signature ………………… Date 27th March, 2009

(Supervisor)

CERTIFIED BY

Mr. Ato Bart Plange Signature ……………… Date 27th March, 2009

(Head of Department)

ACKNOWLEDGEMENTS

I am eternally grateful to my Senior partner, the Holy Spirit for His love, wisdom, help, protection and guidance throughout my life.

My sincere gratitude goes to my supervisors, Professor Nicholas Kyei-Baffour and Dr. Emmanuel Ofori for their corrections and suggestions leading to the successful completion of this research.

I am highly indebted to my family for their love, prayer and financial support.

I am also grateful to Mr. Felix Botir of Anum Valley Irrigation Project for his immerse support throughout the reconnaissance visits, sampling collections and the administration of questionnaires.

I want to extend my sincere thanks to Dr. Shiloh Osai and Mr. Dogbe of Ghana Atomic Energy Commission, Kwabenya-Accra. In addition, I am very much grateful to Uncle Onash, Julian, Mba, John, Adishetu, Mr. Opata and Augustine for their love and selfless laboratory assistance throughout my laboratory work at Ghana Atomic Energy Commission. I say God richly bless you all.

I wish to acknowledge Pastor and Mrs. Rita Adanuvo and all the members of the student chapel of Miracle Life Gospel Church for their love and prayer support.

I am especially grateful to Mr. David Adei, the caretaker of Kwakyewaa hostel at kotei.

My sincere gratitude also goes to all those who have been with me and supported me in every area of my life throughout my postgraduate education.

Finally to my best friend Eugenia for your encouragement, counsel and love.

ABSTRACT

The Anum Valley Rice Project which is one of the 22 active rice irrigation projects in Ghana. The Oweri and Anum rivers are the two main sources of water for this project. However, wastewater from the Mechanic shops, *"Galamsey"* sites and Ghana Water Company Limited are discharged into both the Oweri and Anum rivers, which are in turned used to irrigate the rice. The main objective of the study was to determine the levels of cadmium and lead concentrations in the rice grains, irrigation water and soil samples. Also, the irrigation water quality parameters like the electrical conductivity, temperature and pH were determined. The levels of these heavy metals (Cd and Pb) and irrigation water quality were compared with those of WHO/FAO recommended values. At the end of the water quality analysis the electrical conductivity (EC) values of the irrigation water ranged from 17.34 to113.6 dS/m as against the WHO/FAO recommended value of 3.0 dS/m. The pH values of the water ranged between 1.1 and 1.7 as against the WHO/FAO recommended value range of 6.5-8.4. Again, all the values were outside FAO/WHO recommended limit. Cadmium values in the water samples ranged from <0.002 to 0.063 mg/l as against the WHO/FAO recommended value of 0.01 mg/l. All the samples exceeded the FAO/WHO recommended limit with the exception of only three samples which were within the limit. Lead values in the water samples were from <0.01 to 0.372 mg/l as against the WHO/FAO recommended value of 5 mg/l. All the samples were within the FAO/WHO recommended limit.

At the end of the rice grain samples analysis, cadmium levels in the rice grain recorded ranged between <0.002 mg/kg and 0.80 mg/kg as against the WHO/FAO recommended value of 0.5 mg/kg. All the rice grain samples were within the recommended value with the exception of two samples whose values exceeded the WHO value. Lead values in the rice grain ranged between <0.01 and 5.25 mg/kg as against the WHO/FAO recommended value of 3 mg/kg. All the rice grain samples were within the recommended value with the exception of three samples whose values exceeded the WHO/FAO limit.

Cadmium values in the soil samples were between 0.03 mg/kg and 0.47 mg/kg as against the WHO/FAO recommended value of 3 mg/kg. All the samples were within the FAO/WHO recommended limit. Lead values were between <0.01 and 1.74 mg/kg as against the WHO/FAO recommended value of 300 mg/kg. Also, all the samples were within the FAO/WHO recommended limit. The transfer factor values for both heavy metals in the rice grain were high giving a cause for concern for consumers.

TABLE OF CONTENTS

Page **No.**

CHAPTER TWO : LITERATURE REVIEW

CHAPTER THREE : MATERIALS AND METHODS

CHAPTER FOUR: RESULTS AND DISCUSSION

CHAPTER FIVE : CONCLUSION AND RECOMMENDATION

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

W.H.O - World Health Organisation

F.A.O - Food and Agricultural Organisation of the United Nations

ATSDR - Agency for Toxic Substances and Disease Registry

CHAPTER ONE

1.1 Introduction

A variety of environmental problems have emerged in modern times of which potentially toxic metal pollution is a major issue, especially in urban soils and roadside dust (Madrid *et al.*, 2002; Han *et al.*, 2006; Shi *et al.*, 2007)

Heavy metals are found ubiquitously in both polluted and unpolluted soils. Although these heavy metals occur naturally in the Earth's crust, they tend to be concentrated in agricultural soil because of irrational application of commercial fertilisers, manures and sewage sludge containing heavy metals and of contamination caused by mining and industry (Gimeno-García *et al*., 1996; Grant *et al.*, 1998; McLaughlin *et al.*, 1999; Cheng, *et al* 2006). All heavy metals are toxic at higher concentrations (Marschner, 1995; McLaughlin *et al*., 1999; Cheng, *et al* 2006).

According to various chronic low level intakes of heavy metals such as Lead (Pb), Cadmium (Cd), Mercury (Hg) and Copper (Cu) are cumulative poisons. These metals cause environmental hazards and are reported to be exceptionally toxic.

Some toxic metals, such as Pb, Cr and Cd, will continue to accumulate in urban environments due to their non-biodegradability and long residence time; thus they are also known as 'chemical time bombs' (Stigliani *et al.*, 1991,). In urban areas, these 'bombs' have become a potential threat to human health and safety and severely disturbed the natural geochemical cycling of the ecosystem. Furthermore, metals have a direct influence on public health as they can easily enter the human bodies by dust ingestion, dermal contact or breathing (Abrahams, 2002). In particular, children are more susceptible to a given dose of toxins and likely to ingest inadvertently significant quantities of soil or dust by hand or finger sucking, which has been widely regarded as one of the key pathways of exposure to metals by children (Mielke *et al*., 1999) and [Rasmussen *et al.*, 2001]; Shi *et al*, 2007). Lots of studies have indicated that metals could accumulate in the fatty tissues, subsequently affect the functions of the organs, and disrupt the nervous system or endocrine system ([Waisberg *et al*., 2003] and [Bocca *et al*., 2004]; Shi *et al*, 2007). Therefore, potentially toxic metal pollution in urban environment has given rise to growing concerns from scientists in the past decades, and a large amount of researches have been done all over the world ([Fergusson and Ryan, 1984], [Kelly *et al*., 1996], [Murray *et al*., 2004] and [Möller *et al*., 2005]; Shi *et al*, 2007).

1.2 Background of Study Area

Agriculture plays a vital role in the Ghanaian economy but it is predominantly dependent on natural rainfall. Irrigated agriculture on a fairly limited scale is a recent phenomenon and was necessitated largely by the seasonality and unreliability of natural rainfall (Kyei-Baffour and Ofori, 2006). The important cereals produced in Ghana are maize, rice, sorghum and millet. At the national level cereals and cereal products come only second to roots and tubers and account for 14.1% of total consumption of home produced food. In terms of cash expenditures, cereals and cereal products account for 15% of household food consumption. In the latest living standard measurement survey, 2.4 million out of an estimated 2.7 million households were engaged in harvesting staple grains and cash crops in 1999, and 13% of the households harvested rice (Al-hassan and Jatoe, 2002).

Anum Valley Irrigation Project is one of the rice projects which were set up to supplement the lack of rice in the system due to the high growing demand for rice in the country.

The Anum Valley Irrigation Project is located along the main Accra-Kumasi Highway and is about 217 km from Accra the capital City of Ghana. The Project which is one of the twenty-two public irrigation projects in the country was designed and constructed by the China National Complete Plant Export Cooperation between May 1990 and April 1992 with funds provided by the Government of the People's Republic of China (Anum Valley Project Report, 2006).

Another objective of the Anum Valley Irrigation Project was for community farming to help small scale rice farmers at Nobewam in the Ejisu Juaben District of the Ashanti Region to increase their productivity and livelihoods. There was an initial farmer population of 150 but now only 55 farmers including 17 females are actively in the farming business with a management team of 5 (Anum Valley Report, 1999).

The project has a total land area of 140 hectares and is divided into two areas. The first area, Area A has a net land area of 40 hectares while Area B has a net of 100 hectares. Two rivers serve the project; the Anum river from which the project derives its name serves area A while it's tributary, Oweri river, serves Area B. The Oweri river, which forms an important livelihood in the form of drinking water and bathing for the surrounding villages, has effluent from Konongo mines and "*Galamsey*" activities flowing directly into it. The Oweri finally joins the Anum river at Area A (Personal communication, 2007).

At the irrigation sites, there is the likelihood of heavy metal contamination of the irrigation water and soil from agrochemicals, fertilisers and wastewater from the surrounding towns and villages.

Crops produced from these areas may be contaminated by these heavy metals from the soils and water from the rivers. Besides, the presence of high concentration of heavy metals which is likely to be present in the soils at the irrigation sites might be readily available to the rice grown in these sites.

With regard to this research, the presence of lead and cadmium heavy metals which are hazardous to human health if bioaccumulated are likely to be present in the irrigation water, soils and the rice grain was investigated.

1.3 Problem Statement

Heavy metal contamination is one of the serious environmental problems limiting plant productivity and threatening human health (Luptaka *et al* 2002; Verma and Dubey,2003; Kadukova *et al* 2006). Inputs of heavy metals to agricultural soils can occur from a variety of sources. These include the application of biosolids, fertilisers, livestock manure, agrochemicals, irrigation water and from atmospheric deposition. Some of the concerns about accumulation of heavy metals in agricultural soils stem from their possible negative impacts on soil fertility and in some cases their potential to accumulate in the human chain (McLaugh *et al*.,1999; Gray *et al*., 2003). Among the substances that contribute anthropogenically to pollution of the biosphere, trace elements are the most toxic. Lead and Cadmium are toxic metals of increasing environmental concern as they enter the food chain in significant amounts (Luptaka et al 2002; Verma and Dubey, 2003; Kadukova et al 2006).

Currently, the main source of irrigation water at Anum Valley Irrigation Project is the Anum and Oweri rivers. These rivers contain effluents from "Galamsey" sites, Ghana Water Company Limited and Auto-Mechanic workshops. Farm inputs like fertilisers are also used in the production of rice and all these might contain Cd and Pb metals for rice plant uptake on the farms. There is therefore the need for studies to establish the level of these metals in the rice grain, irrigation water and soil on these farms.

1.4 Objectives

The main objective of the study was to determine the accumulation of lead and cadmium in the environment and rice grain produced from the project site.

In order to achieve the main objective, the following specific objectives were pursued:

- To evaluate the quality of the irrigation water
- To determine the concentration of lead and cadmium in the rice grain, soil and irrigation water
- To compare the values with FAO/WHO permissible levels and
- To determine the extent of heavy metal uptake from the sites by calculating the transfer factor

1.5 Justification of Study

According to Cornish *et al*, (1999) trace quantities of many metals such as Cadmium, Chromium, Copper, Iron, Lead, Manganese, Mercury, Nickel and Zinc are important constituents of most water bodies. However, the presence of any of these metals in excessive quantities will interfere with many beneficial uses of water because of their toxicity.

The problem of environmental pollution due to toxic metals is a major issue in most urban communities because of their effects on human health. Food chain contamination by heavy metals has become a major issue in recent years because of their potential accumulation in biological systems through contaminated water, soil and air. Lead and Cadmium have been identified as part of heavy metals posing a threat to soil quality and human health (Amfo-Out, 2007).

Generally, Cadmium and Lead accumulate in the soil can be taken up by the rice since the rice produced in these areas is consumed by the public and it is important for us to establish the heavy metal (Cd and Pb) concentrations in rice since the farmers in rice production locally use these two rivers (Anum and Oweri) as their source of water for irrigation.

1.6 Limitations of the study

The entire research was conducted in the dry season. Thus, the results may likely be biased towards the dry season. Also, the short duration of the study period coupled with limited resources forced only one time sampling for the water quality measurements and analysis. This might limit the accuracy of the results.

1.7 Method of Investigation

Data would be collected in two main ways; primary and secondary.

1.7.1 Primary data collection

The primary data that was used in this research was collected through different quantitative and qualitative methods**.** The data was obtained from the field through surveys of the project site, towns, field observations and administration of questionnaires and personal interviews.

1.7.1.2 Field observation

Field surveys were made in order to get the visual impression of the research problem, to really ascertain the kind of activities going on in these areas and also to validate the information obtained from the survey.

1.7.1.3 Questionnaires administration

A structured questionnaire, which consisted of both open-ended and closed-ended questions would be administered in each of the selected areas. The questionnaire was designed by the use of the information gathered from the reconnaissance survey and review of relevant literature related to the topic.

1.7.1.4 Sampling and Analysis

Samples of rice grain, water and soil were collected from the selected areas for analysis at the laboratory.

1.7.1.5 Comparison

The results obtained from the analysis of the samples were compared to the WHO/FAO recommended limits. Findings were reported.

1.7.2 Secondary data collection

Data from secondary sources was collected through a review of existing literature by the use of the internet, and published books and journals. Existing reports about the topic and interviews with experts were also used to enhance the research.

1.7.2.1 Data analysis

Data collected was analysed quantitatively.

1.7.2.2 Quantitative analysis

The quantitative analysis involved the use of the Statistical Package for the Social Sciences (SPSS) and Microsoft Excel for the processing and analysing of the information that was obtained through the surveys.

1.8 Organisation of the Research

The research is organised in five chapters. The first chapter is an introduction, where the background of study area, the problem statement, objectives, justification of study and limitations of the study are stated. Chapter Two is dedicated to the review of relevant literature. The methodology of the study is presented in Chapter Three. It involves the sample selection, data collection and analysis. Chapter Four presents the field results and discusses the outcome of the analysis. These results are discussed in relation to the literature reviewed. Chapter Five is the concluding section of the report. It also contains recommendations for implementation. After this chapter is the references section. And the last but not the least is the Appendices.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, the various aspect of the topic under study are introduced. Water quality is defined together with a review on some irrigation water parameters which are useful in this research. The reviews also covers other aspects like wastewater, types of wastewater, wastewater in agriculture, trace metal concentrations in agricultural soils, essential and non-essential metals in plants, chemistry, sources, contamination and toxicity of Lead and Cadmium heavy metals in human beings and plants, their modes of transport and uptake from soils and their effect on plants is also analysed.

2.2 Definition of Water Quality

The term "water quality" is a widely used term, which has an extremely broad spectrum of meaning. Each individual has vested interests in water for a particular use, which may involve commercial and industrial uses or recreational pursuits (Mensah, 2002).

Water quality is the physical, chemical and biological characteristics of water in relationship to a set of standards (Wikipedia, 2006). Also, according to Google (2007) water quality is constituent concentrations based on scientific data and judgments on the relationship between pollutant concentrations and environmental and human health effects.

2.3 Irrigation Water Quality

Important agricultural water quality parameters include a number of specific properties of water that are relevant in relation to the yield and quality of crops, maintenance of soil productivity and protection of the environment. These parameters mainly consist of certain physical and chemical characteristics of the water (FAO, 1992). Some primary wastewater quality parameters of importance from an agricultural viewpoint are pH, Electrical Conductivity and Temperature.

2.3.1 pH

pH is an indicator of the acidity or basicity of water. The normal pH range for irrigation water is from 6.5 to 8.4; pH values outside this range are a good warning that the water is not good for irrigation purposes. Normally, pH is a routine measurement in irrigation water quality assessment (FAO, 1992). Low pH in water is caused by acids, acid-generated salts, and dissolved carbon dioxide. High pH is from carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates (Thomas, 2009). FAO (1992) stated that for irrigation purposes, the permissible pH limit for irrigation water is 6.5-8.4.

2.3.2 Electrical Conductivity

Electrical conductivity (EC), also called salinity, arises from weathering of rocks and soils. Saltwater intrusion into water supplies located near coastal areas also may contribute to electrical conductivity (Thomas, 2009). According to FAO (1992), electrical conductivity is widely used to indicate the total ionised constituents of water. It is directly related to the sum of the cations (or anions), as determined chemically and is closely correlated, in general, with the total salt concentration. Electrical conductivity is a rapid and reasonably precise determination and values are always expressed at a standard temperature of 25°C to enable comparison of readings taken under varying climatic conditions. It should be noted that the electrical conductivity of solutions increases approximately 2 % per °C increase in temperature. Bauder *et al* (2008) stated that the primary effect of high EC_w water on crop productivity is the inability of the plants to compete with ions in the soil solution for water (physiological drought). The higher the EC_w, the less water is available to plants, even though the soil may appear wet. Because plants can only transpire "pure" water, usable plant water in the soil solution decreases dramatically as EC increases.The symbol ECw, is used to represent the electrical conductivity of irrigation water. The unit of electrical conductivity is deciSiemen per metre (dS/m) or millimhos per centimeter (mmhos/cm) and may be converted into total dissolved-salt concentration by multiplying mmhos/cm by 640 or 700. For irrigation purposes, FAO permissible limit for the irrigation water should not be more than 3.0 dS/m (FAO, 1992).

2.3.3 Temperature

According to Wikipedia (2007) temperature is a physical property of a system that underlies the common notions of hot and cold; something that feels hotter generally has the higher temperature. Temperature is one of the principal parameters of thermodynamics. On the macroscopic scale, temperature is the unique physical property that determines the direction of heat flow between two objects placed in thermal contact. If no heat flow occurs, the two objects have the same temperature; otherwise heat flows from the hotter object to the colder object. The unit for temperature is degrees Celsius (˚C) and Kelvin (K).

2.4 Wastewater

Waste water is sewage or stormwater or water that has been used for various purposes around the community. Unless properly treated, wastewater can harm public health and the environment. Most communities generate wastewater from both residential and non-residential sources (NSFC, 1997).

2.4.1 Residential Wastewater

Although the word sewage usually brings toilets to mind, it is actually used to describe all types of wastewater generated from every room in a house. There are two types of domestic sewage: blackwater, or wastewater from toilets, and graywater, which is wastewater from all sources except toilets (NSFC, 1997).

2.4.2 Non-Residential Wastewater

Because of the variety of non-residential wastewater characteristics, communities need to assess each source individually or compare similar types of non-residential sources to ensure that adequate treatment is provided. Non-residential wastewater in small communities is generated by such diverse sources as offices, business, department stores, restaurants, schools, hospitals, farms, manufacturers, and other commercial, industrial, and institutional entities. Stormwater is a non-residential source and carries trash and other pollutants from streets, as well as pesticides and fertilisers from yards and fields (NSCF, 1997).

Manufacturing and service industries have high demands for cooling water, processing water and water for cleaning purposes. Modern economic activity requires transportation and storage of materials used in manufacturing, processing, and construction. Along the line, some of the material can be lost through spillage, leakage, or improper handling (LENNTECH, 2008).

According to Agodzo *et al* 2003, industrial wastewater in Ghana is discharged from the breweries and industries such as the textiles, mining, chemicals and pharmaceutical industries. These liquid wastes are usually discharged into drains without any pre-treatment. Organic waste includes pesticide residue, solvent and cleaning fluids, dissolved residue from fruit and vegetable and aligning from pulp and paper to name a few. Effluent can also contain inorganic waste such as brine salts and metals.

2.5 Wastewater in Agriculture

According to Bjuhr (2007) irrigation of arable land represents a significant fraction of the total demand for fresh water. Wastewater used for irrigation is essential in many countries. Worldwide, it is estimated that 20 million hectares of arable land are irrigated with waste water. Waste water reuse in agriculture is an alternative to treatments aimed at achieving the strict standards for waste water disposal into watercourses. Waste water irrigation saves freshwater which is particularly important in areas suffering from water shortage. Farmers generally do not consider environmental benefits or hazards and are foremost interested in maximising their yields and profits. Waste water is a valuable resource. It allows low-income farmers to produce crops they otherwise would not afford to grow. It is also a reliable resource of water, even during dry seasons and contains valuable nutrients for the crops. The high nutrient content may improve the yield and lead to significant savings on costly mineral fertilizers. However, there are health risks to consider both for farmers and consumers. Direct contact with the untreated waste water exposes farmers to pathogens, viruses and bacteria, as well as toxic elements. Bacteria and toxic elements can also be transmitted to crops which in turn might harm consumers. Since several trace metals are toxic even at rather low concentrations, their accumulation in agricultural soils may affect the microbial activity as well as plant growth and plant quality.

2.5.1 Accumulation in Soils

As a result of the use of wastewater for irrigation, trace metals have accumulated in agricultural soils. The connection between soil and water contamination and metal uptake by plants is determined by many chemical and physical soil factors as well as the physiological properties of the crops. Soils contaminated with trace metals may pose both direct and indirect threats to plants: Direct, through negative effects of metals on crop growth and yield, and indirect, by entering the human food chain with a potentially negative impact on human health. Even a reduction of crop yield by a few percent could lead to a significant long-term loss in production and income. Some food importers are now specifying acceptable maximum contents of metals in food, which might limit the possibility for the farmers to export their contaminated crops.

Therefore the protection of soils from trace metal pollution is essential for maintaining a good soil and food quality. Once soil is contaminated, it is difficult and expensive to decontaminate it (Bjuhr, 2007).

2.5.2 Trace Metal Concentrations in Agricultural Soils

The total metal content **(Mtot)** in the soil is the difference between all inputs and outputs. Input sources are weathering of parent material **(Mp)**, atmospheric deposition **(Mad),** fertilisers **(Mf),** pesticides **(Mpe)**, organic wastes **(Mow)** and inorganic pollutants **(Mip)**. Outputs are removal of crops **(Mcr)**, leaching **(Ml)** and volatilisation **(Mv).** The main input and output source of metals in this study is probably waste water **(in)** and crop up-take **(out)** respectively. The total metal content in the soil can thus be expressed by the following equation**:**

$$\mathbf{Mtot = (Mp + Mad + Mf + Mpe + Mow + Mip) - (Mcr + Ml + Mv).}$$

The equation covers the total concentration of metals while metals speciation, i.e. identification of bio-available metal fractions is a more complex issue (Bjuhr, 2007).

2.6 Essential and Non-essential Heavy Metals in Plants

Heavy metals are elements with a high relative atomic mass. They occur naturally in the earth's crust (Madyiwa, 2006). According to Glanze, (1996) and Sipitey, (2007), they are elements with a specific gravity that is at least five (5) times the specific gravity of water. Also Perk, (2006) and Amfo-Out, (2007) stated that heavy metals are elements having a density greater than 3.6-6g/cm^3. Others define a heavy metal as a metal with atomic mass greater than that of sodium. Other definitions have it that a heavy metal is any of a number of higher atomic weight elements, which have properties of a metallic substance at room temperature. The "heavy metal" is used extensively in literature to refer to metals with atomic number greater than 20 and is also associated with toxicity or pollution. These include Cobalt, Chromium, Iron, Cadmium, Lead, Mercury, Zinc, Nickel, Manganese, Silver, etc (Madyiwa, 2006).

