KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

DEPARTMENT OF ENVIRONMENTAL SCIENCE

COLLEGE OF SCIENCE

ASSESSMENT OF SOME PHYSICO-CHEMICAL QUALITY PARAMETERS IN THE YINYAA KOBLIGA RIVER AND THE DUNGU DAM (TAMALE SOUTH SUB-METROPOLITAN AREA), GHANA.

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OCTOBER, 2012

DECLARATION

I hereby declare that the thesis is the outcome of research work undertaken by the author, any assistance obtained has been duly acknowledged. It is neither in part or whole been presented for another degree elsewhere.

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DEDICATION

This research is dedicated to my father Pius Baapeng Aapengyeb, Basilia Yelkedebo my mother, Cynthia Baapeng my wife and to my two children; Thelma and Terry Baapeng

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ABSTRACT

The activities of the vehicle mechanics in the Tamale South Sub-Metropolitan area Tamale, Ghana contribute to huge industrial wastes. These industrial wastes, coupled with pollutants from farm lands and surface runoff storm water enter into the Yinyaa Kobliga River which feeds the Dungu dam. In view of this, the thesis assessed the concentrations of heavy metals (Cu, Cd, Cr, Zn and Pb) and some physico-chemical quality parameters (Temperature, Dissolved Oxygen, Conductivity, pH, Total Dissolved Solids). Water quality and concentration levels of some heavy metals in the sediments of Yinyaa Kobliga River and the Dungu dam were studied in the months of October 2011 and June 2012. Water and sediment samples of the river and the dam were analyzed for various quality parameters namely pH, Temperature, Conductivity, Total Dissolved Solids (TDS) and Dissolved Oxygen (DO). The results showed that concentration of heavy metals in the sediments especially Cadmium (Cd) and Copper (Cu) exceeded the Threshold Effect Concentration (TEC) in the Yinyaa Kobliga River. This signifies a potential health risk of Cd and Cu toxicity to humans and aquatic life of the river. The heavy metal contamination status of the Yinyaa Kobliga and the Dungu Dam was also evaluated based on the modified degree of contamination and geo-accumulation index (Igeo). The modified degree of contamination showed that Zinc (Zn), Copper (Cu) and Lead (Pb) moderately contaminated the sediments of the river and in some parts of the dam (DDS1 and DDS3). However Copper (Cu) exhibited very high contamination in the sediments of the river and moderate contamination in the sediments of the dam.

The arithmetic mean concentrations of the individual metals in both the rainy and dry seasons far exceeded the maximum contamination permissible levels for fresh water ecosystem as spelt out by USEPA (1991) implying that the water is not safe for human consumption. The correlation factor analysis showed that the metals (Cu, Cr, Cd Pb and Zn) were highly positively correlated and they appear to be associated with each other and coming from a common source as demonstrated by the anthropogenic factor analysis.

Pollution Load Index estimates indicated baseline levels of pollutants (Cu, Cd, Cr, Zn and Pb) in the Dungu Dam whilst that of the Yinyaa Kobliga River indicated progressive deteriorating of the quality of the river by pollutants. (Pollution Load Index greater than one. PLI > 1).The increased in temperature to more than 10^0C in the waters of the Yinyaa Kobliga River and the Dungu Dam, would allow heavy metals to inhibit oxygen consumption by aquatic organisms to more than 54%. The results revealed that both the Yinyaa Kobliga River and the Dungu Dam had low levels of dissolved oxygen (DO). This implies that the decay (chemical and microbial action) on the wastes discharged into the river and the dam reduced the amount of dissolved oxygen (DO).

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CHAPTER ONE

GENERAL INTRODUCTION

1.0Background of the study

Increasing concentration in the natural environment by heavy metals has become a potential worldwide problem. This is because these metals are indestructible and most of them have toxic effects on fauna, flora and water quality (Harikumar *et al.*, 2010). These heavy metals can also bio-assimilate and bio-accumulate in aquatic organisms resulting in potential long-term implication on human health and ecosystems when they exceed a certain threshold (Nuremberg, 1984). Heavy metals contamination in water and soil has therefore become a crucial environmental issue in many countries. When heavy metals are added to an aquatic ecosystem, either by natural or anthropogenic sources, during their transport, they can be distributed among water, sediment and the biota (Moore, 1967). Again when heavy metals are carried by surface runoff water from their sources of generation, they may firstly dissolve in water, then adsorb on the surfaces of particulate matter, and finally accumulated on bottom sediments of aquatic ecosystem acting as a sink (Hakanson, 1980). Pekey, (2006) demonstrated that the heavy metals tend to be trapped in aquatic environments and accumulates in sediments. Sediments act as sinks and sources of contamination in aquatic ecosystems because of their variable physical and chemical properties (Dickinson *et al.*, 1996). There are two major sources of heavy metals entering water bodies in urbanized areas, natural sources from rock weathering within the catchment and anthropogenic sources resulting from activities of mankind (Dickinson *et al.*, 1996). Inappropriate and illegal disposal of industrial and urban wastes and ignorance of their management may result in severe environmental problems such as contamination of receiving waterways and associated sediments by heavy metals and persistent organic pollutants.

Anthropogenic sources may also include sewers and sewage pumping stations, poor industrial yard management practices, illegal dumping and storm water runoff from roads and urban areas (Deely and Fergusson 1994). Input of heavy metals especially Cu, Pb and Zn into the urban environment is strongly influenced by past and present vehicular and road densities (Hoplee *et al.*, 1980). Other sources of heavy metals are associated with various industrial activities as well as urban housing (for example Zn from galvanized roofs and Pb from old house/car paints and leaded fuels) (Hoplee *et al.*, 1980). When heavy metals are released into the water column they may be transferred rapidly to the sediment phase by adsorption onto suspended particulate matter, followed by sedimentation. Intertidal flats may be considered as important heavy metals sinks and estuarine environments act as traps for pollutants (Birch, 2000)

1.1Problem statement

Various surveys have been carried out to determine heavy metals concentration in various parts of the world (Harikumar *et al.*, 2010). These surveys have served to quantify levels of heavy metals in different environments and have provided an understanding of the natural and anthropogenic sources of heavy metal contamination in water and soil sediments. Unlike other pollutants, heavy metals are non-degradable and can accumulate in the earth's surface and thereby endangering human health and livestock through the food chain.

Majority of the inhabitants in the Tamale South Sub-Metropolitan area depend mainly on the Dungu dam water and the Yinyaa Kobliga river for domestic purposes and dry season gardening. This dam takes its source from the Yinyaa Kobliga River, which is heavily polluted by the activities of the vehicular mechanics in the industrial area (Plates 1, 2 and 3). These vehicular mechanics discharge their waste directly into the Yinyaa Kobliga River.

Unfortunately there is no documentation of the water quality in terms of heavy metals concentrations and its possible effects on the individuals who come into contact with the river and dam water daily.