In general essential elements may be defined as metals that are necessary for a plant to complete its life cycle (Welch and Cary, 1987; Madyiwa, 2006). Heavy metals such as Iron, Copper and Zinc are essential for plant growth as they participate in oxidation, electron transfer and various enzyme reactions (Polette *et al*, 1997; Madyiwa, 2006).

Non-essential elements are metals with no known role in plant metabolism. Elements like Pb and Cd are not known to have any metabolic roles in plants and animals and are therefore non-essential (Johannesson, 2002; Elson and Haas, 2003; Madyiwa, 2006).

2.7 Chemistry of Lead and Cadmium

2.7.1 Lead

Lead (Pb) has an atomic number of 82 and atomic mass of 207. It is the heaviest non-radioactive metal that naturally occurs in substantial amounts in the earth's crust (Subhuti, 2001; Madyiwa, 2006). Pb is the most common among the heavy metals and its most abundant isotope is ^{208}Pb. Other stable lead isotopes also exist. Lead has two oxidation states Pb^{2+} and Pb^{4+}. Pb^{2+} dominate environmental chemistry. There is a great similarity in the ionic sizes of Pb^{2+} and Ca^{2+} such that Pb^{2+} may proxy for Ca^{2+} (Johannesson, 2002; Madyiwa, 2006).

2.7.2 Cadmium

Cadmium is a metal that belongs to group IIb, together with zinc and mercury, in the Periodic Table, with atomic number 48 and relative atomic mass of 112.40 (Amfo-Out, 2007). It is a relatively pure metal that is 67th in order of abundance. Cd has an estimated half-life of between

15 and 1100 years implying that it is a long-term problem in humans (Johannesson, 2002; Madyiwa, 2006). It is a soft white solid in nature. It has a density of 8.64 g/cm^3, melting point of 320.9 ˚C and a boiling point of 765˚C at 100kPa (IARC, 1976; Ros & Sloff, 1987; Ware, 1989; WHO, 2004).

2.8 Sources of Lead and Cadmium

The major sources of heavy metals to the environment are direct deposition from mining and industrial processes and waste water from mining activities, industrial and domestic processes (Madyiwa, 2006). Inputs of heavy metals to agricultural soils can occur from a variety of sources. These include land application of biosolids, fertilisers, livestock manure, agrochemicals, irrigation water to the land and from atmospheric deposition. Some of the concerns about accumulation of heavy metals in agricultural soils stem from their possible negative impacts on soil fertility and in some cases their potential to accumulate in the human chain (McLaugh *et al*.,1999; Gray *et al*., 2003). Some metals like cadmium and lead are good indicators of contamination in soils because they appear in gasoline, car components, lubricants, industrial and incinerator emissions (Adriano, 1986; Alloway, 1990; Li *et al*, 2001)

2.8.1 Source of Lead

Lead is a naturally occurring heavy metal with atomic number 82. Average igneous rocks produce about 15ppm of lead which finds its way in to the oceans (Brooks, 1972; Amfo-Out, 2007). According to Madyiwa (2006) Pb is a mineral found deep within the earth and mined together with silver deposits. It exist in nature as sulphate ($PbSO_4$), carbonates ($PbCO_3$) and sulphide (PbS), which constitute the principal ore of Pb, known as galena. Impurities in the ore include silver and gold. Lead ores produce oxides when heated. Pb is the most significant toxin of the heavy metals (Sipitey, 2007). Production of Pb can also be found in the radioactive decay of uranium^{208} and actinium^{207} (Sax and Lewis, 1987; Sipitey, 2007).

Lead is a raw material in the manufacture of tetraethyl lead, the additives in leaded gasoline. It is also used in the production of lead acid storage batteries, pigment and chemicals, solder, other alloys and cables. It therefore becomes part of industrial waste from these industrial activities. Lead is present in tap water primarily from household plumbing systems containing lead in pipes, solder, fittings or service connections to homes. This makes domestic waste a major source of lead. The dissolved amount depends on several factors including pH, temperature and water hardness (Madyiwa, 2006). Other sources of Pb in the environment include automobile exhaust, industrial wastewater, wastewater sludge, pesticides, landfill leachate and atmospheric fallout (Balba *et al*., 1991; Amfo-Out, 2007).

2.8.2 Sources of Cadmium

Cadmium is a metal that belongs to group IIb, together with zinc and mercury, in the periodic table, with atomic number 48 and relative atomic mass of 112.40. Though cadmium is a naturally occurring element, it is rarely found as a pure metal in nature. It is mostly associated with oxygen, chlorides, sulphate, and sulphides (Amfo-Out, 2007). Production of cadmium on large scale started at the beginning of the 20th century. Majority of cadmium use is in the form of compounds that are present at low concentration hence constraining the recycling of cadmium and volcanic actions are the largest natural source of cadmium (ATSDR, 1999a; Sipitey, 2007). Cadmium is present in the earth's crust at an average of 0.2mg/kg and usually occurs in association with Zn, Pb and copper sulphide ore bodies. Cadmium is used in the steel and plastics industries and is released to the environment through wastewater (WHO, 1993; Madyiwa, 2006). According to Madyiwa (2006) the main sources of Cd in the environment are:

1) Air emission from Zn, Pb and copper smelters and industries involved in manufacturing alloys, paints, batteries and plastics
2) Wastewater from mining
3) Agricultural use of sludge and fertilizers containing Cd
4) Burning of fossil fuels and
5) Deterioration of galvanised materials and Cd-plated containers.

Also according to (Baker *et al*.,1979;Garcia *et al*.,1979; Kosla ,1986; Peles *et al*.,1998; Gallardo-Lara *et al*.,1999; Amfo-Otu, 2007) some other human activities which release Cadmium into the soil included the use of commercially available fertilisers and the disposal of sewage sludges, re-incorporation of crop residues and atmospheric fallout.

2.9 Lead Metal Contamination and Toxicity to Human Beings

An estimated 99% of the Pb that enters the adult human body and 33% that enters a child's body are excreted in about two (2) weeks. As a result of this, Pb poisoning is of much concern in children because they are susceptible to developmental delays secondary to Pb toxicity (ATSDR, 1999b); Amfo-Otu, 2007). Pb levels in human body have increased over time (Elson and Haas, 2003; Madyiwa, 2006). The excessive content of metal like Pb in food is associated with a number of diseases, especially with cardiovascular, kidney, nervous as well as bone diseases (WHO, 1992 and 1995; Steenland and Boffetta, 2000; Jarup, 2003; Eslami *et al*, 2007). There is substantial evidence that a high Pb level in the environment could affect blood Pb level, intelligence and behavior (McMichael *et al.*, 1985; Bellinger *et al*., 1990; Dietrich *et al*., 1990; Li *et al*, 2001). Pb poisoning in young children may cause permanent damage to the central nervous system and reduces intellectual capabilities (Wildlife, 2000; WHO, 1993; Madyiwa, 2006). It also causes high blood pressure and hypertension in adults (Staessen, 2002; Madyiwa, 2006).

Galvo (1987) and Ibarra (1998) stated that for Pb in cereal grains, the established WHO value should not exceed 3 mg/person/week in uptake by food.

2.10 Cadmium Metal Contamination and Toxicity to Human Beings

Acute doses (10-30 mg/kg per day) of Cd can cause severe gastrointestinal irritation, vomiting, diarrhoea and excessive salivation, and doses of 25 mgI_2 /kg body weight can cause death (ATSDR, 1999a; Amfo-Out, 2007). Most of the metals ingested by humans and animals are excreted and only small proportions are actually retained in the body tissues (Cameron *et al.*, 1997; Mollar *et al*., 2005). The excessive content of a metal like Cd in food is associated with etiology of a number of diseases, especially with cardiovascular, kidney, nervous as well as bone diseases (WHO, 1992 and 1995; Steenland and Boffetta, 2000; Jarup, 2003; Eslami *et al*, 2007). Among the heavy metals, cadmium is one of the metals commonly considered to be toxic to both plants and humans. For instance, in Japan, Cd contamination of rice led to renal impairment and bone disease in an exposed population. It is necessary to decrease toxic heavy metal accumulation in cereals for food production, particularly in rice, which is one of the most frequently consumed cereals worldwide (Cheng *et al,* 2006). Cd increases in content with age and is estimated to peak at 40 mg in the human body at 50 years of age. Galvo (1987) stated that for Cd in cereal grains, the established limited WHO value should not exceed 0.50 mg/person/week through uptake by food.

2.11 Modes of Transport and Uptake from Soils

Plant uptake of Pb and Cd makes plants potential cleaners of contaminated soils but also major sources of contamination for animals and human beings, if the plant is consumed (Moonlenar and Lexmond, 1999; Madyiwa, 2006).

2.11.1 Lead Transport

Lead is one of the poisonous elements. Industrial pollutants including Pb, may contaminate peri-urban crops and poison consumers (Birley and Lock, 2001).

Drainage, the type of vegetation and pH are some of the factors which may influence the content and distribution of Pb in soils (Lee *et al*., 1997; Sipitey,2007). For acidic soils, there is desorption of lead into solution making it available for uptake by plants or vegetables. Lead desorption into the soil solution increases its mobility through the profile (John and VanLaerhoven,1972; Cataldo *et al*.,1981; Chen *et al*.,1997; Peles *et al*.,1998; Li and Wu,1999; Sipitey,2007). According to FAO (1992) the maximum permissible concentration of Pb in soil should not exceed 300mg/kg.

2.11.2 Cadmium Transport

Cadmium is readily transported from the soil to the upper parts of plants (Mengel and Kirkby, 1982; Madyiwa, 2006). Its transfer from soils to edible plant parts of agricultural crops is significantly greater than for other heavy metals except Zn (Moolenar and Lexmond, 1999; Madyiwa, 2006). Li and Wu (1999) and also Sipitey (2007) stated that one of the factors which significantly influences cadmium concentrations in soils and its uptake into plant tissues is soil pH. When soil pH decreases, cadmium is desorbed from organic and clay particles and ends up in soil solution and become more mobile. At higher pH (>7), Cadmium remains adsorbed and that metals in solution precipitate out in the form of salts (Chen *et al*., 1997; Sipitey,2007). According to John and VanLaer hoven (1972) and Sipitey (2007), higher pH results in lower Cd uptake. From the soil, certain plants (tobacco, rice, other cereal grains, potatoes, and other vegetables) take up cadmium more avidly than they do other heavy metals such as lead and mercury (Satarag *et al.* 2003; ATSDR, 1999). Cadmium moves easily through soil layers and is taken up into the food chain through uptake by plants such as leafy vegetables, root crops, cereals and grains (ATSDR,1999; ATSDR, 2008). According to the FAO (1992) the maximum permissible concentration of Cd in soil should not exceed 3 mg/kg.

2.12 Effect of Lead and Cadmium on Plants

Heavy metals are toxic to higher plants by causing oxidative stress, displacing other essential metals in plant pigments or enzymes, leading to disruption of function of these molecules and of many metabolic processes, and finally reducing growth and yield (Rulkens *et al.*, 1998; Seregin and Ivanov, 2001; Verma and Dubey, 2001; Zhang *et al*., 2002; Wang *et al*., 2003, Cheng *et al*, 2006). In general accumulation of heavy metals in the soil adversely affects the establishment of seedlings and forest regeneration. Heavy metals affect the catalytic function of enzymes, damaging cellular membrane, inhibition of root and shoot development, reduction of net carbon dioxide assimilation and decreasing the stomatal conductance and transpiration, which in turn affect the soil water regime (Rosen, 2002; Amfo-Out, 2007).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter describes the methods used for data collection for the research.

3.2 Reconnaissance Visit

A visit was carried out to the Project site and the surrounding towns to really ascertain the kind of activities that go on in these areas.

After the visit, three major activities were identified which might have a negative impact on rice cultivated at the Project Site. These sites were Ghana Waterworks Company Limited at Nobewam, "*Galamsey*" operators and Mechanic workshops at Konongo.

3.3 Research Design

The research was aimed to determine the concentrations of cadmium and lead metals in the rice grain, the soil and the irrigation water used at the Anum Valley Irrigation Project and to find the way forward for protecting the health of rice consumers of the Ghana Irrigation Development Agency project.

3.4 Methods

The methods used in this research were sample collection, administration of questionnaires and interviews. Four different sets of questionnaires were designed for the study as shown in Appendix G,H,I and J. One set was for the farmers at the project site. The second set was for the management of the Ghana Waterworks Company Limited at the project site. The third set was for the "Galamsey" Operators at Konongo. The last set was for the Mechanics at Konongo. English and Twi were used to ensure effective collection of information.

The questionnaire for the farmers was designed to answer questions about the following:

- Demography
- Farm size
- Years of farming
- Number of Cultivations per year
- Types of rice grown
- Type of irrigation practised
- Source of irrigation water
- Number of irrigation per month
- Number of drainage per farming
- Fertiliser application types

The questionnaire for the Ghana Waterworks company was designed to answer questions about:

- Number of workers
- Source of water
- Where waste water is discharged
- Number of waste water discharged per month
- The company's life span
- Types of chemicals used in treating water

The questionnaire for the *"Galamsey"* Operators was designed to answer questions about the following:

- Demography
- Type of mineral mined
- Number of years in occupation
- Source of water
- Nearest river
- Place of waste water discharge
- Chemicals used to process the mineral

The questionnaire for the Mechanics at Konongo was designed to answer questions about the following:

- Demography
- Number of years in occupation
- Source of water
- Nearest river
- Place of waste water discharge
- Chemicals used to service vehicles

The total number of samples collected randomly was forty-five (45). Thirteen (13) of the samples were rice grain of which seven (7) were from Area A and six (6) from Area B. Twenty (20) of the samples were soils of which twelve (12) were from Area A and eight(8) from Area B . The rest were water samples of which two (2) were from Area A, one (1) from Area B, two (2) from Waterworks area, three (3) from the dam area, one (1) from the mechanics shop area at Konongo and three (3) from "*Galamsey*" area.

The Oweri river flows downward from the mechanics shops at Konongo through the *"galamsey"* operators' area, Dam area, and finally enters Area B on the project site. However, the Anum river flows through the Waterworks area and then finally enters Area A on the project site.

Other materials used in achieving the objectives of this research were a bucket, matchette, concentrated nitric acid, ice cubes, ice chest, polythene bags, de-ionised water, and plastic bottles

3.5 Description of Project Sites

The Anum Valley Irrigation Project which is actually located at Nobewam is about 33 Km Southeast of Kumasi in the Ejisu Juaben District of the Ashanti Region of Ghana. It is on latitude 6˚37` and longitude 1˚18` (Anum Valley Project Report, 1992). Feasibility studies of the site were actually carried out in 1989 and construction started in 1990. The construction of the water distribution and supply networks as well as other infrastructure on site was completed in 1992. The project has a total potential of 140 hectares out of which 90 hectares have been fully developed. The project is divided into two (2) areas. The first area, Area A, has a net area of 40 hectares whilst Area B has a net area of 100 hectares. Two rivers supply water to the Project; the Anum River from which the project gets its name serves Area A whilst its tributary, the Oweri, serves Area B. The type of irrigation practiced is surface irrigation with basins. Each basin covers an area of 0.1 hectare (50m × 20m).

3.6 Geology and Soils

The geology of the area is predominantly granites and granodiorites of the Birimian Series. The dominant soil group is forest ochrosols with high organic matter content at the surface layers. Soils in the immediate peri-urban area are developed over highly weathered (phyllites, greywackes, schists and gneisis). They are predominantly reddish, silty clays and loams and are generally well-drained but with low chemical fertility below a thin organic topsoil (Adu, 1992; Omane, 2002).

3.7 Relief and Drainage

A striking aspect of the landscape is a pattern of interchanging slopes and valleys. These slopes normally degenerate into peneplains of about half to two kilometres stretch before tapering off into other slopes. The slopes vary between 5˚-15˚ with local altitude relief of up to thirty metres. Steeper slopes are, however, prone to erosion, particularly on cleared land during the wet season (Nsiah-Gyabaah, 2000; Omane, 2002).

3.8 Climate and Vegetation

The climate is semi-humid tropical with two (2) seasons, mainly: the rainy and dry seasons. The droughts begin in December and end in February, while the wet season spans from March to November. The annual rainfall distribution is bimodal, with a principal wet season peaking in June and a subsidiary one peaking around October. The average total annual rainfall is variously quoted, for example, 1459mm (FAO, 1984) and a reference long term of 1417mm (Okyeame *et al,* 1994; Omane, 2002).

Similarly, the daily mean temperature has once been given as 25.5˚ (FAO, 1984) and a reference long term mean daily value as 26˚ (Okyeame *et al,* 1994; Omane, 2002).

3.9 Industrial Survey

A survey was carried out for some of the industrial activities taking place along the river courses within the study area. The main industry along the Anum River is the Ghana Waterworks Company Limited. The selection was based on the expectation of wastewater generation and its negative impact on the river. Survey was carried out in a form of inspection, discussion and questionnaire administration.

3.10 Town Survey

Some sites in the town were surveyed for practices that were likely to have negative impacts on the Oweri River that flows through the Konongo town to the project site. The main activities along the river are the "*galamsey*" and Auto-mechanics workshops. The survey involved inspection, discussion and questionnaire administration.

3.11 Selection of Sampling Sites for Water Analysis

Table 3a: Sampling sites

RIVER	SAMPLING SITES	Global Position System Point
Oweri	• Area A-1 (Nobewam) **:** A.A-1.N	(6˚37.403N, 1˚17.133W)
	• Area A-2 (Nobewam) **:** A.A-2.N	(6˚37.413N, 1˚17.136W)
	• Mechanics Shop (Konongo) **:** M.S.K	(6˚37.216N, 1˚12.988W)
	• "Galamsey" Site Upstream - (Konongo) **:** G.S.U.K	(6˚37.600N, 1˚14.014W)
	• "Galamsey" Site Downstream - (Konongo) **:** G.S.D.K	(6˚37.618N, 1˚14.018W)
	• After DownStream Point 1- (Konongo) **:** A.D.S.P-1.K	(6˚37.593N, 1˚13.613W)
	• After Downstream Point 2- (Konongo)**:** A.D.S.P-2.K	(6˚37.633N, 1˚13.658W)
	• Before the Dam - (Nobewam) **:** B.T.D.N	(6˚38.097N, 1˚15.315W)
	• After the Dam - (Nobewam) **:** A.T.D.N	(6˚38.103N, 1˚15.314W)
Anum	• Area B – 1 (Nobewam) **:** A.B-1.N	(6˚38.114N, 1˚16.652W
	• Before Waterworks - (Nobewam) **:** B.W.N	(6˚38.498N, 1˚16.698W)
	• After Waterworks - (Nobewam) **:** A.W.N	(6˚38.460N, 1˚16.712W)

The selection of the sampling sites were based on the type of human, industrial and commercial activities prevailing in a given area and their possible impacts on the environment particularly the Anum and the Oweri rivers. The total number of sites were 12 and these were spread around the study area. Some of the rivers had multiple sampling sites along their courses depending on the length and vulnerability to pollution.

3.11.1 Water Sample Collections

Water samples for quality analysis were taken from designated sites in March 2008. The samples were taken during the day between 8:00 am – 3:00 pm. A plastic bucket was used to fetch these samples from the rivers and refilled into a well labelled 0.5 litre sample containers, decontaminated using distilled water. The sample containers were always filled to the brim, tightly covered and stored under iced cubes in an ice-chest whilst on the field.

For heavy metals, the samples were preserved by the addition of concentrated nitric acid to a pH below 2. They were taken and kept separately from the rest. All the samples were stored below 4˚C when they were not being worked on.

3.11.1.1 Water Quality Parameters Analysed

These were mainly Physical, chemical and some heavy metal parameters were mainly analysed as shown in Table 3b.

Table 3b: Water Quality Parameters

PHYSICAL	CHEMICAL	HEAVY METALS
pH, Temperature, Electrical Conductivity	Sodium, Potassium, Magnesium	Cadmium, Lead, Manganese, Iron

3.11.2 Soil Sample Collection

The soil samples were taken from 0 – 20 cm depth from the surface of the ground. A clean matchette was used in the sampling process and the collected samples were placed in polythene bags. Different samples were taken randomly from both sites. A sampling distance of 100 metres apart was used as the horizontal spacing. The stainless steel cutlass was always cleaned before sampling from a new site.

3.11.3 Rice Sample Collection

The thirteen rice grain samples were taken randomly from the sites or plots where the soil samples were taken for analysis. The collected samples were stored in polythene to be analysed at the laboratory.

3.12 Sample Preparations and Physical Quality Analysis

3.12.1 Rice preparation

The collected rice grain samples from the sites were refined in a mill to get rid of the husk. The polished rice grain was then ground into powder with the help of a mortar and pestle. The ground samples were passed through a 2-mm sieve. The sieved samples were then stored in polythene bags for digestion.

3.12.2 Soil Preparation

The soil samples were air-dried, crushed and passed through a 2-mm sieve to remove gravel-sized materials and large roots, and then homogenized with a mortar and a pestle. The samples were then stored in polythene bags.

3.12.3 Determination of Soil Physical Properties (pH, EC & Temp)

Five grammes each of the soil samples were weighed into different cleaned 100ml plastic containers and 25ml of distilled water was added to obtain a solution. The mixture was shaken for three hours and allowed to stand overnight. The mixture was then filtered into clean plastic containers. After that, a portion of the filtered solution was poured into a clean beaker, and a calibrated Seven (7) Multi pH meter was used to determine the pH, Electrical Conductivity, Salinity and Temperature of the samples. The electrodes were rinsed with distilled water after each sample measurement. The measurement was duplicated for each sample and results are presented in Table A.1 (Appendix A)

3.12.4 Determination of Sodium (Na) and Potassium (K) in the Soil Samples

A clean 15ml beaker was filled with 5ml of the filtered soil solution. 2ml of 100ppm Lithium Standard Solution was then added to the filtered soil mixture solution. The calibrated Sherwood Flame Photometer was used to determine the Na^+ and K^+ in the water samples. The Photometer was rinsed with distilled water after each sample measurement. The test was duplicated for each sample and the results are presented in Table A.2 (Appendix A)

3.12.5 Determination of Water Physical Quality

Clean 250ml beakers were filled with water samples. Calibrated Seven (7) Multi pH meter was then used to determine the pH, Electrical Conductivity and Temperature of the samples. The electrodes were rinsed with distilled water after each sample measurement. The test was duplicated for each sample and the results are presented in Table C.2 (Appendix C)

3.12.5.1 Determination of Sodium (Na^+) and Potassium (K^+) in the Water Samples

A cleaned 15ml beaker was filled with 5ml of sample and 2ml of 100ppm Lithium Standard solution was added. The calibrated Sherwood Flame Photometer was used then used to determine the Na^+ and K^+ concentrations in the water samples. It was rinsed with distilled water after each sample measurement. The measurement was duplicated for each sample and results are presented in Table C.1 (Appendix C)

3.13 Digestion and Analysis of Samples

3.13.1 Digestion of Water Samples

10ml each of the water samples was measured into Tuflon beakers mounted on a rotor followed by the addition of 6ml of 35% HCl and 12ml of 65% HNO_3. The samples were then microwave-digested using the Ethos 900 Milestone Microwave machine Report Code 309. Each of the various digested solutions was then diluted with de-ionised water to a final volume of 30ml. The solutions were finally kept in test tubes. Concentrations of Pb, Cd, Fe, Mn and Mg were determined using the VARIAN 240 FS Atomic Spectroscopy.

3.13.2 Digestion of Soil Samples

1.5g each of the soil samples was measured into Tuflon beakers mounted on a rotor followed by the addition of 3ml of 35% HCl, 6ml of 65% HNO_3 and 0.25ml of 30% H_2O_2.The samples were then microwave-digested using the Ethos 900 Milestone Microwave machine Report Code 309. Each of the various digested solutions were then filtered and diluted with de-ionised water to a final volume of 15ml. The solutions were finally kept in test tubes. Concentrations of Pb, Cd, Fe, Mn and Mg were determined using the VARIAN 240 FS Atomic Spectroscopy.

3.13.3 Digestion of Rice Samples

0.5g each of the powdered rice samples was measured into Tuflon beakers mounted on a rotor followed by the addition of 6ml of 65% HNO_3 and 1 ml of 30% H_2O_2 .The samples were then microwave-digested using the Ethos 900 Milestone Microwave according to machine Report Code 309. Each of the various digested solutions was then filtered and diluted with de-ionised water to a final volume of 25ml. The solutions were finally kept in test tubes. Concentrations of Pb and Cd were determined using the VARIAN 240 FS Atomic Spectroscopy.

3.14 Instrumentation

3.14.1 Varian Atomic Spectroscopy

The Varian Atomic Spectrometer was the instrument used to determine the concentration of lead and cadmium in the various samples (rice grain, water samples and soils). The method is not very sensitive to very low concentrations (< 0.002) for Cadmium, and as low as (<0.01) for lead. The type used was the VARIAN 240 FS Atomic Spectroscopy (2006) model at the Ghana Atomic Energy Commission in Accra.

3.14.1.1 Basic Principles of Atomic Absorption

The basic principles of atomic absorption spectroscopy can be expressed by the following simple statements:

- All atoms can absorb light.
- The wavelength at which light is absorbed is specific for each element. If a sample containing nickel, for example, together with elements such as lead and copper is exposed to light at the characteristic wavelength for nickel, then only the nickel atoms will absorb this light.

- The amount of light absorbed at this wavelength will increase as the number of atoms of the selected element in the light path increases, and is proportional to the concentration of absorbing atoms.
- The relationship between the amount of light absorbed and the concentration of the analyte present in known standards can be used to determine unknown concentrations by measuring the amount of light they absorb. An atomic absorption spectrometer is simply an instrument in which these basic principles are applied to practical quantitative analysis.

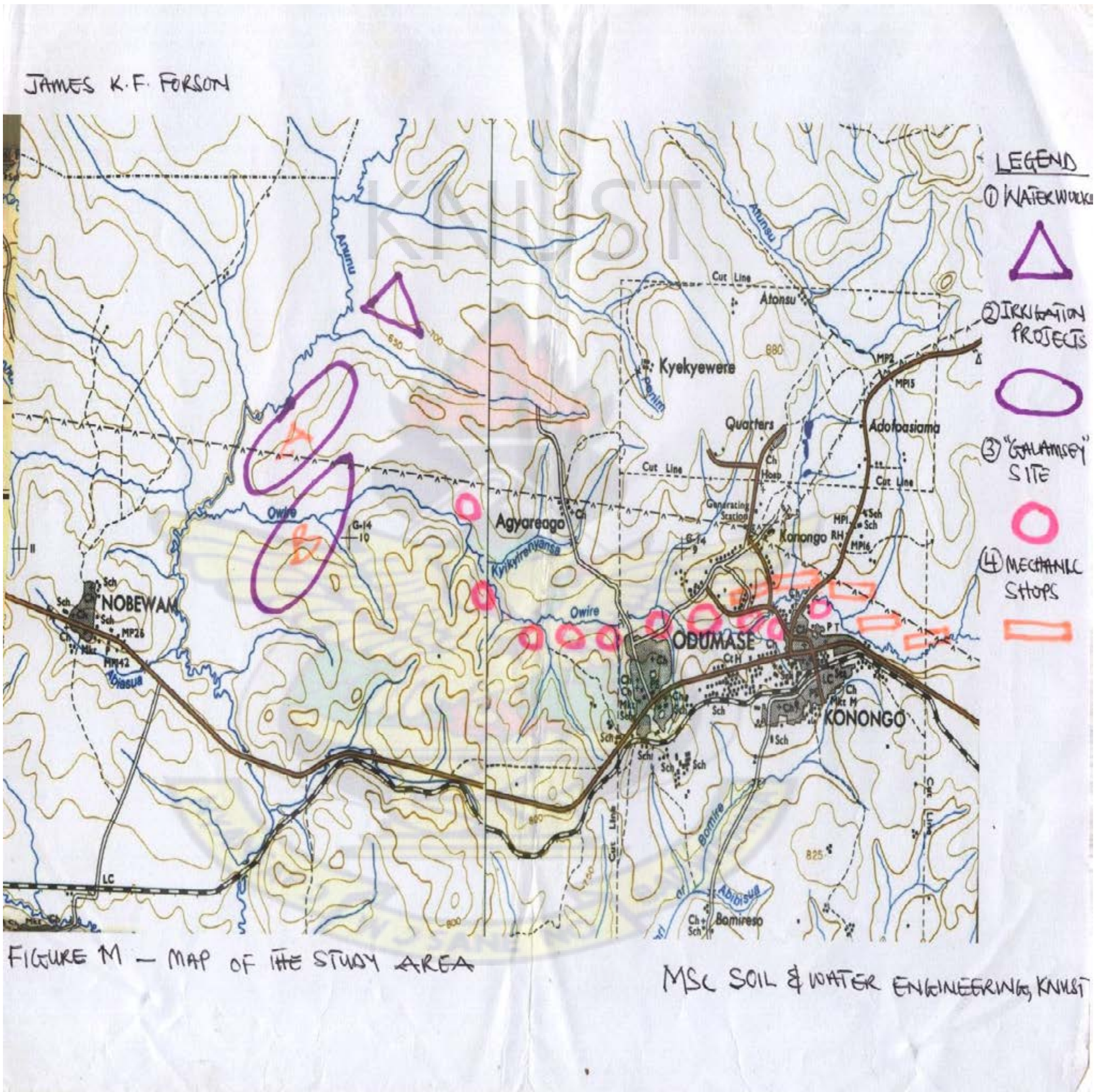

Fig. M: Map of the study area

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter report on the findings of the field survey and observations, interviews, administration of questionnaires and analysis of samples. These results were afterwards discussed in the light of the Literature Review. Thus, the results are grouped into two parts: qualitative and quantitative results.

4.2 Qualitative Results

The qualitative results comprise the outcomes of the industrial survey, town survey and the analysis of the questionnaires administered to the rice farmers, Ghana Water Company Limited, "*galamsey*" operators and the Mechanics at Konongo. The reason for this was to find the possible causes of pollution of both the Oweri and the Anum rivers.

4.3 Analysis of Questionnaires

4.3.1 Rice Farmers

From appendix D, out of the 30 questionnaires administered, 23 farmers representing 76.7% of the total were males whilst the rest were females. This could be owing to the rigorous nature of the rice farming activity such that many females are not attracted to it.

Also from appendix D, Table D.2 and Fig. 2 indicate the respondent age. According to the table, 70% of the total respondents were more than 40 years of age whiles 3.3% were between the ages of 21- 30. This could be due to the fact that the rice farming business is not a very attractive because it is seen as not lucrative to encourage the young men and women.

According to appendix D, Table D.3 and Fig. 3 shows that 56.7% of the total respondents had at least a Basic school education, 3.3% had a Secondary school education, 6.7% had Tertiary education and the rest had not attended school before.

From appendix D, Table D.4 and Fig. 4 indicates the sizes of the various farms. From the Table, 3.3% had only 2 plots, 6.7% had only 5 plots, 43.3% had 4 plots whilst the rest 46.7% of the total respondents, had farm sizes more than 5 plots (0.5 hectares).

According to the Table D.5 and Fig. 5 in appendix D, 6.7% of the respondents had farmed on their plots between 9 to 12 years, 23.3% between 1 to 4 years, 30% of them between 5 - 8 years and the rest 40% for more than 12 years.

From Table D.6 and Fig. 6 in appendix D, only 7 farmers representing 23.3% of the total respondents grow rice twice in a year whilst the rest of the 23 farmers representing 76.3% grew rice only once in a year. This might be due to the high cost involved in rice cultivation and low fertility of the land used for the cultivation or non-availability of water in the dry season.

According to appendix D, Table D.7 and Fig. 7 indicates the types of rice grown. According to the Table, 6 farmers representing 20% grew only Tox 3108 rice, 26.7% grew only Jasmine rice whilst the rest 53.3% grew both Jasmine and Tox 3108 rice. This could be attributed to the high quality of both the Jasmine and Tox 3108 rice.

All the 30 farmers practiced basin irrigation system.

According to table D.8 and Fig. 8 in appendix D, 15 farmers representing 50% of the respondents use the Anum River to irrigate their farms whilst the rest of the 50% used the Oweri River.

From Table D.9 and Fig. 9 in appendix D, 16.7% of the respondents irrigated thrice during a planting season. 20.0% irrigated more than thrice, only 26.7% irrigate once whilst the rest of the 36.7% irrigated only twice. This could be influenced by the availability of water for irrigation.

According to Table D.10 and Fig. 10 in appendix D, one farmer representing 3.3% of the total respondents drained excess water more than thrice out of the plots during a rice cultivation season into the river.13.3% of the respondents do not drain excess water out, for 20% it is only thrice whilst 23.3% drained out excess water only twice and the rest 40%, only once during a cultivation period. It was also, realized that all the farmers used farm inputs like fertilizers (N.P.K compound), weedicides (glyphosate, paraquate and oryzoplus) and pesticides (karate) during rice cultivation.

4.3.2 Ghana Water Company Limited

The survey carried out on some of the major industrial activities in the study area indicated that Ghana Water Company Limited is the only industrial concern undertaking some activities along the Anum river course within the study area. The selection of this industry was based on the expectation of high waste water generation and therefore the pollution of the Anum river which is one of the rivers used for irrigation. From the questionnaire which was administered based on a discussion guide of seven (7) questions, the total work force of the company is six (6). It was confirmed that the main source of water they used in the plant is the Anum River. It was also realised that all the wastewater from this plant was discharged back into the Anum river. Besides, it was noticed that two major wastewater discharges takes place within a every month. It was also found that aluminum sulphate, calcium hydrochlorate, hydrated lime and potassium were the main chemicals used in the treatment of the water (Appendix I).

4.3.3 *"Galamsey"* Site

"*Galamsey"* mining is one of the activities in the town which were surveyed for practices that were likely to have a negative impact on the water quality of the Oweri river. The selection of this activity was based on the expectation of high waste water generation and therefore the pollution of the Oweri River which is one of the rivers used for irrigation. From the questionnaire which was administered based on a discussion guide of nine (9) questions (Appendix H).

The people who engage in the mining activities were all males. This might be due to a lot of strength involved during the processing and the extraction of the mineral.

According to table E.1 and Fig.1 in appendix E, most of the respondents representing 69.4% were between the ages of 21-30 years with only 19.4% between 31-40 years. This might be due to the rigorous nature of the mining process such that it is only the youth that fully participate in it.

From the Table E.2 and Fig. 2 in appendix E, 44.4% had a basic education. 30.6% of the respondent had never been to school before, whereas 2.8% had a tertiary education and the rest of the 22.2% had a secondary education.

It was realized that type of mineral mined in the vicinity which is gold. From table E.3 and Fig. 3 in appendix E, it is clear that most of the respondents representing 41.7% had engaged in this activity for more than 5 years. For 36.1% it is only between 4-5 years, whilst for 13.9% it is between 2 - 3 years and the rest, 8.3% for less than 1 year.

Table E.4 and Fig. 4 in appendix E shows the type of water used to process the gold extraction. According to the Table, 47.2% get their source of water from bore-holes for the processing of the gold. 44.4% also indicated that they get their water from the Oweri River while the rest of the

8.3% get theirs from other sources which might be the effluent flowing through the mining site from the various homes.

All of them responded to the fact that the nearest river to them is the Oweri River. The main chemical used to process the gold is mercury.

4.3.4 Mechanic Shops

The selection of this activity by mechanics was based on the expectation of high waste water generation and therefore the pollution of the Oweri river which is one of the rivers used for irrigation. From the questionnaire which was administered based on a discussion guide of eight (8) questions (Appendix J). The following observations were made:

It is clear that the mechanics were all males. This might be due to the unattractive nature of the work.

According to Table F.1 and Fig. 1 in appendix F, most of the respondent representing71.1% are between the age of 21-30 years whilst only 2.6% were more than 41 years. This might be due to the rigorous nature of the work such that it is only the youth that fully participate in it.

Table F.2 and Fig. 2 in appendix F indicates the educational level of the mechanics. From the table it obvious that none of them had a tertiary education. Whilst it is only 10.5% that had a secondary education. Those with basic education were 76.3% and the rest, 13.1%, had not been to school before.

According to the Table F.3 and Fig. 3 in appendix F, 47.4% of the respondents have engaged in this work for more than 4 years. 26.3% of them have been in it for between 1-2 years and 23.7% between 3-4 years and the rest 2.6%, for less than 1 year.

The source of water used by the mechanics to service their vehicles was bore-hole water.

The entire respondents indicated that the nearest river to their workshop is the Oweri River.

All the 38 mechanics agreed to the fact that they discharged their waste water into the Oweri River.

From table F.4 and Fig. 4 in appendix F, 14 of the mechanics representing 36.8% of the respondents shows that they use items like diesel oil, petrol, engine oil, brake fluid and grease to service their vehicles. 15.8% of them use electrode, lead, solder, metal plates and pipes which could rust or corrode.

4.4 Quantitative Results

The quantitative data represent the actual pollution as obtained from measurement and tests using different kinds of equipment. The results for March 2008 were done during the dry season mainly from sampled rice grains, irrigation water and soils which were analysed at the laboratory.

4.4.1 Water Samples Analyses

4.4.1.1 Physical Qualities

4.4.1.1.1 PH

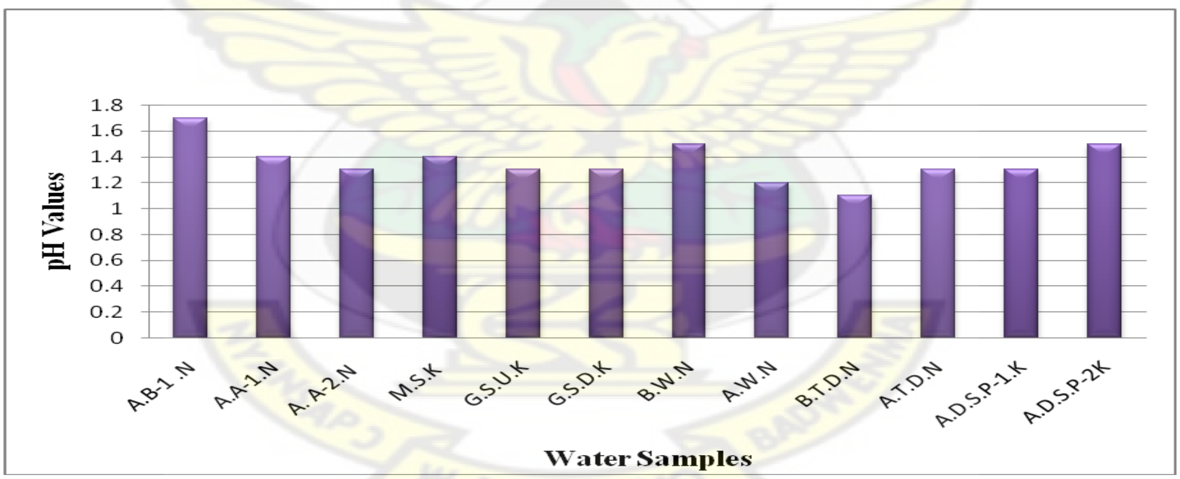

Fig.1: pH of water samples

In Fig.1, the pH values of the water samples collected from the field ranged between 1.1 to1.7. The pH values showed that the water is very acidic. These values were found to be outside the FAO (1992) permissible limit (6.5-8.4) for irrigation purposes. Sample from Before the Dam had the lowest value of 1.1 while Area B-1 had the highest value of 1.7. The quality of this water is considered to be abnormal for irrigation. The acidic nature of the water might be due to wastewater from the mechanic shops at Konongo which discharged into the Oweri river.

4.4.1.1.2 Temperature

From Fig. 2 the values of the temperature of the irrigation water ranged between 24.2 - 25.7 ˚C. Area A-1 had the lowest temperature value whilst the area After the Dam Point-3 had the highest temperature values. However, all the temperatures were around room temperature.

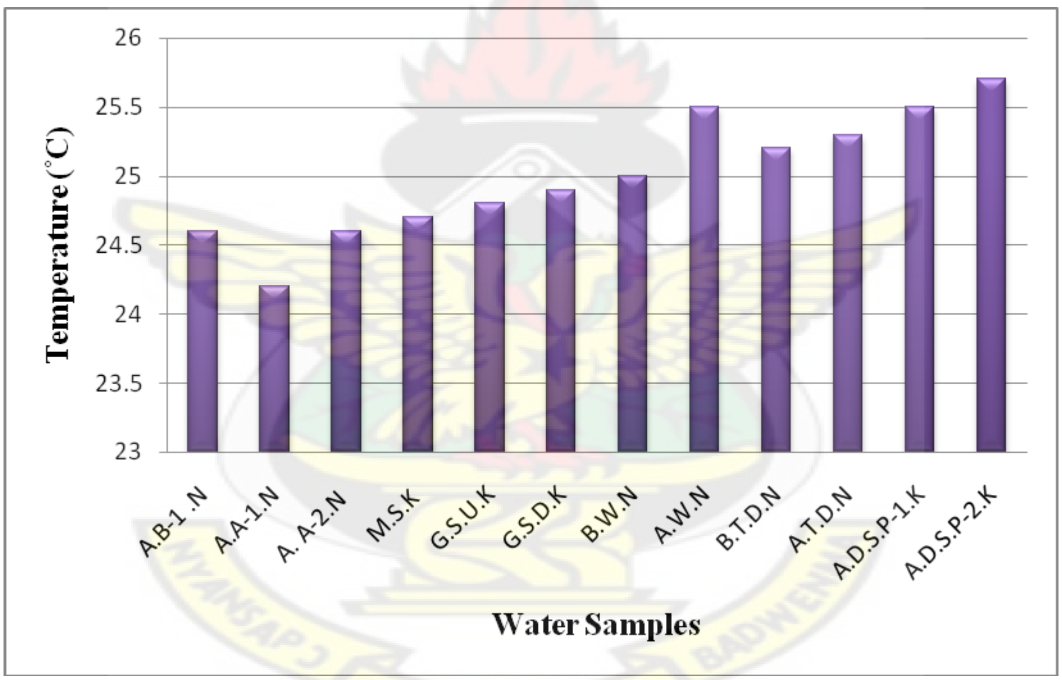

Fig. 2: Temperature of the water samples

4.4.1.1.3 Electrical Conductivity

From Fig. 3, values of all the EC's of the water samples were very far above the FAO permissible (3.0 dS/m) value for irrigation. The value of EC ranged between 17.34 - 113.6 dS/m. It is very obvious that EC of the irrigation water at Area B-1 had the lowest value of 17.34 dS/m whilst the one at Area A-2 had the highest value of 113.6 dS/m. The high values could possibly be due to wastewater from Ghana Waterworks Company Limited at Nobewam which uses a lot of salts at the plant and also leachate from rock weathering.