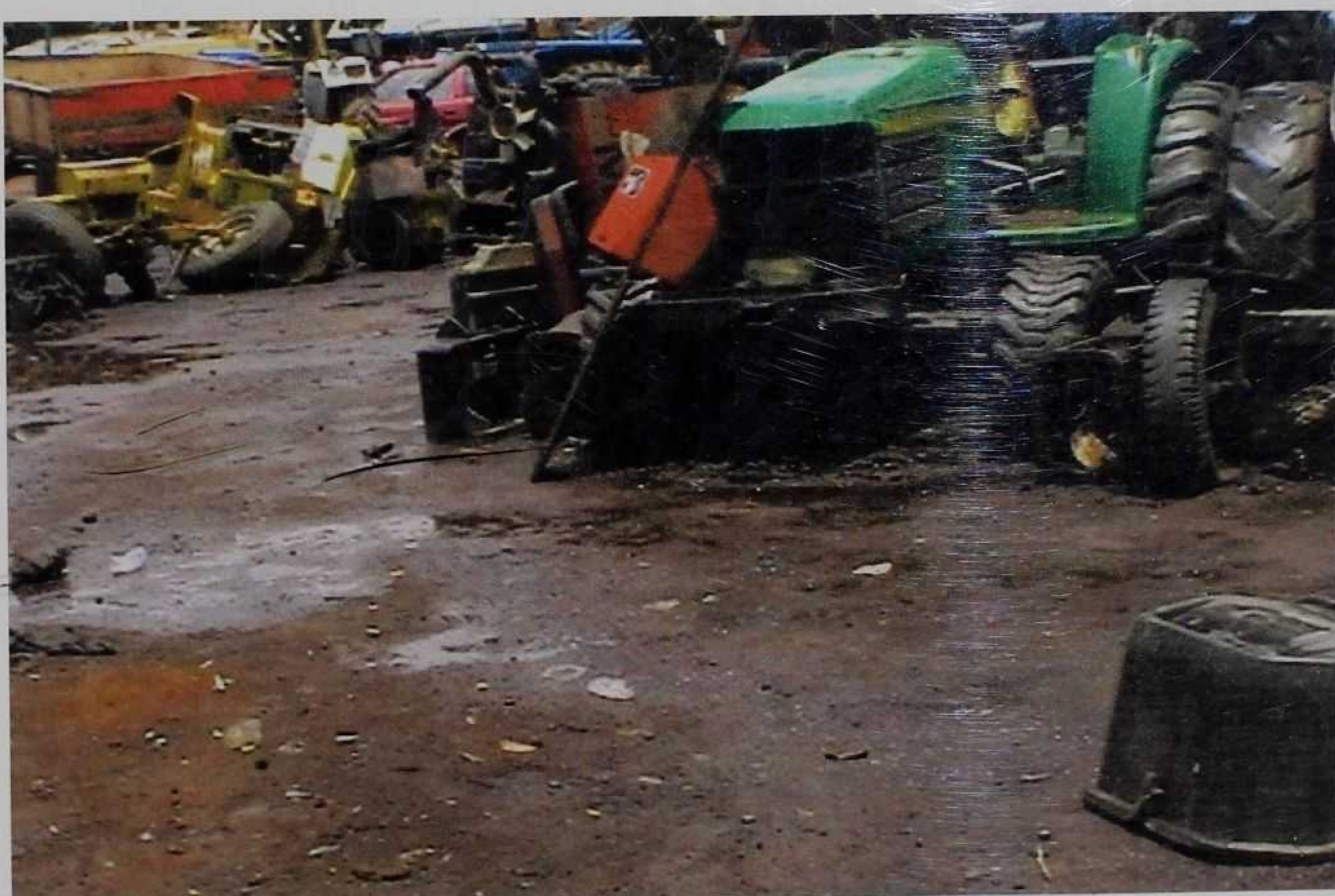


Plate 1 An indicator of pollution on the ground of the vehicle mechanic shop.

Plate 2 Wastes from the vehicle mechanic shops thrown into the Yinyaa Kobliga River.

Plate 3 Domestic wastes and chemicals from farms being carried along by the Yinyaa Kobliga River.

1.2 Research objective

The main objective was to determine heavy metal concentration and water quality in Yinyaa Kobliga River and the Dungu dam.

1.2.1 Specific objectives

1. To determine some heavy metals (Cu, Cr, Cd, Pb, and Zn) concentration in sediments of the Yinyaa Kobliga River and that of the Dungu dam.
2. To determine some of the physico-chemical parameters (pH, Temp., conductivity, Total Dissolved Solids (TDS), and Dissolved Oxygen (DO)) in the water of Dungu dam and Yinyaa Kobliga River.

1.2.2. Justification of the research

The activities of the vehicle mechanics such as servicing of cars, spraying of cars, refilling and charging of car batteries, drilling of holes using lathe machines etc in the Tamale South Sub-Metropolitan area contribute to huge industrial wastes. These industrial wastes, coupled with pollutants from farm lands and surface runoff storm water enter into the Yinyaa Kobliga River which feeds the Dungu dam. These wastes may contain heavy metals which may bio-accumulate in the sediment biota and enter the food chain with long term fatal consequences on biodiversity. In view of the above the researcher sought to assess the levels of heavy metals concentrations and some physico-chemical quality parameters of the waters of Yinyaa Kobliga and the Dungu dam.

CHAPTER TWO

LITERATURE REVIEW

2.0 Heavy metals and the environment

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic at low concentrations. (http//www.lenntech.com)..They include most metals with an atomic number greater than twenty (20), and exclude alkali metals, alkaline earths, lanthanides and actinide (http//en.wikipedia.org/wiki/heavy metals). Some examples of heavy metals include the following; mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Thallium (Tl*),* and Lead (Pb*).* Heavy metals are ubiquitous elements found in rocks, soils, natural waters, atmosphere and organisms. They are mobilized in the environment through a combination of natural processes such as weathering reactions, biological activity, and dispersal of tailings as well as anthropogenic activities (Kumi-Boateng, 2007). Heavy metals are natural components of the earth's crust. Heavy metals concentration is of very high ecological significance since they are not removed from water by self purification but accumulates in reservoirs and enter the food chain (Loska *et al.*, 2003).

2.1 Geochemical occurrence of heavy metals

The occurrence of heavy metals in the environment may result primarily from anthropogenic activities; however the natural process, such as weathering of rocks and volcanic activities play a noticeable role in enriching the water of reservoirs with heavy metals (Forstner and Wittmann, 1979). Sediments are normally mixtures of several components including different mineral species as well as organic debris.

Sediments represent one of the ultimate sinks for heavy metals discharge into the environment (Gibbs, 1977). Heavy metals accumulation in the sediments is through complex physical and chemical adsorption mechanisms depending on the nature of the sediment matrix and the properties of the adsorbed compounds (Maher and Aislabie, 1992). Several processes lead to the association of heavy metals with solid phases, such as the direct adsorption on or complexation with natural organic particles, and direct precipitation as new solid phases (Gibbs, 1973). The adsorption process is influenced by several chemical-physical and chemical parameters such as pH, oxidative-reductive potential, dissolved oxygen, organic and inorganic carbon content, and presence in water phase of some anions and cations that bind or co-precipitate the water-dissolved or suspended pollutants (Di Toro *et al.*, 1991).

2.2. Assessment of heavy metals in bottom sediments

According to Ghrefat and Yusuf, (2006) thirty five bottom sediment samples were collected in a grid pattern from a dam. These sediment samples were assessed for heavy metal concentration. Concentration data were processed using correlation analysis and factor analysis. The results of correlation analysis and factor analysis showed low positive and negative correlations among Mn, Fe, Cu, Zn, and Cd. Their results indicated that heavy metals in sediments of the dam have different anthropogenic and natural sources. Their results also confirmed the complicated behavior of these pollutants, which may be influenced by many factors. Sediments pollution assessment was also carried out using enrichment factor and the geo-accumulation index. In their estimation, enrichment factor showed that Mn and Cu are depleted by 0.76, and 1.33, respectively, whereas Cu, Zn, and Cd were enriched by 3, 6, and 30, respectively.

Their findings of geo-accumulation index revealed that sediments of the dam are uncontaminated with Mn, Fe, and Cu .moderately contaminated with Zn, and strongly to extremely contaminated with Cd. According to them some of the elevated concentration of Zn and Cd are probably due to anthropogenic sources nearby the dam site. These sources mainly included fertilizers and pesticides used in agricultural activities.