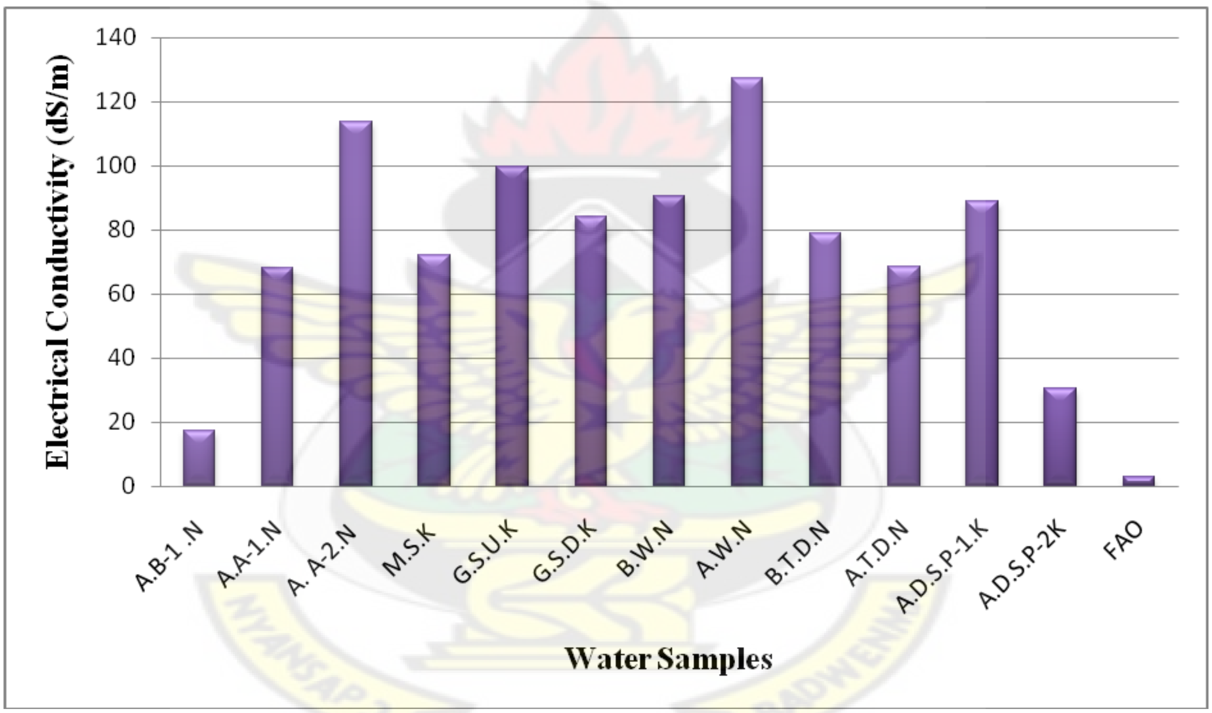

Fig. 3: Electrical Conductivity graph of the water samples

4.4.1.2 Heavy Metals Analysis in Water Samples

4.4.1.2.1 Cadmium

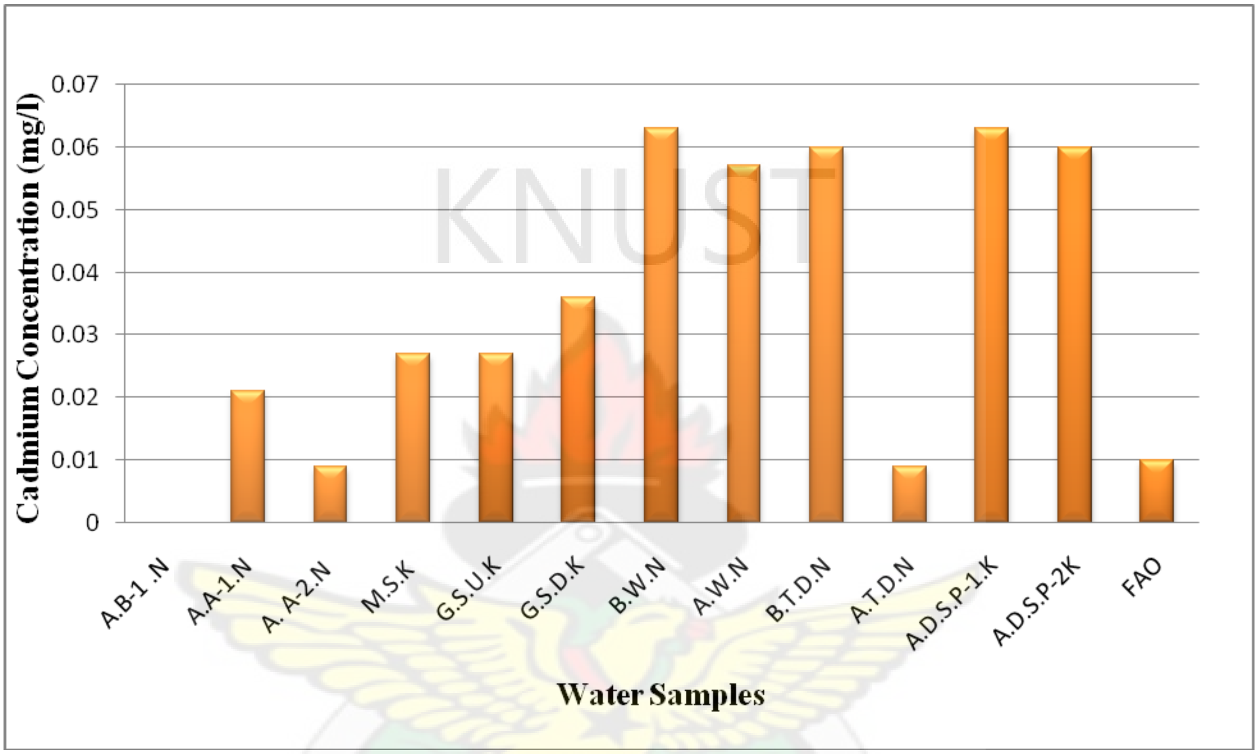

Fig. 4: Cadmium graph of the water samples

The concentration of Cd in the water samples being used for irrigation at the various sites ranged between <0.002 to 0.063 mg/l. According to FAO permissible guidelines values for irrigation, the Cd in irrigation water should not exceed 0.01mg/l. This means, the water from Area A-1 (A.A-1.N), Mechanic Shops at Konongo (M.S.K), "Galamsey" Site Upstream at Konongo (G.S.U.K), "Galamsey" Site Downstream at Konongo (G.S.D.K), Before Waterworks at Nobewam (B.W.N), After Waterworks at Nobewam (A.W.N), Before The Dam at Nobewam (B.T.D.N), After DownStream Point-1 at Konongo (A.D.S.P-1.K) and After DownStream Point-2 at Konongo (A.D.S.P-2.K) which had values of 0.021 mg/l, 0.027mg/l, 0.027mg/l, 0.036mg/l, 0.063mg/l, 0.057mg/l, 0.060mg/l, 0.063mg/l and 0.060mg/l respectively were above the FAO Permissible limit. The high values might be attributed to the application of fertilizers on the farms, wastewater from both the mining sites and the mechanic shops. Thus, application of this type of water for irrigation purposes could be very harmful to both crops and human beings.

4.4.1.2.2 Lead

It was found that the concentration of Pb in the water samples being used for the irrigation of rice in Fig. 5 ranged between < 0.01 to 0.372 mg/l. FAO recommends for irrigation purpose that the concentration of Pb in water for irrigation water should not exceed 5.0mg/l. It is very obvious that all the Pb values in the irrigation water were far below the FAO recommended limit. It implies that the water might be good for irrigation purposes as far as Pb is concerned.

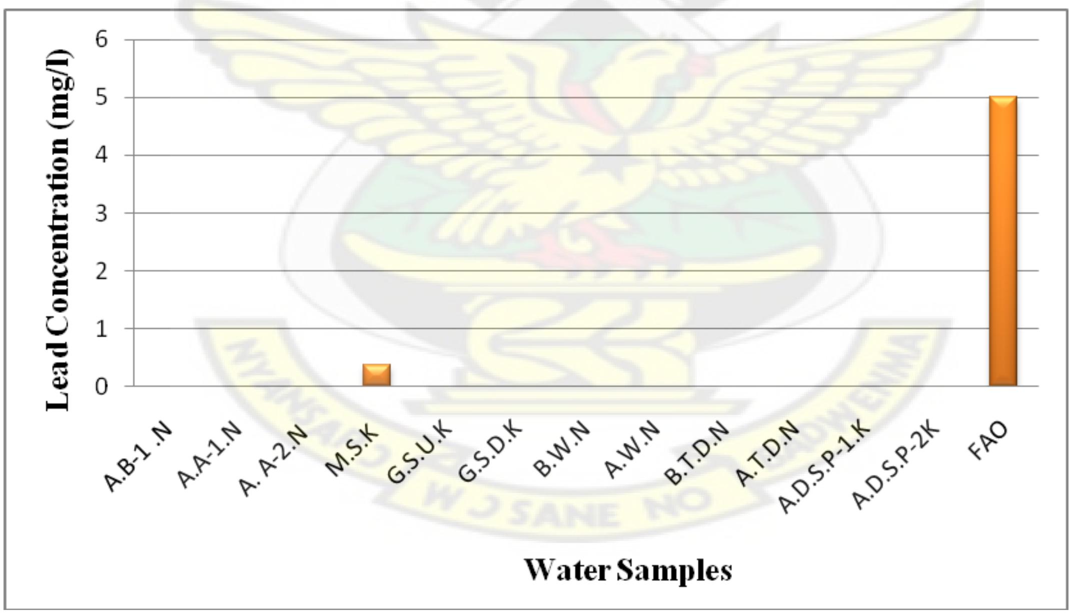

Fig .5: Lead Presence in water samples

4.4.2 Soil Samples Analyses

4.4.2.1 Physical Qualities

4.4.2.1.1 pH

The pH of the soil samples collected from the field in Fig. 6 ranged between 5.2 -7.2. These results indicated that the water samples were slightly acidic to neutral. Area A (Lat-3, plot-5) had the lowest of 5.2 while Area B (Lat-24, Plot-4) had the highest value of 7.2.

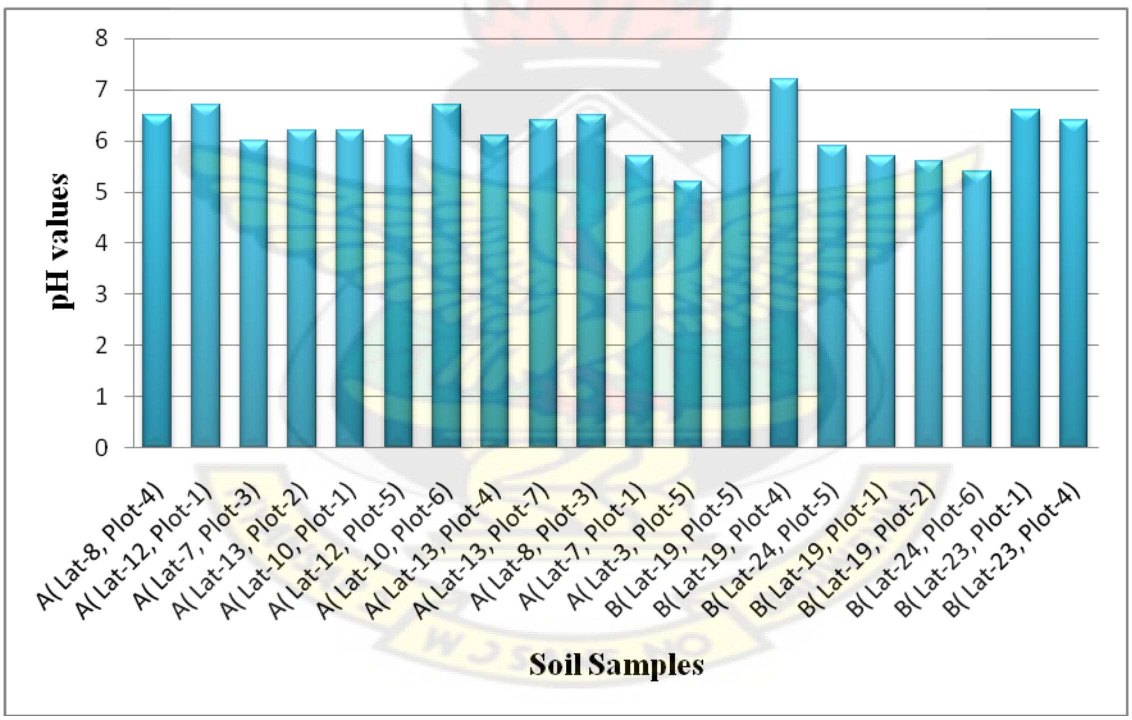

Fig. 6: pH of soil samples

4.4.2.1.2 Temperature

The temperature values of the soils from the sites in Fig. 7 ranged between 27.0 to 28.0 ˚C. Area A (Lat-8, Plot4) had the lowest value of 27.0 ˚C and Area A (Lat-7, Plot-1) had the highest. All the temperature values were relatively above room temperature.

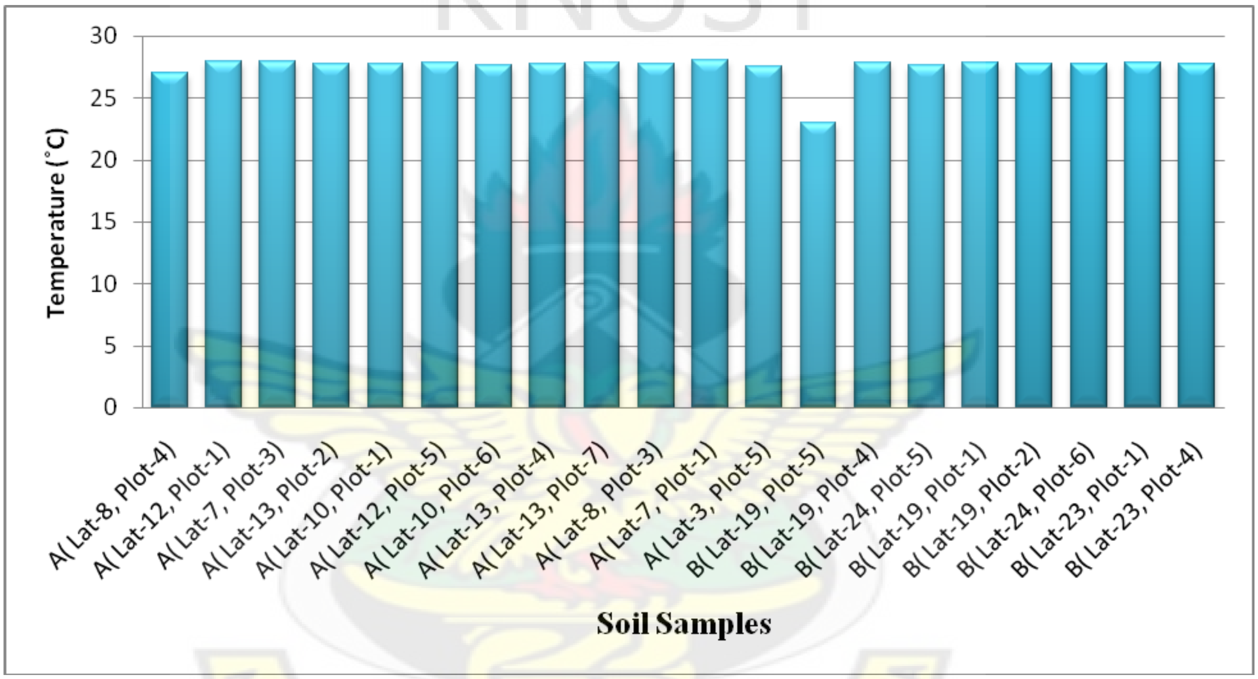

Fig. 7: Temperature of soil samples

4.4.2.1.3 Electrical Conductivity

The values of all the EC values of the soil samples from the field Fig. 8 ranged between 0.002-1.446 dS/m. The soil sample from Area A (Lat-10, Plot-6) had the highest value of 1.446 whereas Area A(Lat-13, Plot-7), Area B(Lat-19, Plot-5) and Area B(Lat-24, Plot-4) had the lowest of 0.002 dS/m.

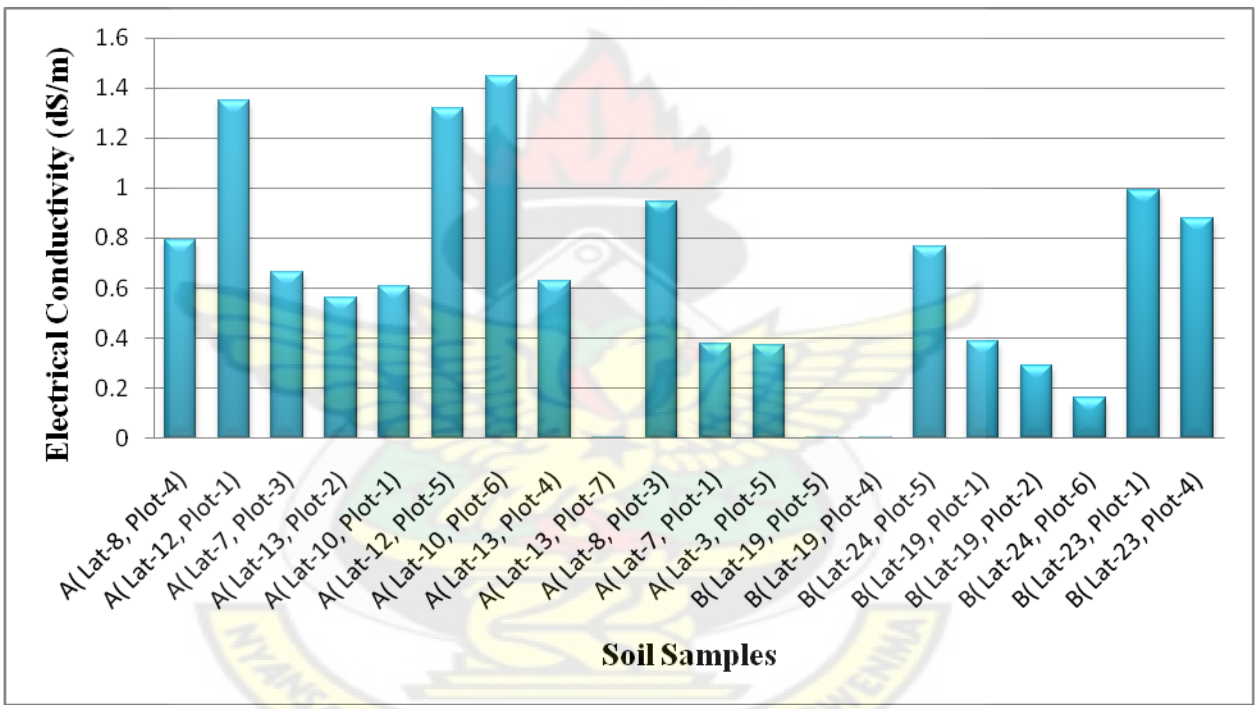

Fig. 8: **Electrical conductivity of soil samples**

4.4.2.2 Heavy Metals Analysis in Soil Samples

4.4.2.2.1 Cadmium in Soil

The total concentration of Cd in the soil samples collected from the various sites in Fig.8 ranged between 0.03 mg/kg - 0.47 mg/kg. The highest value 0.47 mg/kg was at Area B (Lat-24, Plot-4) whilst the lowest value 0.03 mg/kg was at Area A (Lat-7, Plot-3). However, according to FAO guide- lines for crop production, the total Cd in the soil should not exceed 3 mg/kg. Indeed, all the values found in the soil samples were far below the FAO limit. Thus, the total Cd in the soil samples may not be harmful to rice and human beings when used for rice production.

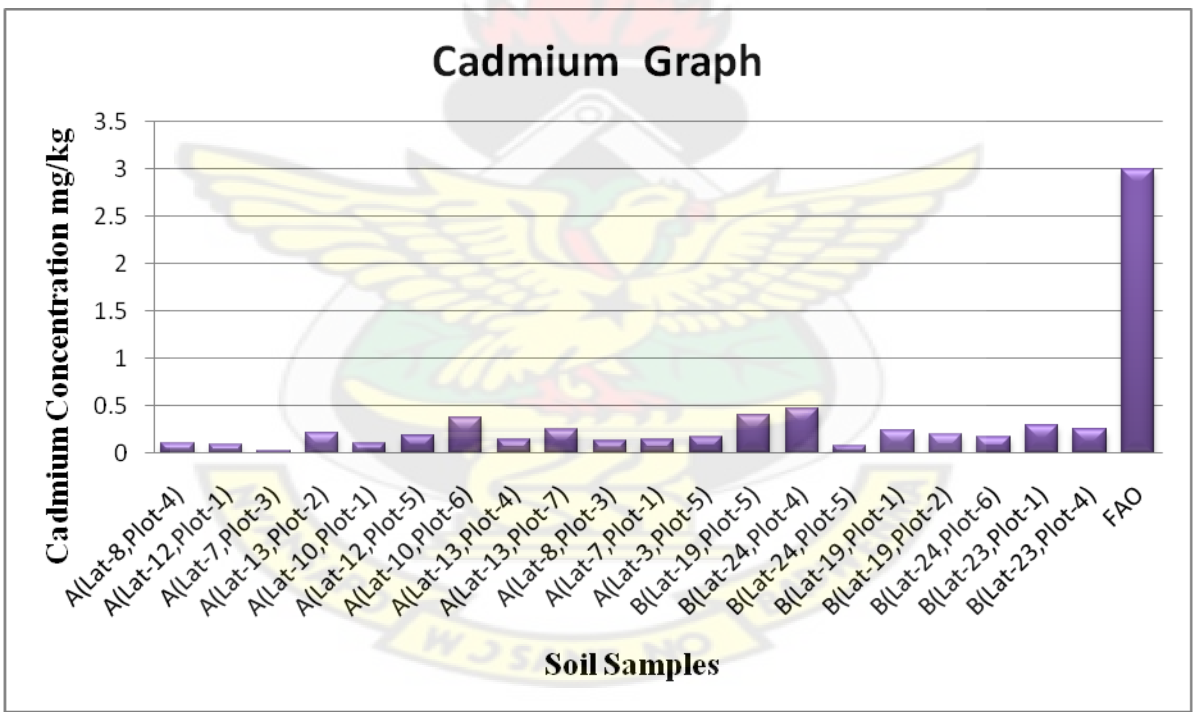

Fig. 9: Cadmium Presence in the soil samples

4.4.2.2.2 Lead in Soil

The total concentration of Pb in the soil samples at the various sites in Fig. 9 ranged between <0.01- 1.74 mg/kg. However, according to FAO permissible values for crop production, Pb should not exceed 300 mg/kg. Since, the Pb concentrations in the soil samples were very far below the FAO recommended limit and the soils at the sites might be considered safe for rice production.