The degree of contamination in the sediments of the Dikrong river (Assam, India) for the metals Al, Fe, Ti, Mn, Zn, Cu, Cr, Ni and Pb, were evaluated using Anthropogenic factor, Enrichment ratio (ER), Pollution load index (PLI) and Geo-accumulation index (Igeo). The sediments were found to be contaminated with Cu and Pb which was attributed mainly to dispersion from the mineralized (Anthropogenic factor) zone of the upper catchment area since no major industrial establishments were present in the area (Chakravarty and Patagri, 2009).

River sediments from Amazon, Congo, Ganges, Magdalena, Mekong, Parana and Orinoco were subjected to analysis for forty (40) elements. From their results Al, Fe and Ti were enriched with respect to the average parent rock, while Na, Ca, Mg and Sr were strongly depleted. This depletion could be directly related to dissolved and particulate transport in rivers. As a result of chemical erosion, Al, Fe and Ti were enriched with respect to the average parent rock. The latter were derived from the elemental content in the average parent rock and the total quantity of weathered material, computed from the Al ratio in parent rock. Observed and theoretical fluxes were balanced for the less mobilized elements (rare earths, Co, Cr, Cs, Fe, Mn, Rb, Si, Th, Ti, U, and V) for which no enrichment relative to Al is noted and for B, Ba, Ca, K, Mg, Na, Sr which were relatively depleted due to their dissolved transport (Jean-Marie *et al*., 1979).

Additional fluxes were found for Br, Sb, Pb, Cu, Mo, Zn and were possible also for Ni and P. this was reflected by marked enrichments relative to Al for the poorly or moderately dissolved transports (Pb, Cu, Zn). Several hypotheses involving either natural origin (volcanic dust, marine aerosols, geochemical fractionation) or the artificial origin (worldwide pollution) were discussed to explain these discrepancies. However, none of them could fully account for these additional fluxes. It is most likely these excesses had multiple origins, anthropogenic or natural or both (Jean- Marie and Michel, 1979).

An assessment was conducted based on the analyzing results of the typical pollutants (Pb, Cu, Cr, Cd, and Zn) contents in the sediments of a river. The results indicated that cadmium (Cd) had the largest pollution index and was the main pollution factor among the metals. The ecological pollution sequence of the metals was Cd > Zn >Pb> Cu >Cr, while the sequence of the potential ecological pollution posed by the metals was Cd >Pb> Cu> Zn >Cr (Chuan Fu *et al*., 2009).

Sekabira *et al*., (2010) analyzed for heavy metal concentration using flame atomic absorption spectrophotometer from channelized stream sediment in Kampala, Uganda reveled the degree of pollution in channelized stream sediments for lead, cadmium, copper, zinc, manganese and iron. Results from the assessment using enrichment factor, Geo-accumulation index and pollution load index, indicated that the sediments had been polluted with lead, cadmium and zinc and had high anthropogenic influences. Their findings, suggested that the stream sediments had background concentration for copper, manganese and Fe (*Igeo*< 0); factor analysis results also revealed three sources of pollutants as explained by three factors (75.0 %); (i) mixed origin or retention phenomena of industrial and vehicular emissions; (ii) terrigenous and (iii) dual origin of zinc (vehicular and industrial).

2.3. Assessment of heavy metals in soils/surface sediments

Harikumar et al., (2010) studied the concentration of six (6) heavy metals (Cd, Cr, Zn, Pb and Cu) in surface sediments of a river in India. They assessed the concentration of heavy metals in the sediment samples of the river using numeric Sediment Quality Guidelines (SQGs). Their findings showed that Zn, Cr and Pb in all sediment samples were lower than the proposed threshold effect concentration which indicated no harmful effects from these metals. Cd in one station, Cu in three stations and Ni in all stations exceeded the threshold effect concentrations. This indicated that the stations were in potential risk. The low values of Geo-accumulation index and Metal pollution index showed that the enrichment of sediment by heavy metals was by natural processes.

Abraham and Parker, (2008) studied eight (8) sediment cores recovered from Tamaki Estuary. These sediment cores were analyzed for Cu, Pb, Zn and Cd using downward cored sub-samples. In estimating pollutant impact on the Estuary, Enrichment factor

(EF), Degree of contamination (Cd), Contamination factor (Cf) and Geo-accumulation index was employed. Geo-accumulation indices suggested that fine fraction sediments in the various Tamaki Estuary cores ranged from uncontaminated to moderately contaminated. Normalized enrichment factors (EF) values for 4 heavy metals produced higher enrichment factor values for Cu, Pb, Zn and Cd as compared to average shale values. The overall degree of contamination indicated that a moderate to high degree of contamination in the Tamaki Estuary cores.

Sugirtha *et al*., (2008) analyzed metal concentration obtained from three core sediments (S1, S2 and S3) of Manakudy estuary on the South-West coast of India.

The acid leachable trace metals (Cr, Cu, Ni, Co, Pb, Zn and Cd showed peak values at sulphidic phase. The study showed moderate level of pollution related to anthropogenic activities. Most of the trace metals were adsorbed onto Fe-Mn oxyhydroxides and some were precipitated by sulphides. The Igeo values revealed that all the core samples fell within uncontaminated to moderately contaminated category. The contamination factor was low indicating low contamination in the core samples. The anthropogenic factor indicated low anthropogenic factor inputs. Samples of soil were collected from both gold mining and non-gold mining regions of the southern part of Ghana and analyzed to determine the concentrations of arsenic and other potentially toxic elements (PTEs). Significant differences were observed between sites with respect to soil As, Co, Cu, Pb and Zn concentrations. Although higher arsenic concentrations were recorded in mine soils from Bogosu in the western region of Ghana, paddy soil samples from this region contained relatively low concentrations of arsenic, suggesting that the contribution of gold mining to soil contamination is a function of distance from the point source of contaminants (Adomako, 2010).

The concentrations of Cr, Mn, Co, Ni, Cu, Zn, Cd and Pb in one hundred and seventy-seven (177) surface sediment samples from throughout Checapeake bay were recorded. Analyses were made of both unfractionated samples and the < 63μm fractions. Analytical uncertainty, always less than ± 10%, controlled reproducibility in analyses of the < 63μm fractions but sampling variance controlled reproducibility in the unfractionated samples, especially when coarse-grained sediments were being analyzed. Sediments in the northernmost part of the bay were enriched relative to average continental crust in all elements except Cr. This reflects the composition of dissolved and suspended material being delivered to that region by the river.

The enriched sediments appear not to be transported southwards in significant quantity. Zinc, Cadmium, and Lead are enriched relative to average crust throughout the bay and in most other estuaries in the eastern United States (Biggs, 1967).

A set of toxic metals ie As, Hg, Cd, Cu, Zn, Ni, and Cr in urban and suburban sediments were investigated comparatively in the biggest metropolitan area of China, Shanghai. Results of the investigation showed that all of the metals except As were accumulated greatly, much higher than background values. Geo-accumulation index indicated that metal contamination in urban sediment was generally heavier than that in suburban sediment. Potential ecological risk index demonstrated that overall risks caused by metals were considerable. Cd was known to have contributed over 50% to the overall risk. Multivariate statistical analysis revealed that in urban sediments, Zn, Ni, Cd, Pb, Cu and Cr were related to traffic and industry; coal combustion led to elevated levels of Hg, soil parent materials controlled As contents. In suburban sediments Pb, Cu, As and Cd largely originated from traffic pollution; Zn, Ni and Cr were associated with industrial contaminants; Hg was mainly from domestic solid waste (Shi *et al.*, 2009).

According to Sharma *et al.*, (1999) Concentrations of metals (Cu, Cd, Zn, Pb, Ni, Cr, V, Fe, and Al) were determined in sediments from 34 sites within the estuaries of Texas, USA. Anomalies in metal concentrations were found at some and were related to probable sources such as military facilities, landfill leaching, and municipal and industrial discharges. The metal concentrations were normalized to Fe and Al for distinguishing natural and anthropogenic sources. Most metals showed positive correlations with Fe and Al which suggested the natural variability of metals in sediments. The concentrations of metals except Cd at most of the sites were found to be below threshold concentrations thought to produce toxic effects in marine and estuarine organisms.

2.4. Assessment of heavy metals in sediment dwelling organisms

Adjei *et al.*, (2010) carried out a study in the Volta Region of Ghana, to assess the levels of some heavy metals; Mn, Zn, Fe and Hg in whole soft tissue of the clam *Galatea paradoxa* and its suitability for human consumption. These clams are mostly found in the sediments of the Volta estuary. These clams constitute an important and affordable protein source and it is mostly consumed by communities around the Volta estuary and beyond. The researcher sampled out thirty (30) clams at each location and he further grouped them into three (3) classes based on their shell lengths. The concentrations of Zn, Fe, and Mn were determined using a flame Atomic Absorption Spectrometer (AAS) and the Hg concentrations were determined using an Atomic Mercury Analyzer. There were no differences in Mn, Fe and Zn concentrations among the different size classes except for Hg concentration in clams from Ada, indicating a similar bioavailability of Mn, Fe, Zn at both locations and, possibly, an efficient metabolism to keep the concentrations of Mn, Fe and Zn relatively similar in the tissues of the different clam were not significant for Mn, Zn and Hg for all the size classes. Heavy metal concentrations in the tissues of the clams were found to be suitable for human consumption based on the WHO Safety Reference Standards for Bivalves and a human health risk assessment methodology.

An index Analysis approach such as Geo-accumulation Index (Igeo), Enrichment Factor (EF), Pollution Load Index (PLI) and Ecotoxicological Risk Assessment for sediment dwelling organisms using consensus- based sediment quality guidelines was used to assess the heavy metal pollution in surface sediments of the watersheds.

The soil/sediment samples were analyzed using the Environmental Protection Agency analytical method SW-6010B for total recoverable elements for environmental contaminants of concern *(*Al, Fe, Mn, As and Pb*)*.The selected heavy metals were also studied to determine the presence of contaminants and extent of anthropogenic and inputs from urban and rural activities (Okweye *et al.*, 2007).

2.5. Assessment of heavy metals in runoff surface water

A series of adsorption experiments was conducted in order to assess the ability of three mulches to remove several of the heavy metal ions typically encountered in urban runoff. Three types of mulch, cypress bark (C), hardwood bark (H), and pine bark nugget (P), were selected as potential sorbents to capture heavy metals in urban runoff. The hardwood bark (H) mulch had the best physicochemical properties for adsorption of heavy metal ions. In addition, because of its fast removal rate and acceptably high capacity for all the heavy metal ions, it was concluded that the (H) mulch is the best of the three adsorbents for treatment of urban runoff containing trace amounts of heavy metals. The sorption of these metals on (H) mulch conformed to the linear form of the Langmuir adsorption equation. At pH 5 and 6, the Langmuir constants (Sm) for each metal were found to be 0.324 and 0.359 mmol/g (Cu); 0.306 and 0.350 mmol/g (Pb); and 0.185 and 0.187 mmol/g (Zn) at 25 (Am Jang, 2004).

2.6. Assessment of heavy metals concentration in industrial waste water

According to Ram., S., L., *et al.,* (2011) industrial waste water effluent samples were collected randomly twice in a month in the morning, afternoon, and evening session from different industries; Engineering industries, paper mills, fine chemical manufacturing industries, dyes industries, paint industries, pharmaceuticals industries, petrochemicals industries and textile industries of Tolaja industrial belt Mumbai, India. The overall results pointed out high concentration of toxic heavy metals in the effluent samples collected from the different industries. From their findings, Cu (33.3mg/L) was highest and it came from the dyes manufacturing industry. Fe had a concentration of

(12.8mg/L) and this high concentration came from the textile industries. The concentrations of Cd (35.8mg/L) and Ni (33.6mg/L) were found in samples from the pharmaceutical industries. These industrial effluents polluted the nearby water bodies which affected the growth of vegetation and aquatic life. These toxic heavy metals when released in aquatic environment will enter the food chain through bio-magnification causing various health problems in humans. According to their findings, there is the need to implement common objectives compatible policies and programmes for improvement in the industrial waste water treatment methods.

2.7. Assessment of heavy metals and some physico-chemical parameters

According to Dhia *et al.*, (2008) many of the water pollution problems in urban areas are due to a large extent pollutants washed off from land by storms. Their study area was divided into six sub-catchment areas and monitored for three years (October 1998 to November 2000). Water samples were collected for both dry and wet periods and stored in polyethylene containers. They tested seventy-eight water samples for heavy metals. The water samples were digested using potassium persulphate ($K_2S_2O_8$) and sodium hydroxide (NaOH) digestion procedure. After the digestion, the samples were analyzed for the concentration of heavy metals; Pb, Cu, and Zn using the Atomic Absorption spectrometer (AAS).

Their findings showed that the heavy metals; Pb, Cu, and Zn were above the normal shale values as per the USA fresh water quality guidelines (1998). In their analysis, the pollution of the water had an anthropogenic factor (AF) as most of the pollutants were wash off from farmlands, landfill sites, household wastes, thrash from nearby areas.

Sarfo-Armah *et al*., (2009) conducted a study in Tarkwa, a mining community in the Western Region of Ghana. Effluents from extractive industries established over the last half century within the study area were directly discharged onto the surrounding land and surface water bodies. The study was conducted in twelve parameters including trace elements (Cu, Mn, Cd, Fe, Pb, As, Hg, and Zn) and physic-chemical parameters (pH, conductivity, turbidity, and total dissolve salts). Data was analyzed using factor analysis (FA). Factor analysis identified four (4) factors responsible data structure explaining sixty-nine percent (69%) of total variance in surface water and two (2) factors in groundwater explaining seventy-nine percent (79%), and allowed the grouping of selected parameters according to common features.

Addo *et al.,* (2011) studied the water quality and levels of trace elements in water and sediments of Kpeshie Lagoon located in Accra, Ghana. Analysis was conducted on the samples of water, sediments and some physico-chemical parameters which included; pH, salinity, dissolved oxygen (DO), and nutrients. Their findings showed that, conductivity which was within (19750-28500:S/cm), total dissolved solids (9750-14180mg/L), chlorine (5725.2-8277.6mg/L) and total alkalinity (800-2000mg/L) were all at an intermediate state between fresh and saline waters. However their findings showed that the content of nutrients in the water was within regulatory levels limits for natural waters. From their results of heavy metals in the sediments of the Lagoon, nickel (71.8-1568:g/g), lead (0.5-27.10:g/g) and chromium (190-26328:g/g) was observed to a potential health risk to humans and aquatic life of the Lagoon's ecosystem.

The sediments were confirmed to be contaminated with heavy metals on the basis of Enrichment Factor (EF) and Geo-accumulation index (Igeo). The sediment samples were found to be unpolluted with Zn, moderately polluted with Pb. However the EF and Igeo results supported the fact that the sediments were highly enriched with Ni, and Cr.

CHAPTER THREE

MATERIALS AND METHODS

3.0Study area

The study area (Tamale South Sub-Metropolitan area) is located within longitude 0'35 S and 1'45 S and latitude 9'55 N and 10'45 N. (Figure 1) Tamale South Sub-Metropolitan area has its boundaries with three districts; Tolong-Kumbugu to the West, Central Gonja to the South and Yendi District to the East. Tamale South Sub-Metropolitan area has a total human population of about 6,823 and a total land size of about 5,013km^2(Statistical Survey, 1992). The study area has savanna vegetation which is characterized by very short trees, vast grassland, shrubs and a few thickets. The topography of the area is that of a large level ground with very few reduced hills.

There is basically one rainy season system which starts between the months of February/March to August/September each year, followed by a prolonged dry season which commences from October/November to January/February.