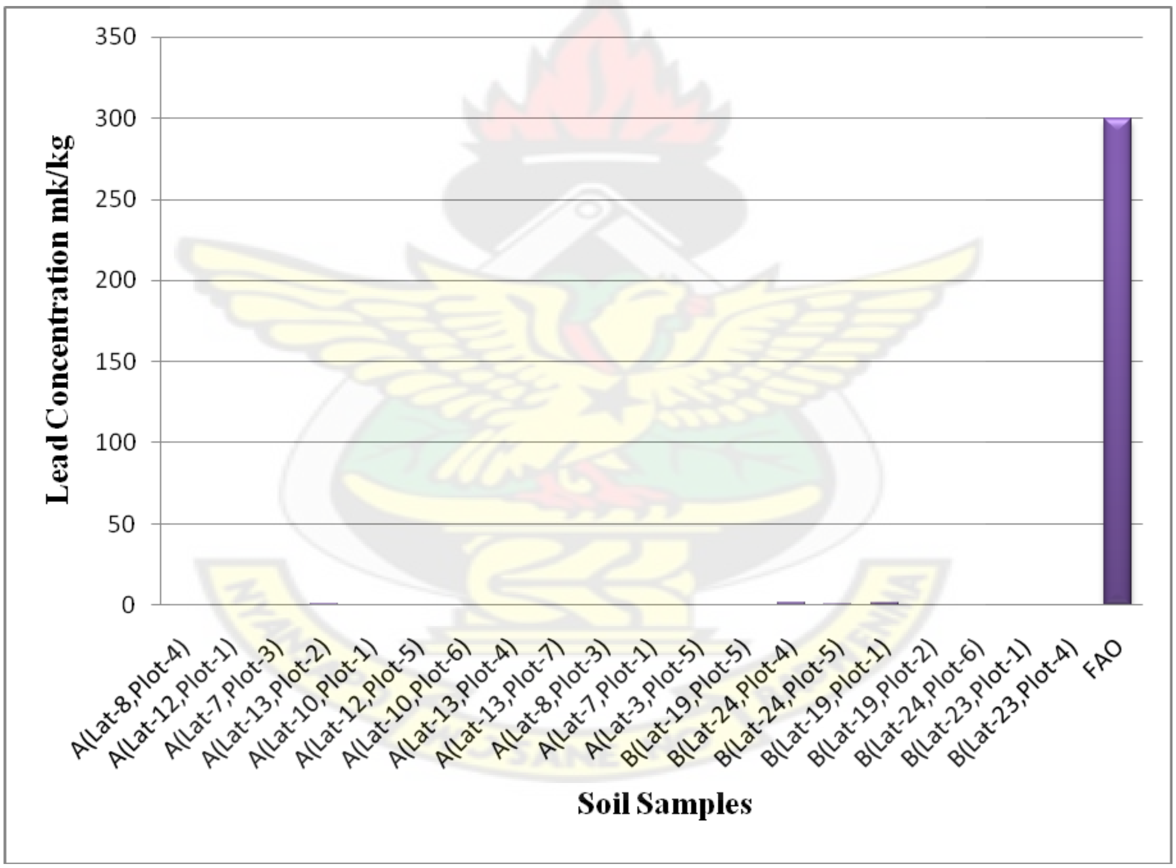

Fig. 10: Lead Presence in soil samples

4.4.3 Rice Grain Samples Analyses

4.4.3.1 Heavy Metals Analyses in rice grain samples

4.4.3.1.1 Cadmium (Cd) in Rice Grain

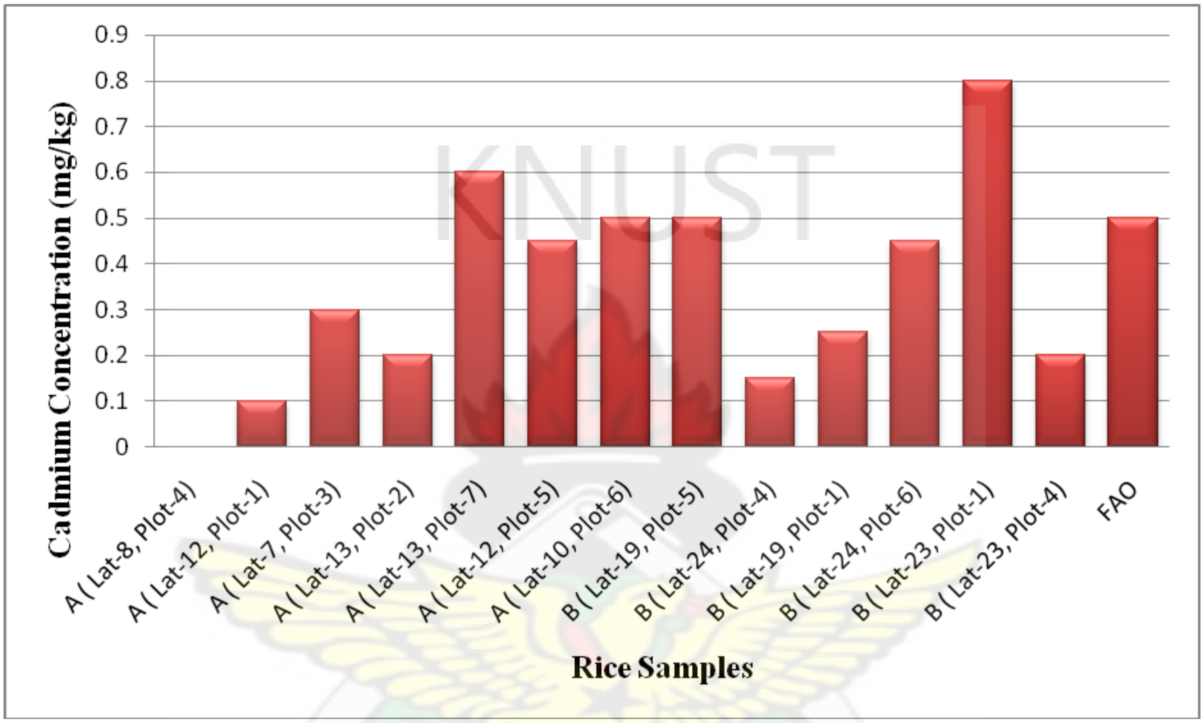

Fig. 11: Cadmium Presence in rice samples

The concentration of Cd in the rice grain samples at the various sites in Fig. 10 ranged between <0.002 mg/kg at Area A (Lat-8, plot-4) to 0.80 mg/kg at Area B(Lat-23, Plot-1). According to the WHO permissible limit, the Cd concentration in the rice grain should not exceed 0.5 mg/kg. This means that the rice grains from Area A (Lat-13, Plot-7) and Area B (Lat-23,Plot-1) which had 0.6mg/kg and 0.80mg/kg far exceeded the WHO limit. The high values in the rice grain might be due to the soils low pH (<7), application of fertilizers and wastewater from the mining sites which is used for rice production This is because according to (Baker *et al.*,1979; Garcia *et* *al.*,1979; Kosla ,1986; Peles *et al*.,1998; Gallardo-Lara *et al.*,1999; Amfo-Otu, 2007) some human activities which releases Cadmium in to the soil included the use of commercially available fertilisers and the disposal of sewage sludges, re-incorporation of crop residues and atmospheric fallout. And also, the application of wastewater from mining sites for irrigation (Madyiwa, 2006). Besides, (Li and Wu, 1999; Sipitey,2007) stated that one of the factors which significantly influences cadmium concentrations in soils and its uptake into plant tissues is pH (when soil pH is < 7). When soil pH decreases, cadmium is desorbed from organic and clay particles and ends up in soil solution and become more mobile. At higher pH (>7), Cadmium remains adsorbed and that metals in solution precipitates out in the form of salts (Chen et al., 1997; Sipitey, 2007). In addition, higher pH results in Lower Cd uptake (John and VanLaer hoven, 1972; Sipitey, 2007). Certain plants like rice and other cereal grains take up cadmium more avidly than they do other heavy metals such as lead and mercury (Satarag *et al.*, 2003; ATSDR, 1999). This might account for the high values of Cd in the rice grains. Hence, the rice grain might not be considered safe for human consumption.

4.4.3.1.2 Lead in Rice Grain

The concentration of Pb in the rice grain samples from the various sites in Fig. 11 ranged between <0.01 - 5.25 mg/kg. The lowest value was at Area A (Lat-8, Plot-4), Area A (Lat-12, Plot-1) and Area B (Lat-19, Plot-5), and the highest value was at Area B (Lat-24, Plot-6). According to WHO permissible limit, the Pb in the rice grain must not exceed 3 mg/kg. This means that rice grains from Area A (Lat-7, Plot-3), Area B (Lat-24, Plot-6) and Area B (Lat-23, Plot-1) which had concentration of 3.6 mg/kg, 3.6 mg/kg and 3.3 mg/kg Pb far exceeded the WHO permissible limit. The higher values in the rice grain might be due to the acidic nature of the irrigated soil. pH is one of the factors which may influences the content and distribution of Pb in soils (Lee *et al*.,1997;Sipitey, 2007). Under acidic soil condition, there is desorption of lead into solution making it available for uptake by plants or vegetables. Lead desorption into the soil solution increases its mobility through the profile (John and VanLaerhoven, 1972; Cataldo *et al*.,1981; Chen *et al*.,1997; Peles *et al*.,1998; Li and Wu,1999; Sipitey,2007). Thus, this increased mobility of Pb makes it readily available for uptake by the roots of the rice plant.

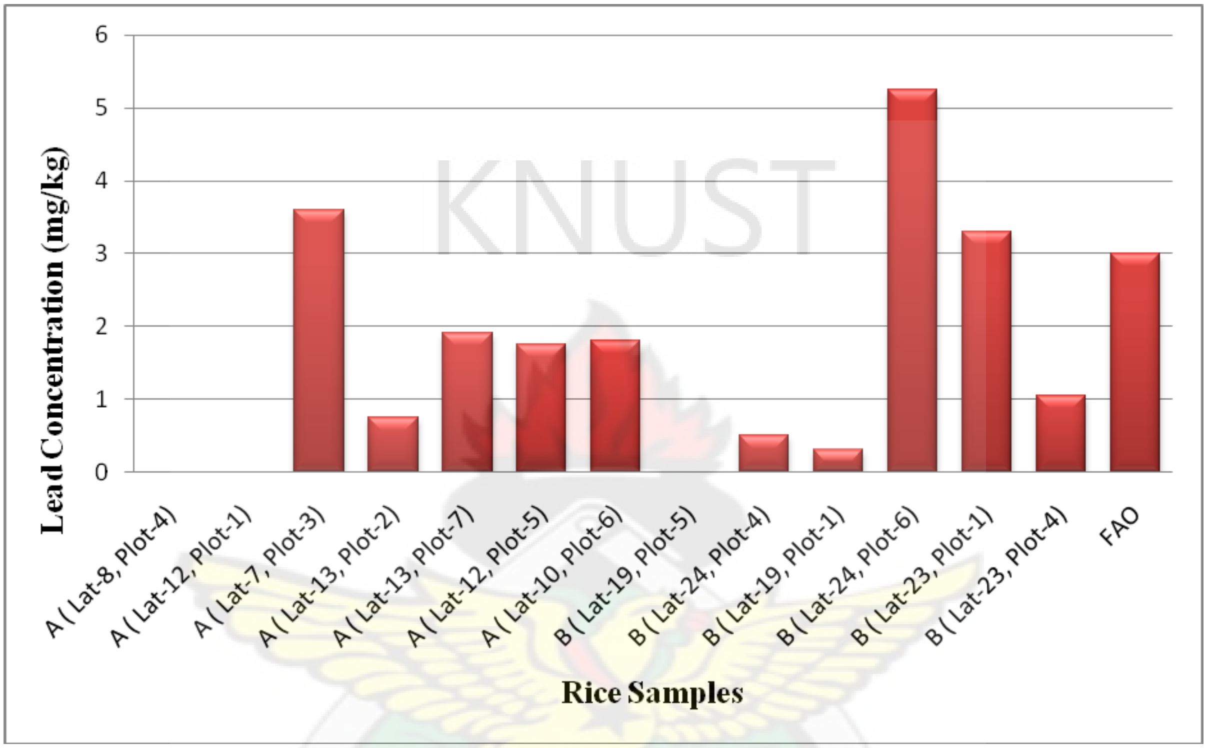

Fig. 12: Lead Presence in rice samples

4.5 Transfer factor (TF)

Transfer factor is the ratio of the heavy metal concentration in the crop to the total heavy metal concentration in the soil at the site (Smith, 1996; Chamberlain, 1983; Harrison *et al*, 1989; Sipitey, 2007). It indicates the amount of heavy metals in the soil that actually ended up in the rice grain.

TF $= C_{HMCr} / C_{THMS}$

C_{HMCr} = **Heavy Metal Concentration in Crop (mg/kg)**

C_{HMS} = **Total Heavy Metal Concentration in the Soil (mg/kg)**

4.5.1 Cadmium transfer factor (CTF)

From the various plots/areas (Table 4.T), the transfer factor ranged from 32% - 1000%. The highest value was at Area A (Lat-7, Plot-3) and the lowest value was at Area B (Lat-24, Plot-4). This goes to establish the fact that certain plants like rice, take up cadmium more avidly than they do other heavy metals such as lead and mercury (Satarag *et al*. 2003; ATSDR, 1999).

- **Area B (Lat-24, Plot-4) has the lowest CTF value :**

Cadmium Transfer Factor (CTF) $= C_{CR} / C_{CS}$

C_{CR} = **Concentration of Cadmium in Rice grain=0.15mg/kg,**

C_{CS} = **Concentration of Cadmium in the Soil =0.47mg/kg,**

CTF $= C_{CR} / C_{CS}$ **= (0.15mg/kg) / (0.47mg/kg)**

= 0.319

CTF (%) = 32 %

- **<u>Area A (Lat-7, Plot-3) has the highest CTF value :</u>**

Cadmium Transfer Factor (CTF) = $\mathbf{C_{CR} / C_{CS}}$

$\mathbf{C_{CR}}$ **= Concentration of Cadmium in Rice grain=0.3mg/kg,**

$\mathbf{C_{CS}}$ **= Concentration of Cadmium in the Soil =0.03mg/kg,**

CTF = $\mathbf{C_{CR} / C_{CS}}$ **= (0.3mg/kg) / (0.03mg/kg)**

= 10

CTF (%) = 1000%

4.5.2 Lead transfer factor (LTF)

Again, from the various plots/areas (Table 4.T), the transfer factor ranged from 21% - 17500%. The highest value was at Area B (Lat-24, Plot-6) and the lowest value was at Area B (Lat-19, Plot-1). This goes to establish the fact that the rice plant is one of the potential cleaners of contaminated soils but also major sources of contamination for animals and human beings, if the plant is consumed (Moonlenar and Lexmond, 1999; Madyiwa, 2006).

- **<u>Area B (Lat-19, Plot-1) has the lowest LTF value :</u>**

Lead Transfer Factor (LTF) = $\mathbf{C_{CR} / C_{CS}}$

C_{CR} = Concentration of Lead in Rice grain=0.3mg/kg,

C_{CS} = Concentration of Lead in the Soil =1.46mg/kg,

LTF = C_{CR} / C_{CS} = (0.3mg/kg) / (1.46mg/kg)

= 0.205

LTF (%) = 21%

- **Area B (Lat-24, Plot-6) has the highest LTF value :**

Lead Transfer Factor (LTF) = C_{CR} / C_{CS}

C_{CR} = Concentration of Lead in Rice grain=5.25mg/kg,

C_{CS} = Concentration of Lead in the Soil =0.03mg/kg,

LTF = C_{CR} / C_{CS} = (5.25mg/kg) / (0.03mg/kg)

= 175

LTF (%) = 17500%

Table 4.T Transfer factor

Sample No.	Area (ha)	Transfer Factor (%)	
		Cd	**Pb**
1.	A (Lat-8, Plot-4)	-	-
2.	A (Lat-12, Plot-1)	111	-
3.	A (Lat-7, Plot-3)	1000	1895
4.	A (Lat-13, Plot-2)	91	71
5.	A (Lat-13, Plot-7)	240	864
6.	A (Lat-12, Plot-5)	237	-
7.	A (Lat-10, Plot-6)	132	-
8.	B (Lat-19, Plot-5)	125	-
9.	B (Lat-24, Plot-4)	32	29
10.	B (Lat-19, Plot-1)	104	21
11.	B (Lat-24, Plot-6)	265	17500
12.	B (Lat-23, Plot-1)	267	-
13.	B (Lat-23, Plot-4)	77	-

Nil = -

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Introduction

In this Chapter, conclusions are drawn from the results and discussions and the necessary recommendations are also made.

Rice which is an important staple food in Ghana with consumption per capita of 35-37 kg per annum has a consumption growth rate of 3.3%. It has been realised that only 20% of the rice consumed annually is produced locally is produced locally with the remaining 80% imported from outside the country (MOFA, 2006). The Anum Valley Rice Project, which is one of the 22 active rice irrigation project in Ghana has an average project yield of 3.5 tonnes/hectare (Anum Valley Project Report, 1996).

5.2 Conclusions

This research has attempted to analyse the questionnaires from the selected areas and also, the analyses of various concentrations of Cadmium and Lead in the various samples from the sampling points have been done. Based on the outcome of the research, the following conclusions have are drawn**:**

5.2.1 For the Analysis of Questionnaires

- All the wastewater from the mechanic shops at Konongo, which uses chemicals like gasoline, diesel, lead, acid, grease and solder to service their vehicles, are discharged in to the Oweri river. This practice affects the quality of the irrigation water.
- All the wastewater from the Ghana Water Company Limited at Nobewam, which uses chemicals like aluminum sulphate, calcium hydrochlorate, hydrated lime and potassium at the plant, are discharged into the Anum river. This practice also affects the quality of the irrigation water.

- All the wastewater from the “Galamsey” sites, which uses chemicals like mercury are discharged into the Oweri River. Hence, they could affect the quality of the irrigation water.

5.2.2 For the Analysis of Samples

- Electrical Conductivity, pH and temperature of the irrigation water quality were analysed and :
- Some parameters of the irrigation water exceeded the FAO/WHO recommended values.
- The EC values of the irrigation water ranged between 17.34 - 113.6 dS/m as against the WHO/FAO recommended value of 3.0 dS/m.
- The pH values of the irrigation water ranged between 1.1 - 1.7 as against the WHO/FAO recommended value of 6.5-8.4 indicating very acidic environment.
- All the two heavy metals, lead and cadmium were present at all the sampling sites.

- Some of the concentrations of both cadmium and lead in the rice grains and soil samples exceeded the FAO/WHO recommended values.

- The concentration of Pb in the rice grain samples from the various sites ranged between <0.01 - 5.25 mg/kg as against the WHO/FAO recommended value of 3 mg/kg.

- The concentration of Cd in the rice grain samples from the various sites ranged between <0.002 mg/kg - 0.80 mg/kg as against the WHO/FAO recommended value of 0.5 mg/kg.
- The concentration of Pb in the soil samples from the various sites ranged between <0.01 - 1.74 mg/kg as against the WHO/FAO recommended value of 300 mg/kg.

- The concentration of Cd in the soil samples from the various sites ranged between 0.03 mg/kg - 0.47 mg/kg as against the WHO/FAO recommended value of 3 mg/kg.
- The concentration of Pb in the water samples from the various sites ranged between <0.01 - 0.372 mg/l as against the WHO/FAO recommended value of 5 mg/l.
- The concentration of Cd in the water samples from the various sites ranged between <0.002 - 0.063 mg/l as against the WHO/FAO recommended value of 0.01 mg/l.
- Recorded transfer factors for both the cadmium and lead ranged between 32% - 1000% and 21% - 17500%.

5.3 RECOMMENDATIONS

Based on the outcome of the research conducted and conclusions, the following recommendations have been proposed**:**

- The mechanics at Konongo needs to be made aware that their wastewater which is discharged into Oweri river after servicing their vehicles pollutes the river, and therefore should be made to move further away from Oweri river to avoid further pollution. Otherwise an efficient wastewater management system should be devised.
- There should also be further research to evaluate the level of mercury heavy metal in the irrigation water and rice grain, since it is the main chemical used to process the gold at the *"Galamsey*" sites as well as
- Evaluate the level of other toxic heavy metals Nickel, Zinc and Chromium in the irrigation water
- There should be a proper and efficient wastewater management system at the Ghana Water Company Limited at Nobewam to reduce the contamination from their wastewater discharged into the river.
- The management of the Anum Valley Irrigation Project should be encouraged to carry out periodic quality tests on the irrigation water to ensure that they do not exceed the FAO permissible limits.

REFERENCES

1. Abrahams, P.W. 2002. *Soils: Their implications to human health*, Science of the Total Environment 291, pp. 1–32.
2. Adu, S. V. 1992. *Soils of the Kumasi Region of Ghana.* Soil Research Institute, Kwadaso, Kumasi. 141 pp.
3. Adriano, D.C., 1986. *Trace Element in the Terrestrial Environment*. Springer-Verlag, Heidelberg. 43 pp.
4. Agency for Toxic Substances and Disease Registry (ATSDR), Case Studies in Environmental Medicine (2007). US Department of Health and Human Services, Public Health Service. 205-99-0606. 4 pp.
5. Agodzo, S.K., Huibers, F.P., Chenini, F., van Lier, J.B. and Duran, A. 2003. *Use of Wastewater in irrigated agriculture*.Country Studies from Bolivia, Ghana and Tunisia. Volume 2: Ghana. WUR, Wageningen, The Netherlands, 71 pp.
6. Alloway, B.J., 1990. *Heavy Metals in Soils*. Blackie, London. pp78.
7. Al-Hassan, R. and Jatoe, J.B.D 2002. *Adoption and Impact of Improved cereals varieties in Ghana.* Paper prepared for the workshop on the revolution in Asia and its Transferability to Africa. Organised by Foundation for Advanced studies in International Development (FASID), from 8th to 10th December, 2002 in Tokyo, Japan. 1 pp.
8. Amfo-Out, R. 2007. *Behaviour of Lead and Cadmium concentration from Irrigation waterin Soils at Five urban irrigation sites in Ghana.* Unpublished Postgraduate Thesis, Department of Civil Engineering, KNUST – Kumasi.
9. Anum Valley Project Report, 1999. GIDA, ACCRA, 3 pp.
10. Anum Valley Project Report, 2004. GIDA, ACCRA, 1 pp.
11. ATSDR. 1999a. *Toxicological Profile for Cadmium.* US Department of Health and Human Services, Public Health Service. 205-93-0606. 9 pp.

12. ATSDR. 1999b. *Toxicological Profile for Cadmium.* US Department of Health and Human Services, Public Health Service. 205-93-0606. 9 pp.

13. Baker, D.E., Amacher, M.C., Leach, R.M. 1979. Sewage *sludge as a source of cadmium in soil –plantation systems.* Environmental Health Perspective 28:45-91.

14. Balba, A., Shibiny, G. and El-Khatib, E. 1991. *Effect of Lead Increments on the Yield and Lead Content of Tomato Plants*. Water, Air, and Soil Pollution 57-58, 93-99.

15. Bauder, T.A., Waskom, R.M. and Davis, J.G. 2008. *Irrigation Water Quality Criteria.* Colorado State University Extension Service. Cited (17th February, 2009) available from Internet http://www.ext.colostate.edu/pubs/crops/00506.pdf.

16. Bellinger, D., Leviton, A., Slowman, J., 1990. *Antecedents and correlates of improved cognitive performance in children exposed in utero to low levels of lead*. Environ. Health Perspective. 89: 5–11.

17. Birley, M.H. and Lock, K. 2001. *A review of the Health Impacts of Peri-urban natural resource development.* International Centre for Health Impact Assessment Liverpool School of Tropical Medicine. Draft. Pembroke Place, Liverpool, England. Draft. 13 pp.

18. Bjuhr, J. 2007 . *Trace Metals in Soils irrigated with wastewater in peri-urban area downstream Hanoi City, Vietnam.* Department of Soil Sciences, SLU. Examens-och seminariearbeten/sveringes lantbruksuniversitet, Institutionen for markvetenskap, Avdelningen for markkenmi och jordmanslara vol.79. Cited (2nd January, 2008) Available from the internet (http://ex-epsilon.slu.se/archive/00001518/01/Josefs_Exjobb_Final.pdf

19. Bocca, B., Alimonti, A., Petrucci, F., Violante, N., Sancesario, G., and Forte, G. 2004. *Quantification of trace elements by sector field inductively coupled plasma spectrometry in urine, serum, blood and cerebrospinal fluid of patients with Parkinson's disease*, Spectrochim Acta *Part B* **59**, pp. 559–566.