Apart from few settlers who are working for the public sector in Governmental Agencies, the indigenous people are mostly petty traders, farmers and tradesmen (vehicle mechanics). Tamale South Sub-Metropolitan area is made of the urban, semi-urban and rural settlements.

The Yinyaa Kobliga River (Figure 2) and the Dungu Dam (Plate 4) constitute one of the largest water bodies in the Tamale south area. The river has a length of about 16km south flowing river of the Tamale South Sub-Metropolitan area. The river discharges into the Dungu dam. The river and the dam serve as the major source of water for both domestic and Agricultural purposes.

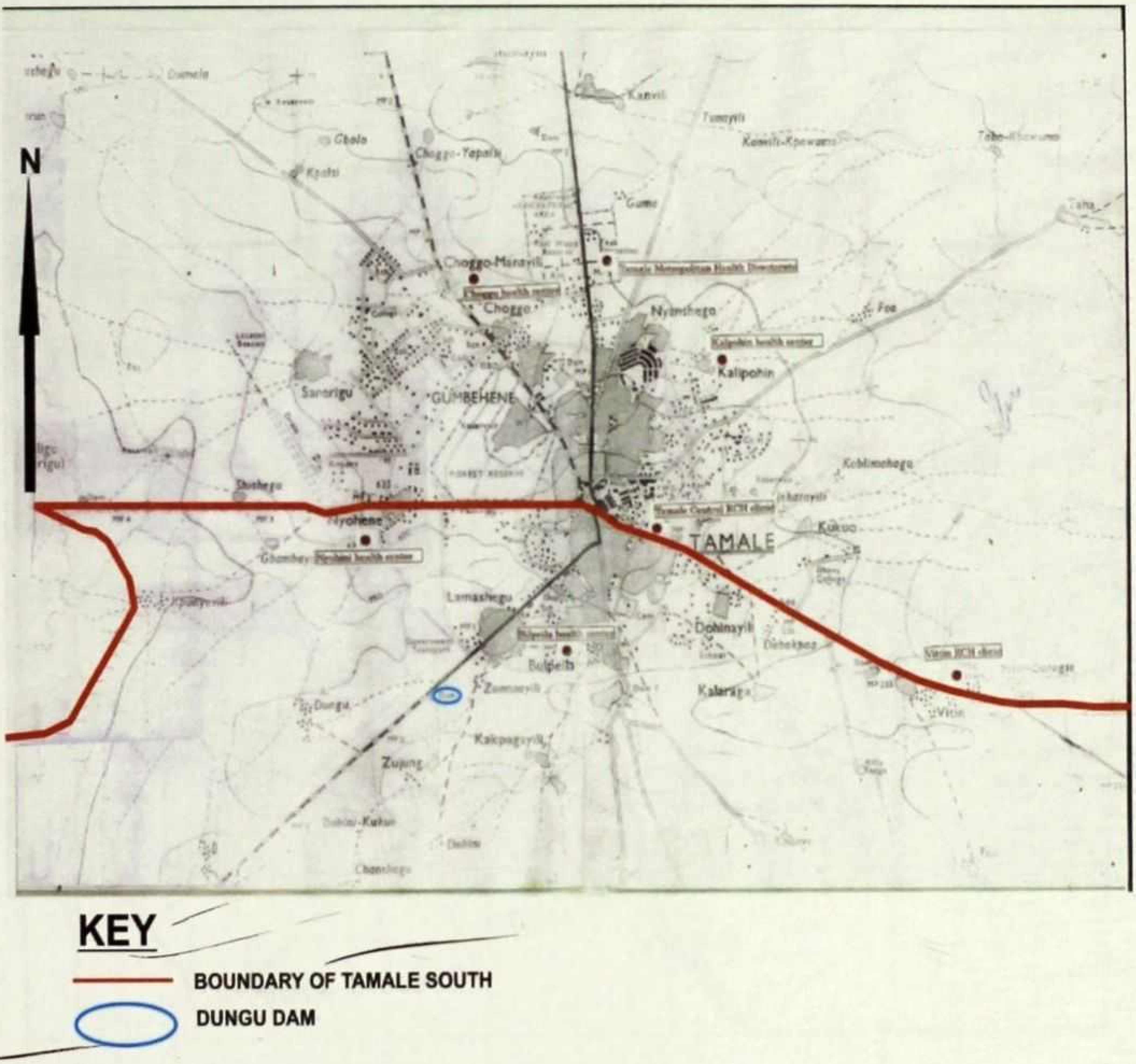
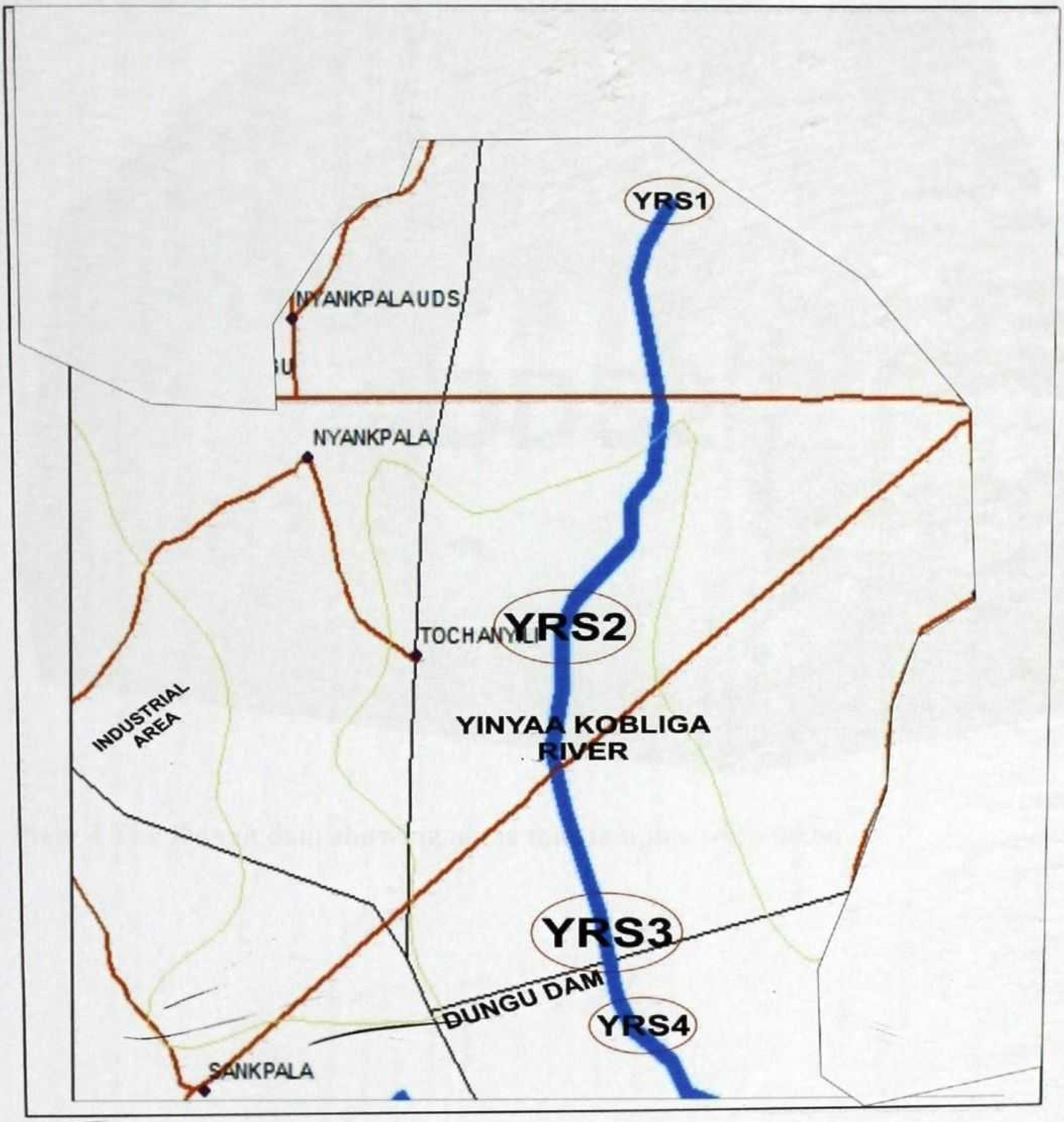


Figure 1.The map of Tamale South showing the Study area.



Key

YRS1------------Yinyaa River Site

YRS2------------------Yinyaa River Site 2

YRS3------------------Yinyaa River Site3

YRS4------------------Yinyaa River Site 4

Figure 2.The map showing the Yinyaa Kobliga River.

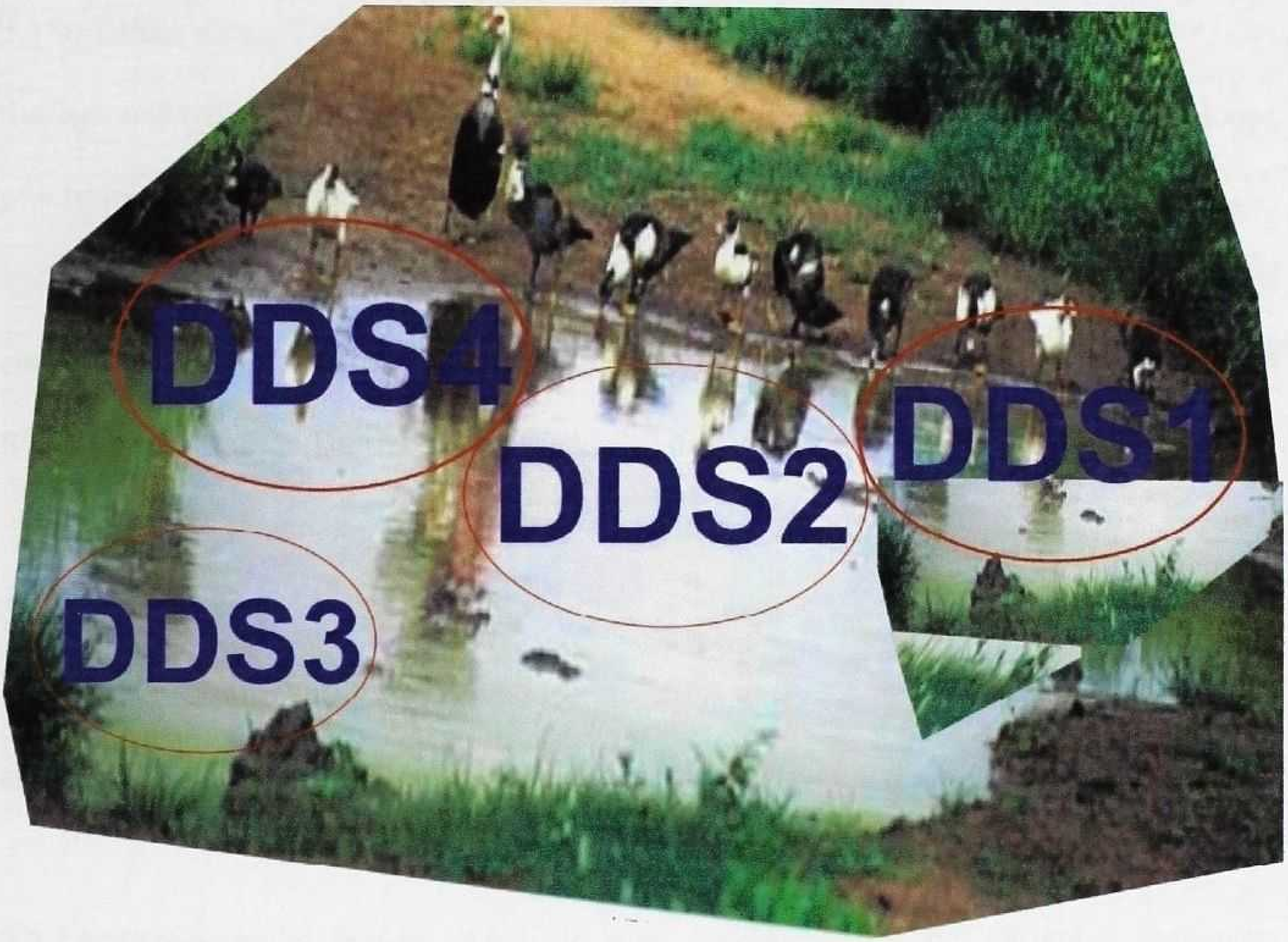


Plate 4 The Dungu dam showing areas that samples were taken

3.1Software used

Statistical Analysis System (SAS) software was employed to determine whether groups of variables have the same means of data or shows a trend of elemental concentration. Additionally, it was employed to assess the relationship between heavy metal concentrations and their elemental relationship between sections of the Yinyaa Kobliga River and the Dungu Dam.

3.2 Research methods

3.2.1 Correlation analysis: Pearson correlation analysis was adopted to analyze and establish inter-metal relationships of heavy metals of river and dam sediments.

3.2.2Anthropogenic factor: Analysis was employed on the variables that were correlated to isolate or determine specific factors that were associated with such groupings of metal concentration.

The enrichment was normalized relative to the depth in sediment core using the following formula; AF = Cs/ Cd where Cs and Cd referred to the mean concentration of elements in the surface sediments and at a depth in sediment column respectively (Williamson *et al.,* 1992). If AF≥ 1 for a particular metal, it means contamination exists otherwise if AF ≤ 1 there is no metal enrichment of anthropogenic origin.

3.2.3 Contamination factor (Cf); The overall proposed indicator of contamination which is based on integrating data for a series of specific heavy metals was used to calculate for each pollutant a contamination factor (C_f) (Hakanson, 1980). The contamination factor (C_f) required that at least five (5) surficial sediment samples are averaged to produce a mean pollutant concentration which is then compared to a baseline reference level, according to the following equation; $C_f = M_x/M_b$, Where M_x and M_b respectively refer to the mean concentration of pollutant in the contamination sediment and the local 'baseline' sediments (Hakanson, 1980). The local 'baseline' was established by taking the mean of five (5) low or least impacted levels of concentrated sediment samples selected from a nearby dam (Bulpiela Dam). This was done by inspection of the metal trends in the lower core (Siegel *et al*., 1994).

When; $C_f<1$; low contamination, $1\leq C_f\leq 3$; moderate contamination, $3 = C_f< 6$; considerable contamination, $C_f = 6$; very high contamination (Hakanson, 1980).

3.2.4 Modified degree of contamination;The formula for the modified degree of contamination; $mCd = \sum_{i=1}^{i=n} Cfi/n$ was used to calculate for the degree of contamination.

Cfi = sum of i contamination factors.

n = number of analyzed pollutants

The formula defined the modified degree of contamination as the sum of all contamination factors (C_{fis}) for a set of pollutants divided by the number of analyzed pollutants (n) (Abrahim and Parker, 2008). The mean concentration of a pollutant element was based on the analysis of at least five (5) samples of the impacted elements taken from the uppermost layers of a core (Abrahim and Parker, 2008). A local baseline concentration for each core was established by taking the mean of five (5) selected low concentrations of least impacted elements in the sediment cores of Bulpiela Dam. (Abrahim and Parker, 2008).

The modified equation for the generalized approach to calculating the modified degree of contamination is given below as: mCd = $\sum_{i=1}^{i=n}$ Cfi/n ,

Where n = number of analyzed elements,

i= ith element or (pollutant) and

Cfi= contamination factor of the element i.