20. Brooks, R.R .1972. *Geobotany and Biogeochemistry in mineral exploration*, Hasper and Raw, New York. 13 pp.
21. Cameron, K.C., Di, H.J., McLaren, R.G., 1997. *Is soil an appropriate dumping ground for our wastes*? Aust. J. Soil Resources. 35: 995–1035.
22. Cataldo, D., Garland, T. and Wildung, R. 1981. *Cadmium Distribution and Chemical Fate in Soyabean Plants*. Plant Physiology 68: 835-839.
23. Cheng, W., Zhang, G., Yao, H., Wu, W., and Xu, M (2006) *Genotypic and environmental variation in cadmium, chromium, arsenic, nickel, and lead concentrations in rice grains* . Journal of Zhejiang University Sciences 7(7): 565–571.
24. Chamberlain, A.C. 1983. *Fallout of Lead and Uptake by Crops*. J. Atmos. Environ., 17: 693-706.
25. Cornish, G., Mensah, E. and Ghaesquire, P. 1999. *Water Quality and Peri-urban Irrigation.* An assessment of surface water quality for irrigation and its implication for human health in the Peri-urban Zone of Kumasi, Ghana. Wallingford, UK: Department for International Development(DFID) Report OD/T 95. 16 pp.
26. Dietrich, K.N., Succop, P.A., Bornschein, R.L., Kraft, K.M., Berger, O., Hammond, P.B., Buncher, C.R., 1990. *Lead exposure and neurobehavioral development in later infancy*. Environ. Health Perspective. 89, 13–19.
27. Ellen, G., Loon, J.W., and Tolsma, K. (1990) *Heavy Metals in Vegetables Grown in the Netherlands and in Domestic and Imported Fruits*. Z Lebensm Unters Forsch,190:34-39.
28. Elson, M. and Haas, E. M. 2003. *The Complete guide to diet and nutritional medicine*. Excerpt from staying healthy with Nutrition. File // A: Health World Online-minerals-cadmium.htm.
29. Eslami, A., Khaniki, J. Gh. R.., Nurani, M., Mehrasbi, M., Peyda, M., and Azimi, R. (2007) *Heavy Metals in Edible Green Vegetables Grown Along the Sites of the Zanjanrood River in Zanjan, Iran.* Journal of Biological Sciences 7 (6): 943-948.
30. FAO, 1992. *Wastewater treatment and use in agriculture* by Pescod, M.B. Irrigation and Drainage Paper 47. FAO, Rome. 2 pp.

31. FAO. 1984. *Plant Production and Protection Series-Agrochmatological Data for Africa. Countries north of the Equator.* FAO, Rome. 1(22): 8 pp.

32. Fergusson, J.E., and Ryan, D.E. 1984. *The elemental composition of street dust from large and small urban areas related to city type, source and particle size,* Science of the Total Environment 34, pp. 101–116.

33. Galvao L. Y G.C. 1987, Cadmio *serie vigilancia Centro Panamericano de Ecologia Humana y Salud OPS y OMS Metepec Edo. de Mexico,* Mexico. No. 4. 41 pp.

34. Galvao L. Y G.C. 1987. *Plomo serie vigilancia Centro Panamericano de Ecologia Humana y Salud OPS y OMS Metepec Edo. de Mexico*, Mexico. No. 8. 41 pp.

35. Gallardo-Lara, F., Azcon, M., Quesda, J.L., Polo, A. 1999. Phytoavailability *and extractability of copper and zinc in calcareous soil amended with composted urban wastes*. J. Environ Sci Health B 34(6): 1049-64.

36. Garcia, W.J., Blessin, C.W., Sandford, H.W and Inglet, G.E. 1979. *Translocation and accumulation of seven heavy metals in tissue of corn plants grown on sludge-treated strip-mined soil*. J. Agric Food Chem 27(5):1088-94.

37. Gimeno-García, E; Andreu, V; Boluda, R. (1996) *Heavy metals incidence in the application of inorganic fertilizers and pesticides to rice farming soil*. Environmental Pollution. 92(1):19–25.

38. Grant, CA; Buckley, WT; Bailey, LD; Selles, F. (1998) *Cadmium Accumulation in crops.* Can Journal Plant Science; 78:1–17.

39. Gray, C.W., McLaren, R. G., Roberts, A.H.C. 2003. *Atmospheric accessions of heavy metals to some New Zealand Pastoral Soils.* The Science of the Total Environment, 305:105-115.

40. Han, Y., Du, P., Cao, J., and Posmentier, E.S. (2006) *Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Central China,* Science of the Total Environment **355** , pp. 176–186.

41. Harrison, R.M. and Chirgawi, M.B. 1983. *The assessment of air and soil as contributors of some trace metals to vegetable plants I*. Use of a filterate air growth cabinet. Sci. Total Environ. 83: 13-34.

42. Ibarra, V., Gomez, R., and Arriaga, R. M. 1998. Cadmium and Lead in agricultural soil of Santiago Ixcuintla nayarit, MEXICO. 7 pp.

43. *Industrial Effluents as a source of Drinking water contamination.* Cited (4th February, 2008) available on the internet (http://extoxnet.orst.edu/faqs/safedrink/indust.htm.)

44. IARC (1976) *Cadmium, nickel, some epoxides, miscellaneous industrial chemicals and general considerations on volatile anaesthetics*. Lyon, International Agency for Research on Cancer, pp. 39–74 (IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man, Vol. 11).

45. Johannesson, M. 2002. A *review of risks associated to Cadmium, Lead, Mercury and Zinc* p.62. Appendix A in Johannesson, M.ed Etal (2002). *The Market Implication of Integrated Management for Heavy Metals flows for Bio energy use in the European Union*. Kalma University, Department of Biology and Environmental Science, Kalmar, Sweden. 115 pp.

46. Kelly, J., Thornton, I., and Simpson, P.R. 1996. *Urban Geochemistry: a study of the influence of anthropogenic activity on the heavy metal content of soils in traditionally industrial and non-industrial areas of Britain*, Applied Geochemistry 11: 363–370

47. Kyei-Baffour, N. and Ofori, E. 2006. *Irrigation development and management in Ghana.* Journal of Science and Technology. 26(2):148-159.

48. KaduKova, J., Manousaki, E., Kalogerakis, N. 2006. *Lead and Cadmium Accumulation from contaminated soils by Nerium Oleader.* Acta Metallurgica Slovaca, 181-187.

49. Kosla, T. 1986. *Studies of the levels of copper and zinc in the soil, grass and blood serum and hair of bulls from the area irrigated with wastewater from the Ner River*. Pol Arch Water 25(1): 145-54.

50. Lee, B.D., Carter, B.J., Basta, N.T and Weaver, B. 1997. *Factors influencing heavy metal distribution in six Oklahoma benchmark soils*. Soil Sci. Soc. Am.J.61: 218-223.

51. Li, L and Wu, G. 1999. *Numerical Simulation of Transport of Four Heavy Metals in Kaolinite Clay*. J. Environ Engineering 125(4): 314-324.

52. LuptaKova A., Gesperova D., Kupka, D. 2002. *The Selective chemical-biological precipitation of Cu and Cd from solutions,* in : Fecko, P., Cablik, V. (Eds) Proceedings of 6th Conference on Environment and Mineral Processing, Part 2, Ostrava, 509-514.

53. Marschner, H.(1995) *Mineral Nutrition of Higher Plants*. London: Academic Press. 2 pp.

54. McLaughlin, MJ; Parker, DR; Clarke, JM. (1996) *Metals and micronutrients-food safety issues.* Field Crops Resources. 60(1-2):143–163

55. Madrid, L., Díaz-Barrientos, E., and Madrid, F. (2002) *Distribution of heavy metal contents of urban soils in parks of Seville, Chemosphere* **49** (2002), pp. 1301–1308.

56. Madyiwa, S. 2006. *Modelling Lead and Cadmium uptake by Star Grass under Irrigation with treated wastewater.* Published Philosophiae Doctor Thesis, University of Pretoria-South Africa. 4 pp.

57. McLaughlin, M.J., Parker, D.R., Clarke, J.M., Welch, R.M., Graham, R.D. 1999.

58. Mensah, I. 2002. *Impact of surface gold mining on surface water quality at Bibiani, Ghana.* Unpublished Postgraduate Thesis, Department of Mineral Processing and Extraction metallurgy, KNUST – Kumasi

59. Mielke, H.W., Gonzalez, C.R., Smith, M.K., and Mielke, P.W. 1999. *The urban environment and children's health: soils as an integrator of lead, zinc and cadmium in New Orleans, Louisiana, USA*, Environmental Research 81, pp. 117–129.

60. Murray, K.S., Rogers, D.T. and Kaufman, M.M. 2004. *Heavy metals in an urban watershed in Southeastern Michigan*, Journal of Environmental Quality 33: 163–172.
61. Möller, A., Müller, H.W., Abdullahm, A., Abdelgawadm, G. and Utermannm, J. 2005. *Urban soil pollution in Damascus, Syria: concentrations and patterns of heavy metals in the soils of the Damascus Ghouta*, Geoderma 124: 63–71.
62. National Small Flows Clearing House (NSFC), 1997. *Wastewater.* Pipeline.Fall 1997, 8(4): pp 1 .Cited (14th February, 2008). Available from internet (http://cobweb.een.purdue.edu/~epados/sceptic/water.htm).
63. Nsiah-Gyabaah, K. 2000. *Changing Patterns in the Peri-urban Environment: Characterisation of Peri-urban Kumasi.* Kumasi Natural Resource Management Research Project (KNRMP). Proceedings of Final Workshop Levine Hall, KNUST, Kumasi. March, 2000. pp38-43.
64. Okyeame, A.A., Manful, G.A., Fleicher, E., Opam, M., and Ameyaw, A. M. 1994.*Climate and Africa-Country Report, Ghana.* UNEP Conference in Nairobi, Kenya. Stockholm Environmental Institute Publishers, 1-42.
65. Omane, O.K. 2002. *Peri-Urban Water Quality Monitoring in the SISA-ODA Catchment, Kumasi.* Kwame Nkrumah University of Science and Technology, Department of Mineral Processing and Extraction Metallurgy, Kumasi-Ghana.

66. Peles, J., Brewer, S. and Barrett, G. 1998. Heavy *Metal Accumulation by Old-field Plant Species During Recovery of Sludge-treated Ecosystems*. The American Midland Naturalist 140(2), 245-251.
67. Perk, Marcel van der. 2006. *Soil and Water contamination from molecular to catchment scale.* Taylor and Francis group plc, London, Uk. 76-78, 125.

68. Rasmussen, P.E., Subramanian, S.K., and Jessiman, B.J. 2001. *A multi-element profile of housedust in relation to exterior dust and soils in the city of Ottawa, Canada,* Science of the Total Environment 267, pp. 125–140.

69. Ros JPM, Slooff W, eds. (1987) *Integrated criteria document. Cadmium*. Bilthoven, National Institute of Public Health and Environmental Protection (Report No. 758476004). 28 pp.

70. Rosen, C. J. 2002. Lead in the home garden and urban environment. Regent of the University of Minnesota. Extention Service office or the Distribution Centre at (800) 876-8636. 14 pp.

71. Rulkens, WH; Tichy, R; Grotenhuis, JJC. 1998. *Remediation of polluted soil and sediment: perspectives and failures*. Water Sci Techn 37(8):27–35. doi: 10.1016/S0273-1223(98)00232-7.

72. Sax, N. and Lewis, Sr. R. 1987. *Hawley's Condensed Chemical Dictionary*. 11th Edition. New York: Van Nostrand Reinhold Co. pp 32.

73. Seregin, IV and Ivanov, VB. 2001. *Physiological aspects of cadmium and lead toxic effects on higher plants*. Russ J Plant Physiol 48(4):523–544. doi: 10.1023/A:1016719901147.29.

74. Shi, G., Chen, Z., Xu, S., Zhang, J., Wang, Li., Bi., C., and Teng, J. (2007***)*** *Potentially toxic metal contamination of urban soils and roadside dust in Shanghai, China.* Environmental Pollution. 156(2) pp251-26*0.*

75. Smith, S.R. 1996. *Agricltural Recycling of Sewage Sludge and the Environment*. Biddles Ltd., Guildford. 23 pp.

76. Stigliani, W.M., Doelman, P., Salomons, W., Schulin, R., Schmidt, G.R.B., and Van Der Zee, S.E.A.T.M. 1991. *Chemical time bombs-predicting the unpredictable*, Environment 33, pp. 4–30.

77. Thomas, J.G. 2009. *Irrigation Water Quality Guidelines For Mississippi.* Mississippi State University Extension Service. Cited (15th February, 2009) available from Internet http://msucares.com/pubs/publications/p1502.htm.

78. Verma, S., Dubey, R.S. 2003. *Lead toxically induces –lipid peroxidation and alters the activities of antioxidation enzymes in growing rice plants.* Plant Science, 645-655.

79. Wang, CX; Mo, Z; Wang, H; Wang, ZJ; Cao, ZH. 2003. *The transportation, time-dependent distribution of heavy metals in paddy crops*. Chemosphere; 50 (6):717–723. doi: 10.1016/S0045-6535(02)00211-4.

80. Waisberg, M., Joseph, P., Hale, B., and Beyersmann, D. 2003. *Molecular and cellular mechanisms of cadmium carcinogenesis*, Toxicology 192, pp. 95–117

81. Ware GW, ed. (1989) Cadmium. US Environmental Protection Agency Office of Drinking Water health advisories. *Reviews of Environmental Contamination and Toxicology*, 107:25–37.

82. Wikipedia (2007). *Thermodynamic property*. Wikimedia Foundation, Inc., U.S. Cited (15th November, 2008) available from Internet (http://en.wikipedia.org/wiki/temperature.html).

83. Wikipedia (2006). *Thermodynamic property.* Wikimedia Foundation, Inc., U.S. Cited (5th October, 2008) available from Internet (http://en.wikipedia.org/wiki/waterquality.html)

84. WHO. 2004. Cadmium in Drinking-water Background document for development of WHO *Guidelines for Drinking-water Quality.*WHO. 45 pp.

85. Zhang, GP; Fukami, M; Sekimoto, H. 2002. *Influence of cadmium on mineral concentrations and yield components in wheat genotypes differing in Cd tolerance at seedling stage*. Field Crops Res 77(2-3):93–98. doi: 10.1016/S0378-4290(02)00061-8

86. Google 2007. *Water Quality.* Cited on (12th September, 2008) available on from Internet (http://www.dep.state.fl.us/evergladesforever/about/glossary.htm) in Google website.

APPENDICES

APPENDIX A: RESULTS OF THE ANALYSIS OF SOIL SAMPLES

Table A.1: Total Concentration of Elements in Soil Samples

Sample No.	Area (ha)	Fe (mg/kg)	Mn (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Mg (mg/kg)	Na (mg/kg)	K (mg/kg)
1.	A(Lat-8,Plot-4)	150.0	5.79	0.11	<0.01	0.88	53.7	13.9
2.	A(Lat-12,Plot-1)	114.1	14.85	0.09	0.30	1.60	63.0	5.1
3.	A(Lat-7,Plot-3)	111.5	3.38	0.03	0.19	0.74	9.1	2.8
4.	A(Lat-13,Plot-2)	115.8	246.10	0.22	1.06	0.57	30.3	9.1
5.	A(Lat-10,Plot-1)	110.5	5.12	0.11	<0.01	1.37	17.4	17.4
6.	A(Lat-12,Plot-5)	114.3	15.01	0.19	<0.01	1.90	25.3	5.5
7.	A(Lat-10,Plot-6)	117.3	126.30	0.38	<0.01	2.83	24.5	4.4
8.	A(Lat-13,Plot-4)	112.8	22.47	0.14	<0.01	0.61	28.6	2.2
9.	A(Lat-13,Plot-7)	114.2	30.24	0.25	0.22	1.84	27.6	3.0
10.	A(Lat-8,Plot-3)	109.0	6.88	0.13	<0.01	0.39	53.6	5.6
11	A(Lat-7,Plot-1)	111.3	4.63	0.14	<0.01	0.70	6.5	3.6
12.	A(Lat-3,Plot-5)	112.3	37.04	0.17	<0.01	0.66	28.0	14.9
13.	B(Lat-19,Plot-5)	118.8	30.71	0.40	0.25	0.50	92.7	4.3
14.	B(Lat-24,Plot-4)	117.4	253.80	0.47	1.74	2.39	26.5	10.8
15.	B(Lat-24,Plot-5)	114.5	9.46	0.08	0.56	0.3	21.4	4.6
16.	B(Lat-19,Plot-1)	115.1	258.2	0.24	1.46	0.37	23.4	9.6
17.	B(Lat-19,Plot-2)	114.5	7.64	0.20	<0.01	0.61	12.5	15.0
18.	B(Lat-24,Plot-6)	111.9	2.62	0.17	0.03	0.42	7.8	8.9
19.	B(Lat-23,Plot-1)	114.4	144.3	0.30	<0.01	1.34	67.0	20.0
20.	B(Lat-23,Plot-4)	116.3	3.78	0.26	<0.01	0.66	61.8	18.0

SOURCE: Field Data (March, 2008) *Lat-Lateral

Table A.2: Physical Properties of Soil Samples

Sample No.	Area	pH	Temp (˚C)	Electrical Conductivity (dS/m)
1.	A(Lat-8, Plot-4)	6.5	27.0	0.791
2.	A(Lat-12, Plot-1)	6.7	27.9	1.348
3.	A(Lat-7, Plot-3)	6.0	27.9	0.663
4.	A(Lat-13, Plot-2)	6.2	27.7	0.562
5.	A(Lat-10, Plot-1)	6.2	27.7	0.605
6.	A(Lat-12, Plot-5)	6.1	27.8	1.321
7.	A(Lat-10, Plot-6)	6.7	27.6	1.446
8.	A(Lat-13, Plot-4)	6.1	27.7	0.629
9.	A(Lat-13, Plot-7)	6.4	27.8	0.002
10.	A(Lat-8, Plot-3)	6.5	27.7	0.947
11.	A(Lat-7, Plot-1)	5.7	28.0	0.375
12.	A(Lat-3, Plot-5)	5.2	27.5	0.369
13.	B(Lat-19, Plot-5)	6.1	23.0	0.002
14.	B(Lat-24, Plot-4)	7.2	27.8	0.002
15.	B(Lat-24, Plot-5)	5.9	27.6	0.765
16.	B(Lat-19, Plot-1)	5.7	27.8	0.387
17.	B(Lat-19, Plot-2)	5.6	27.7	0.291
18.	B(Lat-24, Plot-6)	5.4	27.7	0.161
19.	B(Lat-23, Plot-1)	6.6	27.8	0.989
20.	B(Lat-23, Plot-4)	6.4	27.7	0.881

SOURCE: Field Data (March, 2008)

*Lat-Lateral

APPENDIX B: RESULTS OF THE ANALYSIS OF RICE SAMPLES

Table B.1: Concentration of Cadmium and Lead Heavy Metals in rice grain

Sample No.	Area	Cd (mg/kg)	Pb (mg/kg)
1.	A (Lat-8, Plot-4)	< 0.002	< 0.01
2.	A (Lat-12, Plot-1)	0.10	< 0.01
3.	A (Lat-7, Plot-3)	0.30	3.60
4.	A (Lat-13, Plot-2)	0.20	0.75
5.	A (Lat-13, Plot-7)	0.60	1.90
6.	A (Lat-12, Plot-5)	0.45	1.75
7.	A (Lat-10, Plot-6)	0.50	1.80
8.	B (Lat-19, Plot-5)	0.50	< 0.01
9.	B (Lat-24, Plot-4)	0.15	0.50
10.	B (Lat-19, Plot-1)	0.25	0.30
11.	B (Lat-24, Plot-6)	0.45	5.25
12.	B (Lat-23, Plot-1)	0.80	3.30
13.	B (Lat-23, Plot-4)	0.20	1.05

SOURCE: Field Data (March, 2008)

*Lat-Lateral

APPENDIX C: RESULTS OF THE ANALYSIS OF WATER SAMPLES

Table C.1: Concentrations of Element in Water Samples

Sample No.	Location	Cd (mg/l)	Pb (mg/l)	Fe (mg/l)	Mn (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)
1.	Area B (Nobewam)	<0.002	<0.01	0.261	0.009	8.55	38.4	14.6
2.	Area A-1 (Nobewam)	0.021	<0.01	0.105	0.039	7.71	36.3	15.6
3.	Area A-2 (Nobewam)	0.009	<0.01	0.111	0.027	7.53	55.5	50.0
4.	Mechanics Shop (Konongo)	0.027	0.372	1.05	0.306	4.17	25.7	9.6
5.	"Galamsey" site Upstream (Konongo)	0.027	<0.01	0.279	0.027	5.91	29.6	6.2
6.	"Galamsey" site Downstream (Konongo)	0.036	<0.01	0.264	0.039	5.88	29.4	6.8
7.	Before Waterworks (Nobewam)	0.063	<0.01	0.276	0.381	6.0	29.0	22.3
8.	After Waterworks (Nobewam)	0.057	<0.01	0.753	0.81	5.07	27.4	21.7
9.	Before the Dam (Nobewam)	0.060	<0.01	0.303	0.111	5.97	38.8	12.5
10.	After the Dam (Nobewam)	0.009	<0.01	0.369	0.102	8.52	37.6	12.6
11.	After Downstream Point-1(Konongo)	0.063	<0.01	0.162	0.03	9.57	38.9	10.8
12.	After Downstream Point -2(Konongo)	0.060	<0.01	0.177	0.096	9.96	39.3	10.9

Table C.2: Physical Properties of Water Samples

Sample No.	Location	pH	Temp (˚C)	Electrical Conductivity (dS/m)
1.	Area B-1 (Nobewam)	1.7	24.6	17.34
2.	Area A-1 (Nobewam)	1.4	24.2	67.9
3.	Area A-2 (Nobewam)	1.3	24.6	113.6
4.	Mechanics Shop (Konongo)	1.4	24.7	72.1
5.	"Galamsey" Site Upstream (Konongo)	1.3	24.8	99.6
6.	"Galamsey" Site Downstream (Konongo)	1.3	24.9	84.2
7.	Before Waterworks (Nobewam)	1.5	25.0	90.5
8.	After Waterworks (Nobewam)	1.2	25.5	127.3
9.	Before the Dam (Nobewam)	1.1	25.2	78.7
10.	After the Dam (Nobewam)	1.3	25.3	68.4
11.	After Downstream Point-1 (Konongo)	1.3	25.5	89.0
12.	After Downstream Point-2 (Konongo)	1.5	25.7	30.4

SOURCE: **Field Data (March, 2008)**

APPENDIX D: RESULTS OF THE ANALYSIS OF RICE FARMERS QUESTIONNAIRES

Table D.1: Gender of Rice farmers

Sex	Frequency	Percent
Male	23	76.7
Female	7	23.3
Total	30	100.0

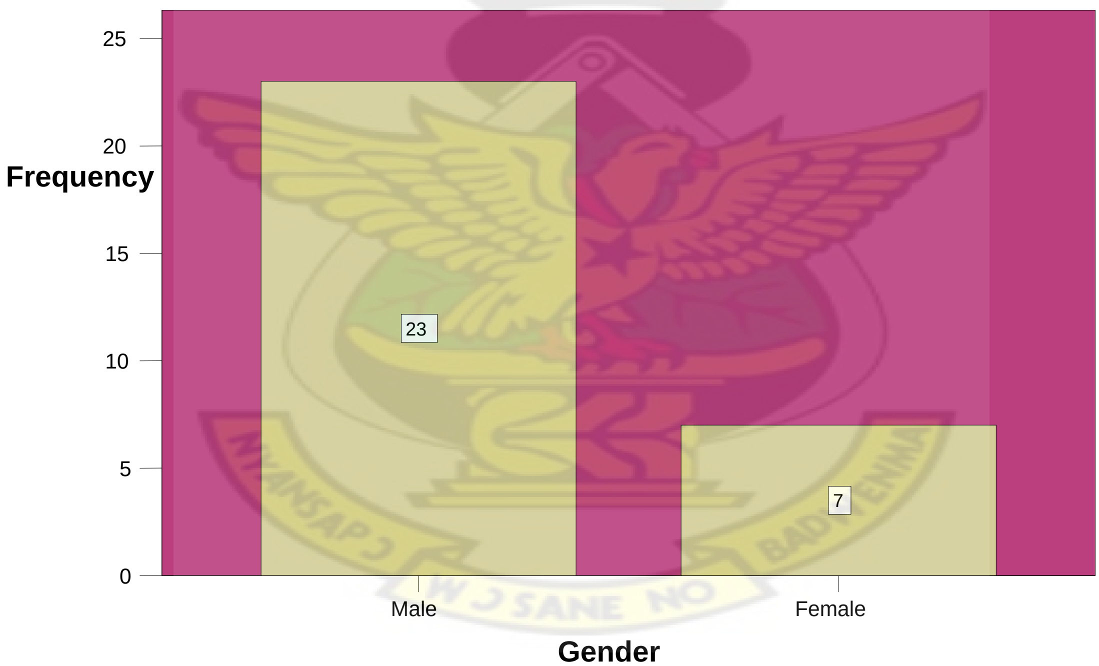

Fig. D.1: Gender of Rice farmers

Table D.2: Age of Rice farmers

Age (years)	Frequency	Percent
21 - 30	1	3.3
31 - 40	8	26.7
> 40	21	70.0
Total	30	100.0

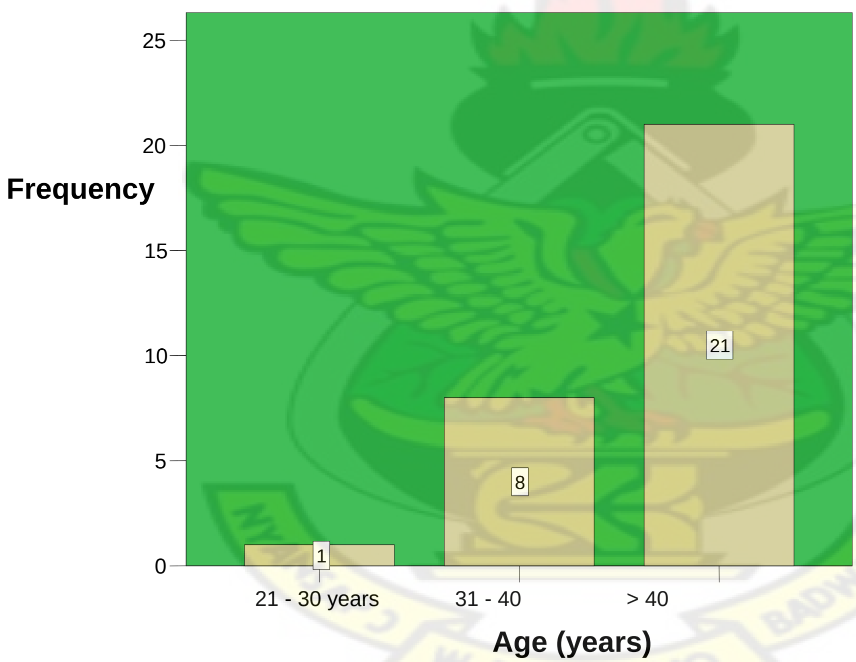

Fig. D.2: Ages of Rice farmers

Table D.3: Farmers Educational Level

Education	Frequency	Percent
Basic (Primary, Middle Sch, J.S.S)	17	56.7
Secondary (S.S.S, O & A Levels)	1	3.3
Tertiary (Polytechnic, University)	2	6.7
None	10	33.3
Total	30	100.0

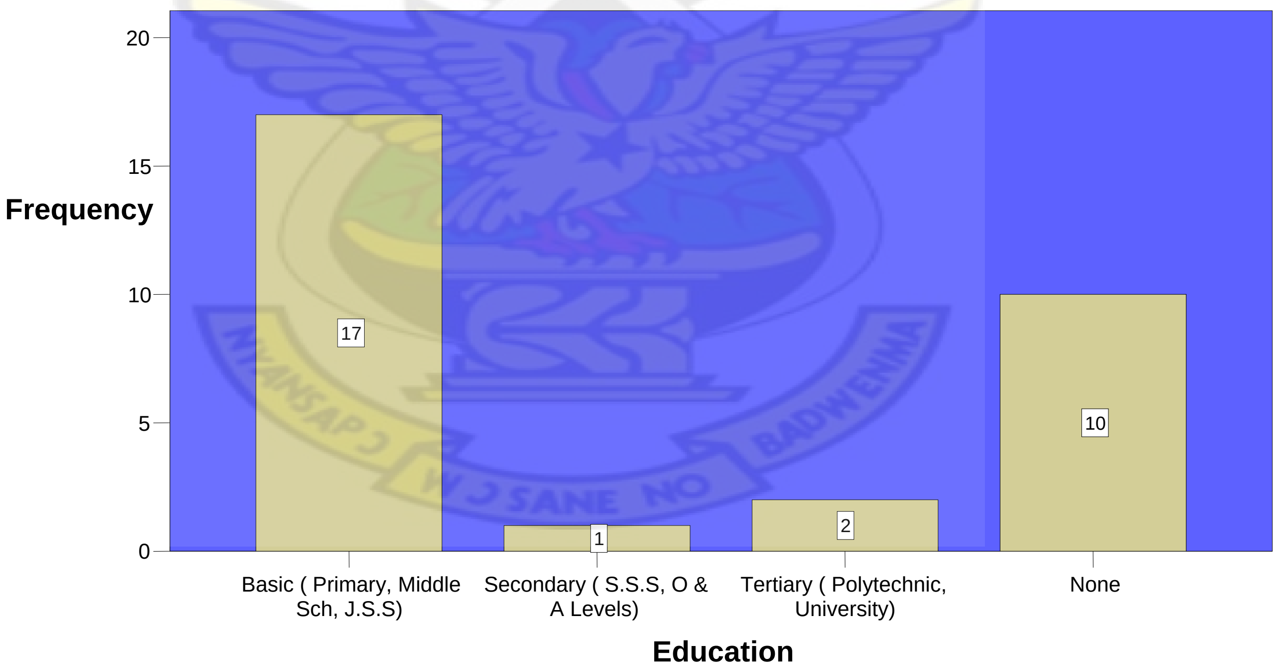

Fig. D.3: Educational Level of Farmers

Table D.4: Size distribution of the farmers farm

Size (ha)	Frequency	Percent
2 Plots / 0.2	1	3.3
4 Plots / 0.4	13	43.3
5 Plots / 0.5	2	6.7
> 5 Plots / 0.5	14	46.7
Total	30	100.0

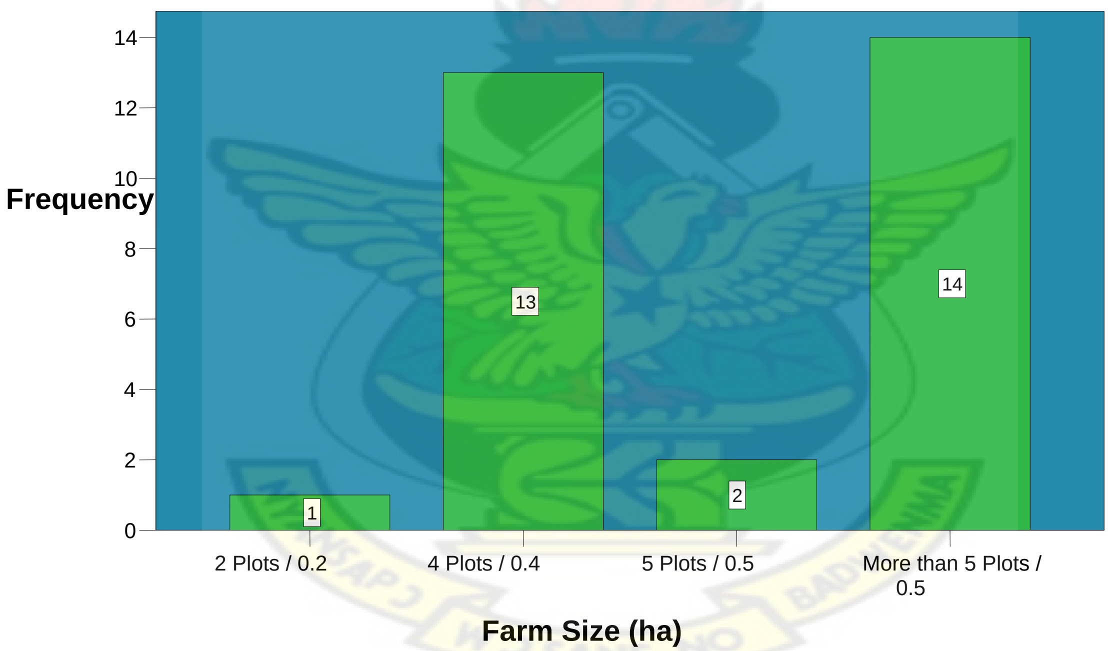

Fig. D.4: Size of farmers farm

Table D.5: The number of years of farming on Plot / Land

Duration (Years)	Frequency	Percent
1 - 4	7	23.3
5 - 8	9	30.0
9 - 12	2	6.7
> 12	12	40.0
Total	30	100.0

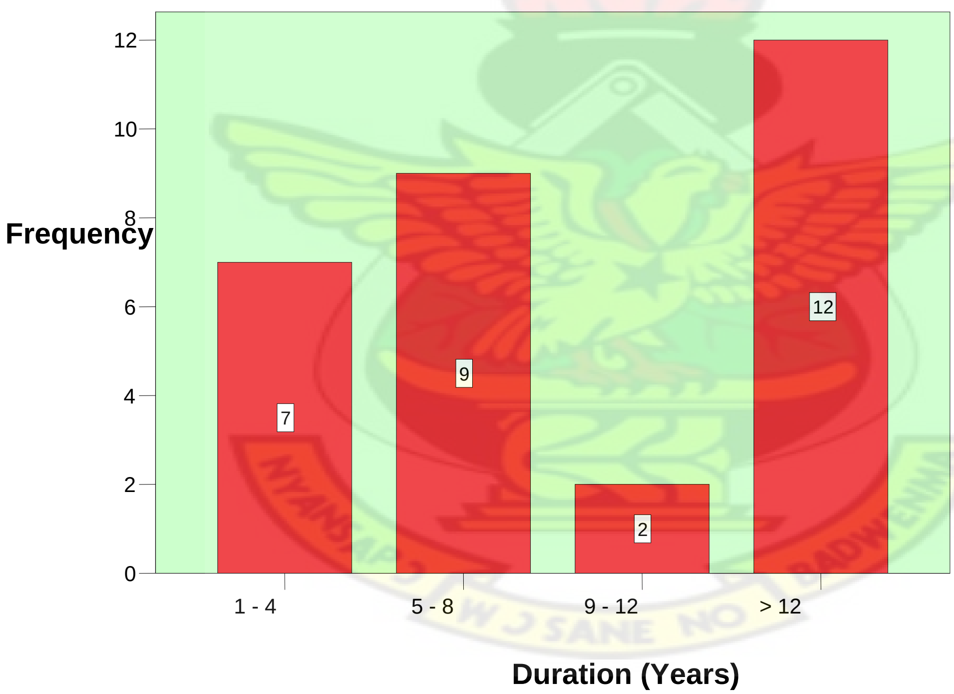

Fig.D.5: The number of years of farming on Plot / Land

Table D.6: Number of times rice is grown in a year

Number of Times	Frequency	Percent
Once	23	76.7
Twice	7	23.3
Total	30	100.0

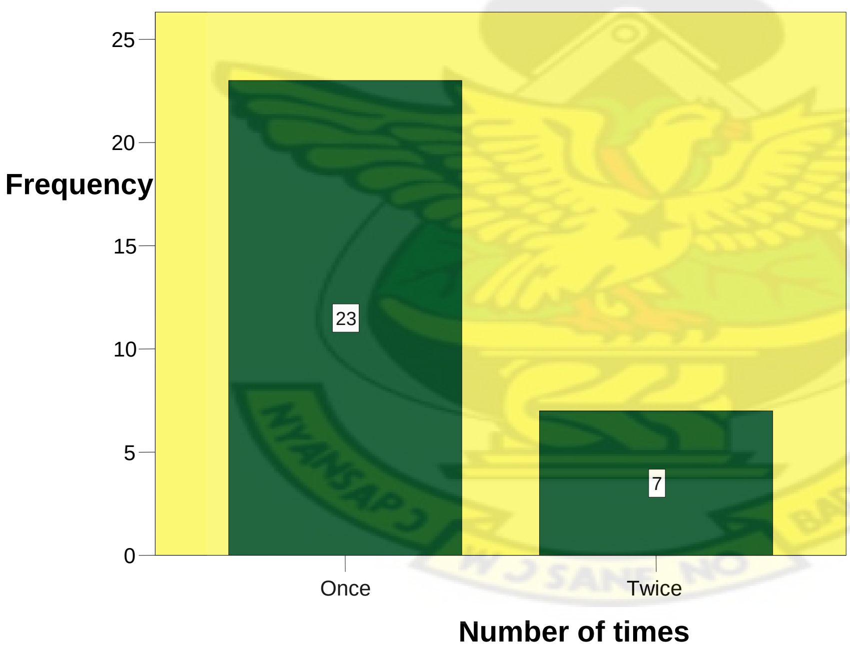

Fig. D.6: Number of times rice is grown in a year

Table D.7: Types of rice grown

Types	Frequency	Percent
Jasmine	8	26.7
Tox 3108	6	20.0
Both (Jasmine & Tox 3108)	16	53.3
Total	30	100.0

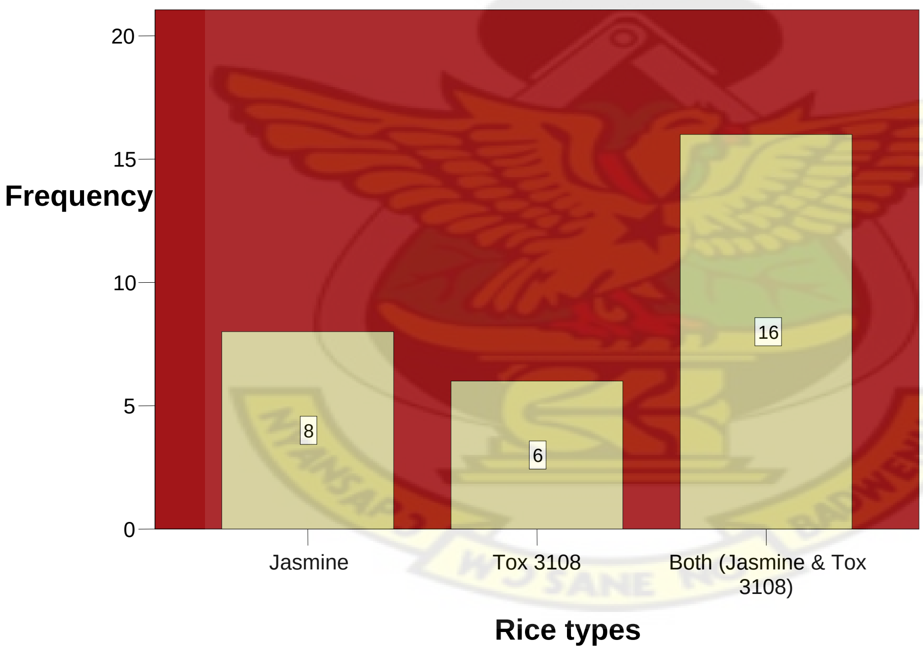

Fig. D.7: Types of rice grown

Table D.8: Source of irrigation water

Source	Frequency	Percent
Anum river	15	50.0
Oweri river	15	50.0
Total	30	100.0

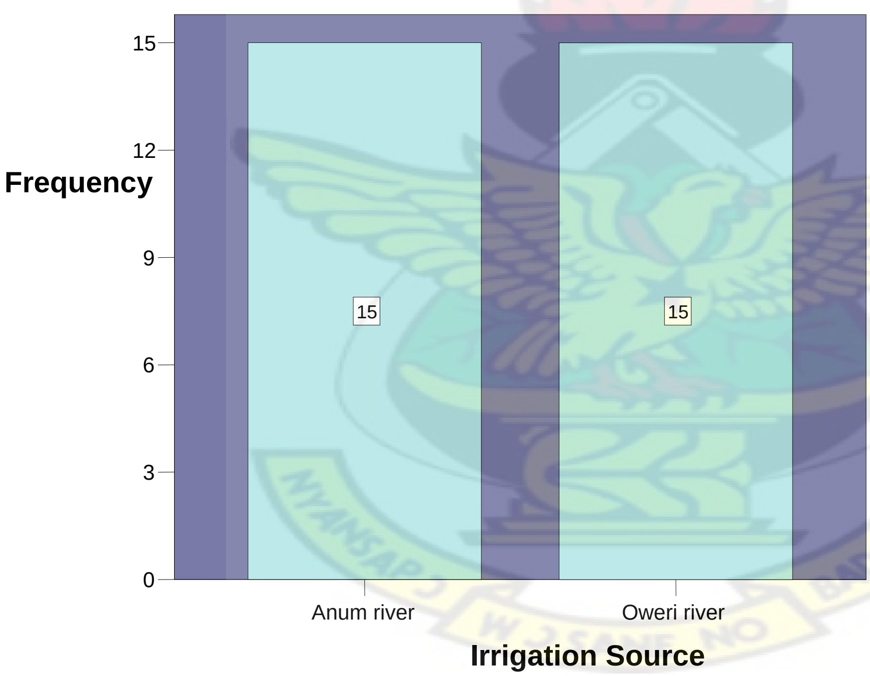

Fig. D.8: Source of irrigation water for farming

Table D.9: The number of irrigations usually carried out during planting season

Irrigate	Frequency	Percent
Once	8	26.7
Twice	11	36.7
Thrice	5	16.7
> thrice	6	20.0
Total	30	100.0

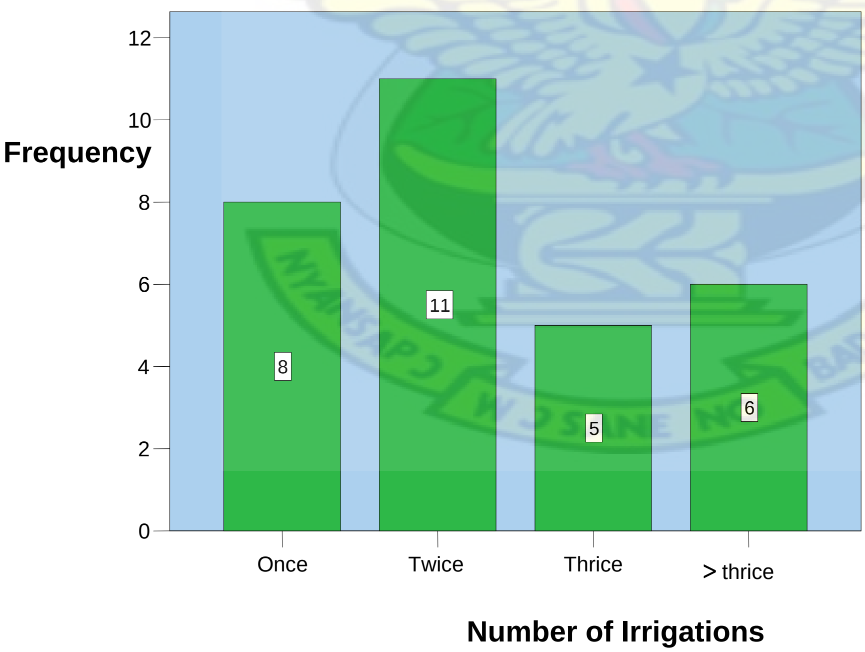

Fig. D.9: The number of irrigations usually carried out during planting season

Table D.10: The number of times excess waste water is drained out during planting season

Excess Waste water Drainage	Frequency	Percent
Once	12	40.0
Twice	7	23.3
Thrice	6	20.0
More than thrice	1	3.3
None	4	13.3
Total	30	100.0

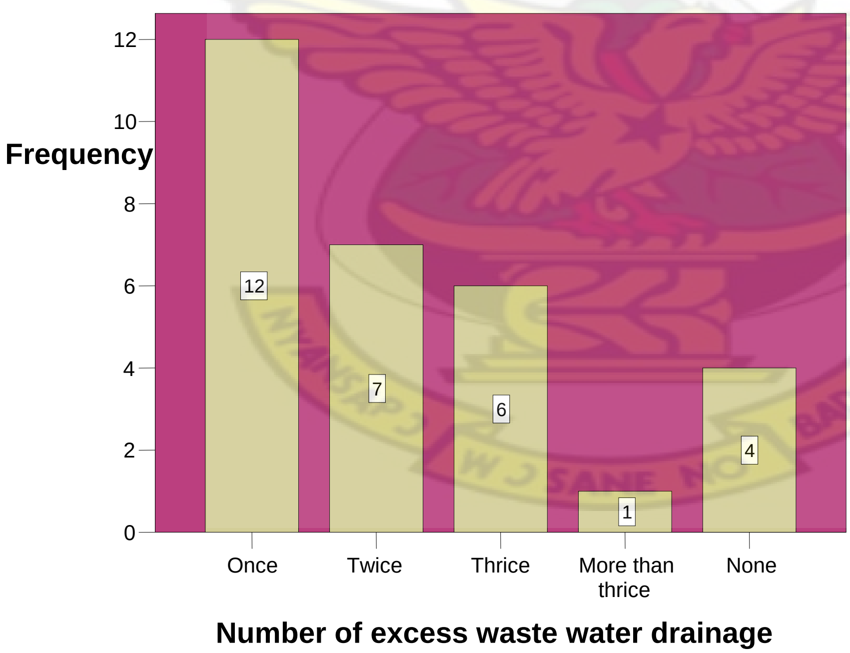

Fig. D.10: The number of times excess wastewater is drained out during planting season