Using this generalized formula to calculate the modified degree of contamination (mCd) allows the incorporation of as many metals as the study may analyze with no upper limit. The expanded range of possible pollutants can thus include both heavy metals and organic pollutants. Should the latter be available for the studied samples. For the classification and description of the modified degree of contamination (mCd) in sediments the following gradations were proposed by (Abrahim and Parker, 2008).

Table1Classification and description of modified degree of contamination (Data after Abrahim and Parker, (2008))

$mCd < 1.5$……………………………………………Nil to very low degree of contamination

$1.5 \leq mCd < 2$……………………………………………Low degree of contamination

$2 \leq mCd < 4$……………………………………………Moderate degree of contamination

$4 \leq mCd < 8$……………………………………………High degree of contamination

$8 \leq mCd < 16$……………………………………………Very high degree of contamination

$16 \leq mCd < 32$……………………………………………Extremely high degree of contamination

$mCd \geq 32$……………………………………………Ultra high degree of contamination

3.2.5 Geo-accumulation index (Igeo) was used to estimate the enrichment of metal concentrations above background or baseline concentrations. Muller, (1981) equation was employed as shown below;

$Igeo = \log_2 Cn/1.5Bn$.

where Cn is the concentration of the element in the enriched samples and

Bn is the background or baseline value of the element.

1.5 is introduced to minimize the effect of possible variation in the background values which may be attributed to lithologic (variation from rock source) variations in the sediments (Stoffers *et al.*, 1986).

TABLE 2GEO-ACCUMULATION INDEX (data after Stoffers *et al.*, 1986)

Igeo value	Class	Quality of sediment
< 0	0	Unpolluted
0-1	1	From unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	From moderately polluted to strongly polluted
3-4	4	Strongly polluted
4-5	5	From strongly polluted to extremely polluted
= 6	6	Extremely polluted

3.2.6 Pollution Load Index (PLI); The extent to which the heavy metals polluted the Dungu dam and the Yinyaa river were assessed using the Pollution Load Index based on the pollution load index developed by Tomilson *et al.*, (1980) as shown below.

$PLI = n\sqrt{\text{product of n number of } C_f \text{ values}}$.

Where C_f = Contamination Factor and

n = number of metals.

PLI provided a simple comparative means for assessing the quality of a site (river and the dam). A value of zero indicates perfection; a value of one indicates baseline levels of pollutants present. Values above one would indicate progressive deterioration of the site quality.

3.3Sampling technique

The sampling methods were based on those recommended by the USEPA but were modified to suit the field situations and the available resources. The methods employed maintained the primary features of the EPA methods (USEPA, 1991).

The samples investigated in this work were water and sediments samples from the Yinyaa Kobliga River and the Dungu dam. The Yinyaa Kobliga River and the Dungu dam were purposively selected due to the perceived pollution by the activities of the vehicle mechanics within the area. The sampling area was stratified, the major criterion being peculiar pollution perception characteristics of the stratified area.

3.3.1 Water samples collection, storage and measurement of physico-chemical parameters.

3.3.2 Collection procedure

A total of thirty-two (32) samples/readings were collected/taken from the Yinyaa Kobliga River and the Dungu dam just below the surface of each sampling locations in two seasons. (dry and rainy seasons). Sixteen (16) samples were collected in the dry season at the eight (8) sampling points and the results averaged into eight (8). This was replicated in the rainy season. These water samples were placed into polyvinyl bottles that had been pre-washed with detergent and tap water rinsed with 1;1 concentrated nitric acid and distilled water. The sampling bottles were rinsed three times with the water samples from the Yinyaa Kobliga River and the Dungu dam after which 1.5Litres of the water samples were collected using a hand held GPS in order to locate the coordinates of the sampled area. Identification labels were fixed on each water sample collected.

3.3.3 Sample storage

The samples were stored in an iced-chest at 4^0C and later conveyed to the laboratory for analysis.

3.3.4 Measurement of physico-chemical parameters

Temperature and pH were measured at each of the eight (8) sampling points (Figure 2 and Plate 4) for the two seasons using a Fisher Scientist Accumet Portable AP6 pH/mV/°C Meter. Dissolved Oxygen (DO) was determined using Winkler's Modification Method (Standard Method, 1998). In the laboratory; A Seven Multi-Mettler Toledo was used in the determination of the conductivity. Total Dissolved Solids (TDS) was determined gravimetrically by filtering 100cm^{3}samples through a weighted filter paper followed by evaporation and ignition (Standard Method, 1998).

3.3.5 Sediment collection, preparation and storage

A total of (one hundred and sixty) (160) river/dam sediment samples were taken in two seasons. Eighty (80) sediment samples were collected during the rainy season as follows; five (5) sediment samples were collected at each sampling point for the eight (8) sampling sites Yinyaa River Sample 1 (YRS1), Yinyaa River Sample 2(YRS2), Yinyaa River Sample 3(YRS3),Yinyaa River Sample 4(YRS4), (Figure 2), Dungu Dam Sample 1(DDS1), Dungu Dam Sample 2 (DDS2), Dungu Dam Sample 3(DDS3) and Dungu Dam Sample 4 (DDS4)(Plate 4) giving a total of forty (40). These forty (40) sediments were taken at the surface to 10cm deep of the river and the dam beds. Another forty (40) sediment samples were collected from the river and the dam using a PVC coring tube (7.5cm in diameter, 2.5m in length) at depths in the sediment column at each sampling point of the eight (8) sampling sites. All these sediment samples were collected at 8.00AM 25th June 2012 after three successive heavy rains. Eighty (80) sediment samples were again collected during the dry season as follows; five sediment samples were collected at each sampling point for the eight (8) sampling sites giving a total of forty (40) sediment samples. These forty (40) sediment samples were taken at the surfaces of the river and dam beds respectively. A PVC coring tube (7.5cm in diameter, 2.5m in length) was used to collect forty (40) sediment samples at depths along the sediment column in the hours of 8AM Monday, 24th October 2011.

The collection of sediment samples was done in two phases, the dry season (24^{th} October, 2011) and the rainy season (25^{th} June, 2012). These sediment samples were quickly packed in air tight polythene bags. The coordinates of the sampled points were recorded using a hand held GPS.

3.3.6 Digestion of sediment samples

The sediment samples were oven dried at 50 ^{0}C for 48 hours and ground using mortar and pestle. The samples were sieved by a sieve (of aperture 2mm). The lower particle size fraction was homogenized by grinding again in mortar and stored in plastic bottles. For the levels of; Cu, Cr, Cd, Pb and Zn, about 0.5g was weighed and quantitatively transferred into a 10ml test-tube. 2ml hydrochloric acid (HCl) and 1ml nitric acid (HNO_3) were added. The solution was placed on a hot plate set at 95^{0}C to heat for an hour. The solution was removed from the hot plate, cooled and topped to a 10ml mark with de-ionized water. It was then filtered and aspirated to determine heavy metals levels using AAS. Precautions were taken to avoid contamination during drying, grinding, sieving and storage. All the reagents and chemicals used were of analytical grade. The extraction method used in this study was adapted from Stewart, (1989) and is based on $4HNO_3$ digestion. The efficiency of the $4HNO_3$ extraction is 98% for Pb and Cd, 95% Cu and 91% Zn (Stewart, 1989).

3.3.7 Analysis using the atomic absorption spectrometer (AAS) machine

The method for the analysis of the water samples was based on standard methods adopted by the US Environmental Protection Agency and American Water Works Association. The analysis of sediment samples for the heavy metals (Cd, Cr, Cu, Pb and Zn) were carried out by the Chemistry Department of the Faculty of Applied Science in the University for Development Studies, Navrongo Campus whilst the instruments for the measurement of the physico-chemical characteristics of the Dungu dam and Yinyaa Kobliga river waters were supplied by Ghana water Company Tamale Northern Region.