APPENDIX E : RESULTS OF THE ANALYSIS OF "GALAMSEY" OPERATORS QUESTIONNAIRES

Table E.1: Respondent Age Distribution

Age	Frequency	Percent
< 20	4	11.1
21 - 30	25	69.4
31 - 40	7	19.4
> 40	0	0.0
Total	36	100.0

SOURCE: Field Data

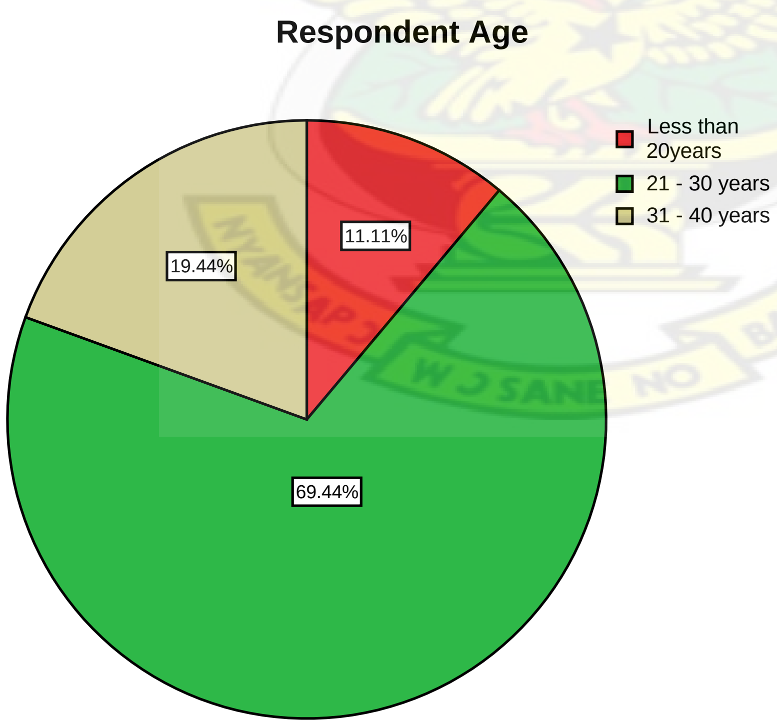

Fig. E.1: Respondent Age Distribution

Table E.2: Educational Levels of Respondent

Education	Frequency	Percent
Basic(Primary, Middle Sch & J.S.S)	16	44.4
Secondary(S.S.S , O&A Level)	8	22.2
Tertiary (Polytechnic & University)	1	2.8
None	11	30.6
Total	36	100.0

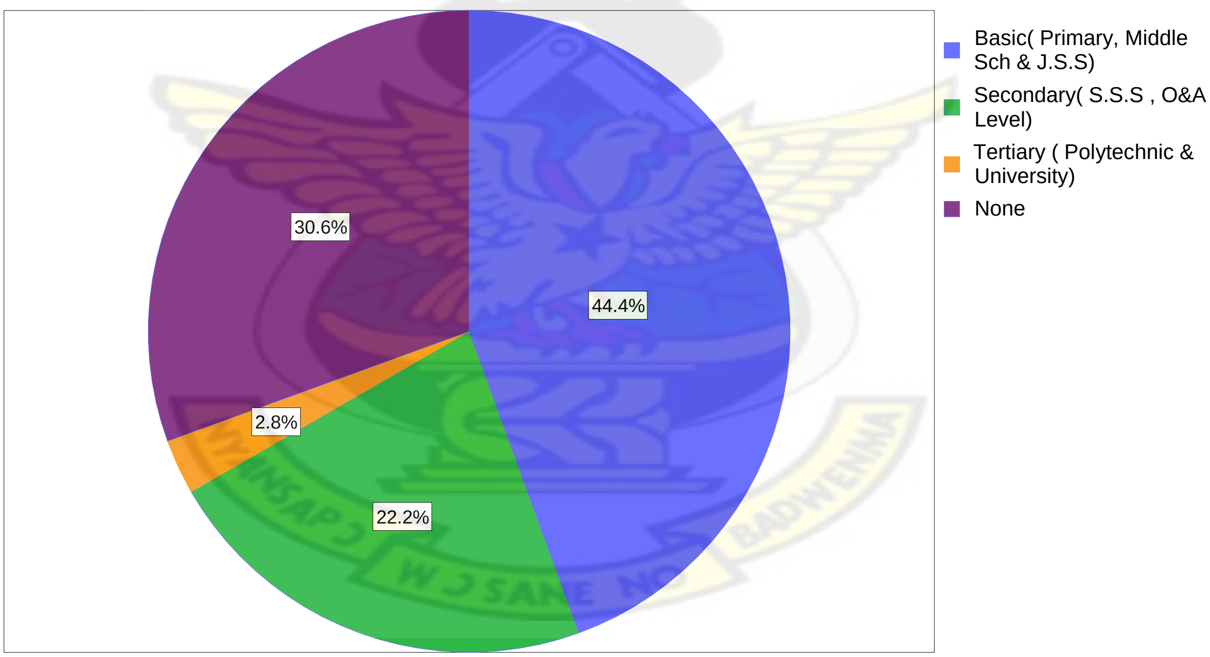

Fig. E.2: Educational Level of Respondents

Table E.3: Number of years in mining activity

Duration (years)	Frequency	Percent
< 1	3	8.3
2 - 3	5	13.9
4 - 5	13	36.1
> 5	15	41.7
Total	36	100.0

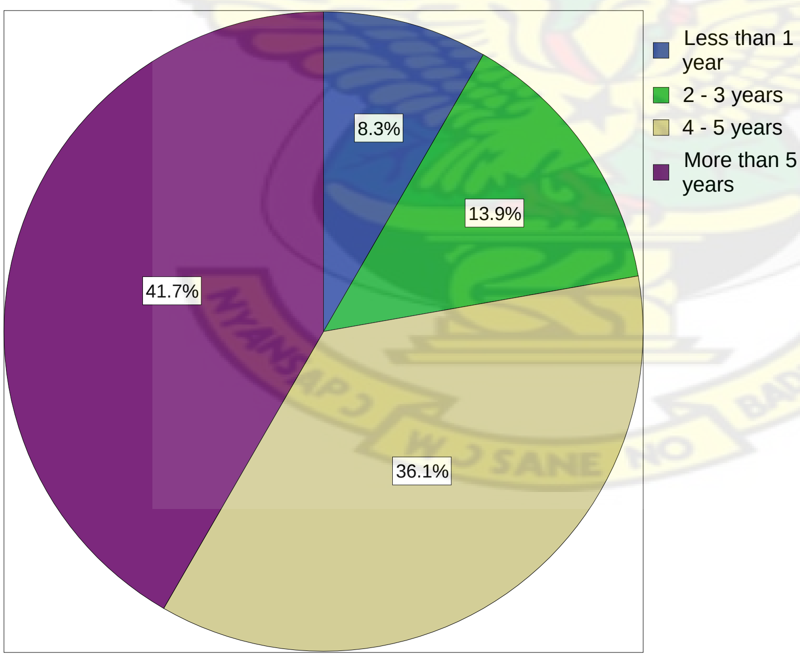

Fig. E.3: Number of years in mining activity

Table E.4: Source of water for mining activity

Source of Water	Frequency	Percent
Pipe-borne	0	0
Well / Borehole	17	47.2
Oweri river	16	44.4
Other	3	8.3
Total	36	100.0

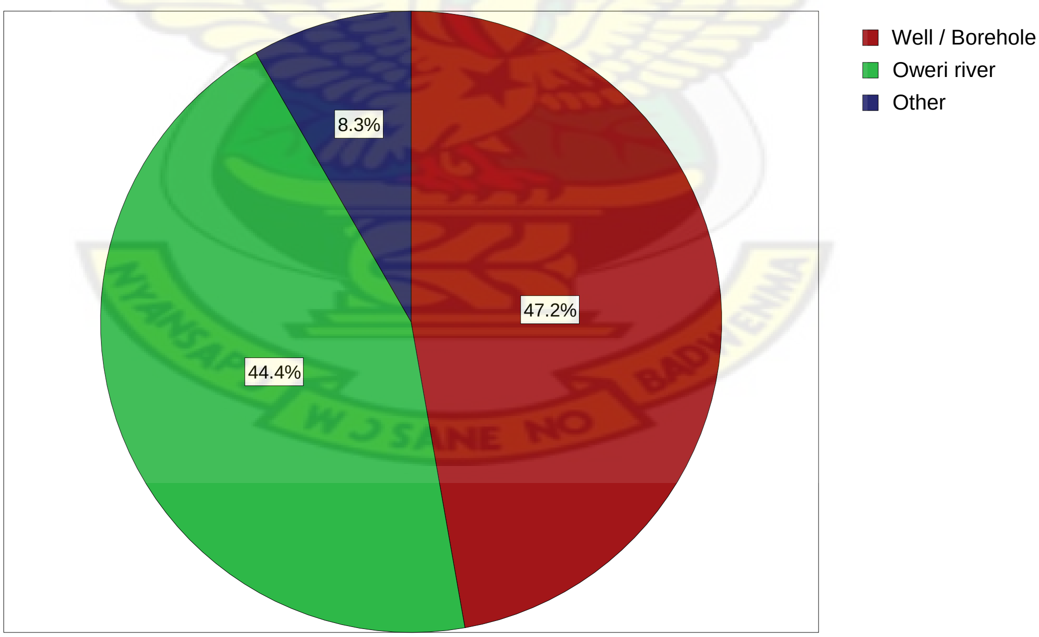

Fig. E.4: Source of water for mining activity

APPENDIX F: RESULTS OF THE ANALYSIS OF MECHANIC SHOP QUESTIONNAIRES

Table F.1: Respondents age

Age (years)	Frequency	Percent
< 20	2	5.3
21 - 30	27	71.1
31 - 40	8	21.1
>41	1	2.6
Total	38	100.0

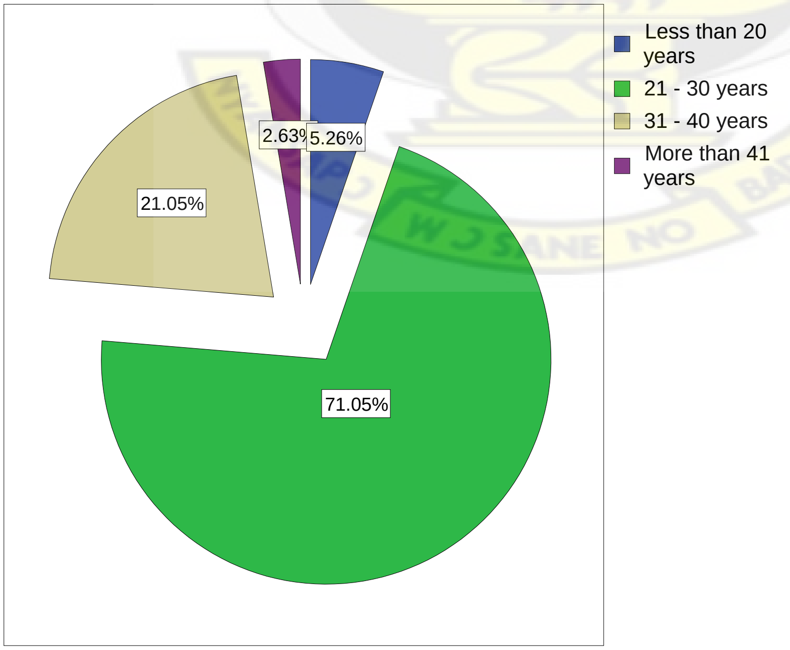

Fig. F.1: Respondents age

Table F.2: Educational Level of Respondent

Education	Frequency	Percent
Basic (Primary, Middle Sch & J.S.S)	29	76.3
Secondary (S.S.S, O & A Level)	4	10.5
Tertiary(Polytechnic, University)	0	0
None	5	13.2
Total	38	100.0

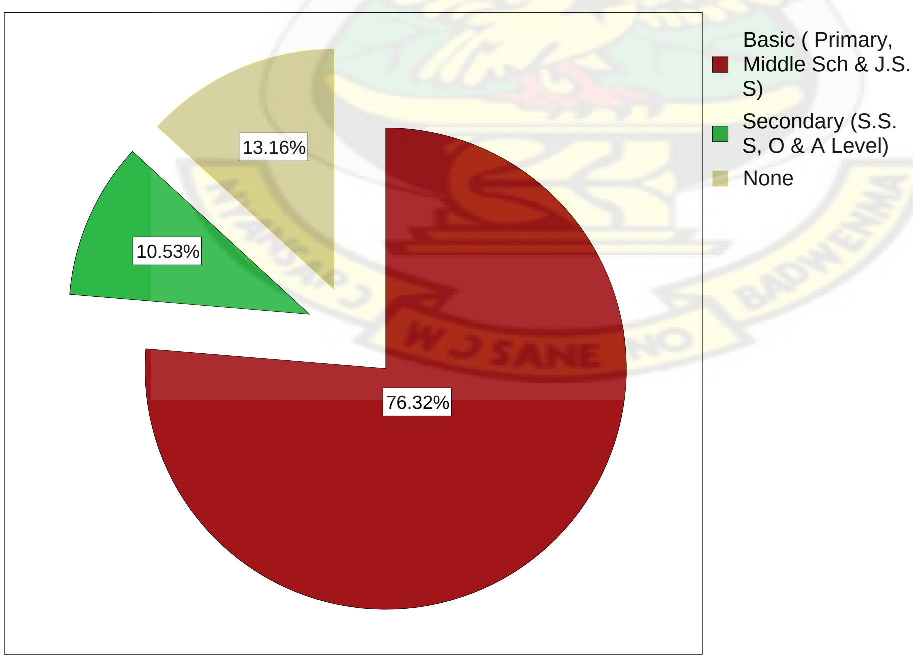

Fig. F.2: Educational Level of Respondents

Table F.3: The number of years they have engaged in this activity

Duration (years)	Frequency	Percent
< 1	1	2.6
1 - 2	10	26.3
3 - 4	9	23.7
> 4	18	47.4
Total	38	100.0

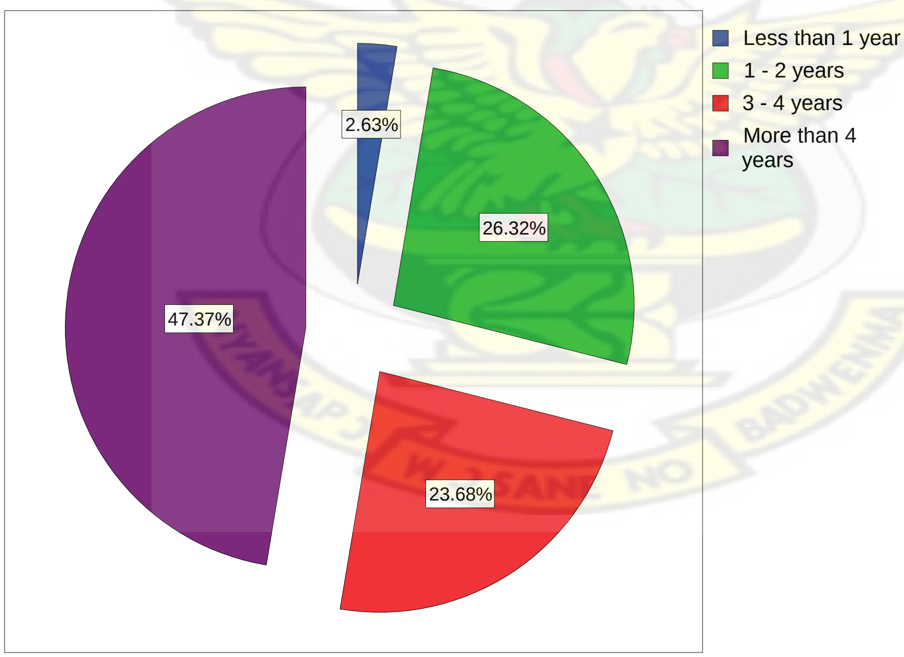

Fig F.3: The number of years they have engaged in this activity

Table F.4: The chemicals used to service the vehicles

Chemicals	Frequency	Percent
Oil (Diesel, Petrol, Engine, Brake fluid &Grease)	14	36.8
Electrode, Lead, Solder, Metals & Pipes	6	15.8
Acid, Carbide & Glue	3	7.9
Soap & Detergent	5	13.2
Other	10	26.3
Total	38	100.0

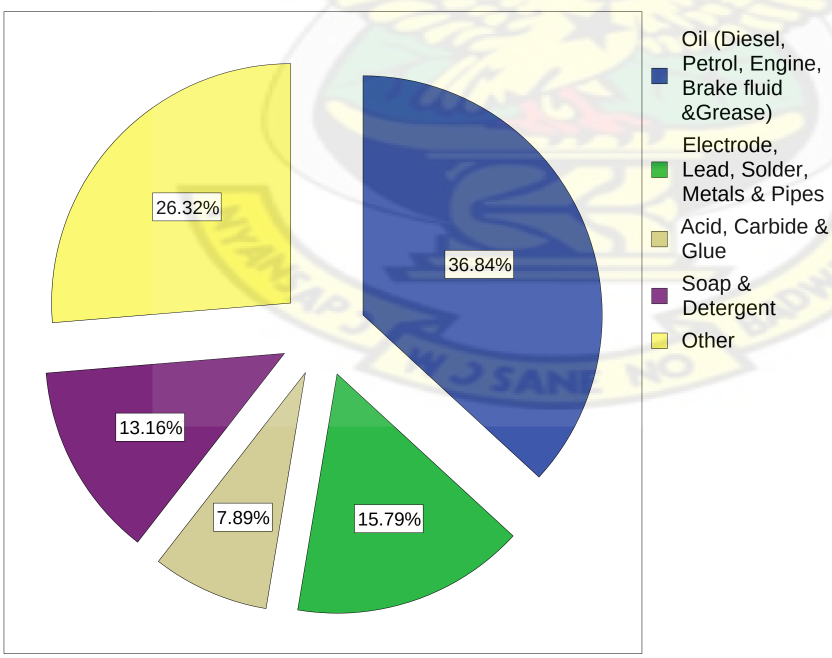

Fig. F.4: Chemicals used to service the vehicles

APPENDIX G.

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

MSC. SOIL AND WATER ENGINEERING

DEPARTMENT OF AGRICULTURAL ENGINEERING

QUESTIONNAIRE FOR RICE FARMERS

1) Name (Optional)………………… 2). Gender a) Male b) Female

3) Age a) 21- 30 yrs b) 31 – 40 yrs c) More than 40 yrs

4) Educational Level a) Basic(Primary, Middle sch.& J.S.S) b) Secondary (S.S.S, O &A Level) c) Tertiary (University, Polytechnic) d) None

5) What is the size of your farm ? a) 2-plot/0.2 hectare b) 4-plots/0.4 hectare c) 5-plots/0.5 hectare d) More than 5-plots/0.5 hectare

6) For how many years have you been farming on this land/plot? a) 1-4 yrs b) 5-8yrs c) 9-12 yrs d) More than 12yrs

7) How many times do you grow rice in a year? a) Once b) Twice

8) What type of rice do you grow? a) Jasmine b) Tox 3801 c) Both (Jasmine &Tox 3108)

9) What type of irrigation practice do you engage in? a) Basin b) Other

10) What is the source of your irrigation water? a) Anum river b) Oweri river

11) How often do you irrigate in a month? a) Once b) Twice c) Thrice d) More than Thrice

12) How many times do you drain the land /plot of excess water during the growth of rice?

a) Once b) Twice c) Thrice d) More than Thrice e) None

13) Do you apply any farm inputs like Fertilizers, Weedicides, and Pesticides?

a) Yes b) No

APPENDIX H.

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

MSc. SOIL AND WATER ENGINEERING

DEPARTMENT OF AGRICULTURAL ENGINEERING

QUESTIONNAIRE FOR "GALAMSEY" OPERATORS

1) Name (Optional)…… 2) Gender a) Male b) Female

3) Age a) < 20 yrs b) 21– 30 yrs c) 31- 40 yrs d) More than 40 yrs

4) Educational Level a) Basic (Primary, Middle & J.S.S) b) Secondary (S.S.S, O & A Level) c) Tertiary (University , Polytechnic) d) None

5) What type of mineral do you mined? a) Gold b) Diamond c) Manganese d) Copper e) Other

6) How many years have you been engaging in this activity? a) < 1yr b) 2-3 yrs c) 4-5 yrs d) More than 5 yrs

7) Where do you get your source of water for your activity from ? a) Pipe-borne b)Well/Bore hole c) Oweri river d) Other

8) What is the name of the nearest river to you? a) Oweri river b) Other…..

9) Where do you discharge your wastewater? a) Oweri river b) Other …….

10) What chemicals do you use in processing the mineral a) Mercury b) Other…..

APPENDIX I

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

MSc. SOIL AND WATER ENGINEERING

DEPARTMENT OF AGRICULTURAL ENGINEERING

QUESTIONNAIRE FOR WATERWORKS COMPANY

1) Name of Company ……………………………………..........

2) What is the total number of workers a) 10-20 b) 21-30 c) 31-40 d) 41-50 e) >50

3) Where do you get your source of water from? a) Anum river b) Oweri river

c) Other……..

4) Where do you discharge your wastewater to? a) Anum river b) Oweri river

c) Other…

5) How many times in a month do you discharge wastewater? a) Once b)Twice

c) Thrice d) > Thrice

6) For how many years has the company be in existent a) Less than 5yrs b) More than 5yrs

7) What type of chemicals do you use in treating the water. ....

APPENDIX J.

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

MSc. SOIL AND WATER ENGINEERING

DEPARTMENT OF AGRICULTURAL ENGINEERING

QUESTIONNAIRE FOR MECHANICS AT THE FITTING SHOP

1) Name (Optional)………………… 2). Gender a) Male b) Female

3) Age a) < 20 yrs b) 21 – 30 yrs c) 31- 40 yrs d) > 41 yrs

4) Educational Level a) Basic (Primary, Middle & J.S.S) b) Secondary (S.S.S, O &A Level) c) Tertiary (University, Polytechnic) d) None

5) For how many years have you been engaging in this activity/occupation? a) < 1yr b) 1-2 yrs c) 3-4yrs d) > 4yrs

6) Where do you get your source of water to service the vehicles from? a) Oweri river b) Well/Bore hole c) Pipe-borne d) Other……

7) What is the name of the nearest river to your shop? a) Oweri b) Other…

8) Where do you discharge your wastewater to? a) Oweri b) Other………….

What chemicals do you use in servicing the vehicles? a) Oil (Diesel, Petrol, Engine, Brake fluid, Grease) b) Electrode, Lead, Metals, Solder, Pipe c) Acid, Carbide & Glue d) Soap & Detergents e) Other ……..