3.3.8 Calibration of the AAS machine

The instrument was calibrated using prepared standard solutions of the corresponding metal reagents in series: 2ppm, 4ppm and 10ppm.

3.3.9 Determination of the concentration of the heavy metals.

The concentrations of Cu, Cr, Cd, Pb and Zn were determined using the Thermo Scientific Atomic Absorption Spectrometer (AAS), ICE 3000 Series after double distilled water had been used to zero the instrument. After the calibration of the instrument, the blank solution was measured followed by the concentrations of (Cu, Cr, Cu, Pb and Zn) in the digested samples (Stewart, 1989).

3.3.10 Recovery and reproducibility

To check the sensitivity and efficiency of the method used in the chemical analysis, recovery and reproducibility studies were conducted. In the recovery studies known concentrations of; Cu, Cr, Cd, Pb and Zn were determined using Atomic Absorption Spectrometer (AAS). The percentage (%) of Cu, Cr, Cd, Pb and Zn recovered from double distilled water is between 95%-100% and a standard error of 0.001. It was realized that the method used for the chemical analysis was efficient. To check for reproducibility of the method used, reproducibility studies were conducted. In reproducibility studies double distilled water containing 1.0mg/L of Cu, Cr,, Cd, Pb and Zn solutions respectively were determined using the flame vapour Atomic Absorption Spectrometer ICE 3000 model. The percentage (%) of the metals recovered in their studies showed that the standard error was less than 1; this suggested that the method employed for the chemical determination of Cu, Cr, Cd, Pb and Zn is reproducible (Marine Test Methods – precision and interpretation 2011).

CHAPTER FOUR

4.0 Results

A representative analytical data of heavy metals concentration (in mg/kg) from the sampling sites (Yinyaa Kobliga and the Dungu dam) were presented in Tables as shown below. To evaluate dataset, the Thermo – Scientific ICE 3000 Atomic Absorption Spectrometer model was used to analyze heavy metal concentrations in the sediments of Yinyaa Kobliga River and the Dungu dam respectively. The concentration of each sampled site in Table 3, 4, 5 and 6 below represented the mean concentration of five sediment samples collected from the same sampled site and averaged into a single concentration. The levels of heavy metals concentrations extended over several orders of magnitudes with the River sediments revealing much higher concentrations of heavy metals than the dam.

Table 3: The mean concentrations of heavy metals in the surface sediments of Yinyaa Kobliga River and the Dungu dam during rainy season.

SAMPLE ID	CONCENTRATION OF HEAVY METALS (mg/kg)				
	Cd	Zn	Pb	Cu	Cr
YRS1	1.10	127.50	8.85	74.86	21.60
YRS 2	1.00	106.78	10.25	44.82	28.65
YRS3	1.10	116.86	15.90	63.70	25.12
YRS4	1.10	105.80	11.67	8.50	22.30
DDS 1	0.99	112.10	7.75	0.30	18.12
DDS 2	0.89	22.50	8.55	5.23	18.60
DDS 3	0.80	31.25	3.95	7.75	14.90
DDS4	0.78	35.87	7.80	9.20	18.40
BLANK	0.00	0.00	0.00	0.00	0.00
Maximum	1.10	127.50	10.25	74.86	28.65
Minimum	0.78	22.50	3.95	0.30	14.90
Arith. Mean	0.97	82.33	9.34	26.80	20.96
Baseline	0.65	22.48	3.90	5.20	14.88
TEC.	0.99	120	36	32	43
PEC.	5.0	460	130	150	110
Max.contamin.	0.1	10	0.1	5.0	0.1

Key for the codes

YRS1 ----------Yinyaa River Site 1

YRS2 ----------Yinyaa River Site 2

YRS3 ----------Yinyaa River Site 3

YRS4 ----------Yinyaa River Site 4

DDS1 ----------Dungu Dam Site 1

DDS2 ----------Dungu Dam Site 2

DDS3-----------Dungu Dam Site 3

DDS4-----------Dungu Dam Site 4

TEC------------Threshold Effect Concentration

PEC------------Probable Effect Concentration

Table 3 above shows the concentrations of heavy metals in the Yinyaa Kobliga River and the Dungu dam. Maximum concentration values of heavy metals recorded were all from the river while minimum concentration values recorded were all from the dam.

Table 4: The mean concentrations of heavy metals in sediments of Yinyaa Kobliga River (YRS) and the Dungu Dam (DDS) during the rainy season using a coring tube along sediment columns.

SAMPLE ID	CONCENTRATION OF HEAVY METALS(mg/kg)				
	Cd	Zn	Pb	Cu	Cr
YRS1	1.00	97.42	8.00	54.85	20.00
YRS 2	0.87	96.77	8.20	24.0	23.62
YRS3	1.10	96.80	14.98	52.98	25.00
YRS4	1.00	95.70	11.65	8.00	22.10
DDS 1	0.88	62.00	6.80	0.28	16.10
DDS 2	0.80	22.48	8.51	5.20	18.58
DDS 3	0.79	31.20	3.90	7.70	14.88
DDS4	0.65	35.72	6.75	9.00	18.00
BLANK	0.00	0.00	0.00	0.00	0.00
Maximum	1.00	97.42	14.98	54.85	25.00
Minimum	0.65	22.48	3.90	0.28	14.88
Arith. Mean	0.89	67.26	8.60	20.35	19.79
TEC.	0.99	120	36	32	43
PEC.	5.0	460	130	150	110
Max.contamin.	0.1	10	0.1	5.0	0.1

Key for the codes

YRS1 ----------Yinyaa River Site 1

YRS2 ----------Yinyaa River Site 2

YRS3 ----------Yinyaa River Site 3

DDS1 ----------Dungu Dam Site 1

DDS2 ----------Dungu Dam Site 2

DDS3-----------Dungu Dam Site 3

YRS4 ----------Yinyaa River Site 4 DDS4-----------Dungu Dam Site 4

TEC------------Threshold Effect Concentration

PEC------------Probable Effect Concentration

Maximum concentration values of the heavy metals were higher in the river compared to that of the dam.

Table 5: The mean concentrations of heavy metals in the surface sediments of the Yinyaa Kobliga River and the Dungu dam during the dry season

SAMPLE ID	CONCENTRATION OF HEAVY METALS (mg/kg)				
	Cd	Zn	Pb	Cu	Cr
YRS1	1.00	97.43	8.86	54.85	21.60
YRS 2	0.99	96.79	10.25	4.81	23.64
YRS3	0.97	96.83	10.10	50.85	24.98
YRS4	0.98	95.20	9.20	7.80	22.00
DDS 1	1.00	62.00	7.73	0.29	18.13
DDS 2	0.89	22.49	8.52	5.22	18.60
DDS 3	0.80	31.22	3.93	7.71	14.89
DDS4	0.79	32.00	7.72	8.90	14.87
BLANK	0.00	0.00	0.00	0.00	0.00
Maximum	1.00	97.43	10.25	54.85	23.64
Minimum	0.79	22.49	3.93	0.29	14.87
Arith. Mean	0.93	66.75	8.29	17.55	19.84
Baseline	0.84	48.30	7.47	5.13	17.45
TEC.	0.99	120	36	32	43
PEC.	5.0	460	130	150	110
Max.contamin.	0.1	10	0.1	5.0	0.1

Key for the codes

YRS1 ----------Yinyaa River Site 1 DDS1 ----------Dungu Dam Site 1

YRS2 ----------Yinyaa River Site 2 DDS2 ----------Dungu Dam Site 2

YRS3 ----------Yinyaa River Site 3 DDS3-----------Dungu Dam Site 3

YRS4 ----------Yinyaa River Site 4 DDS4-----------Dungu Dam Site 4

TEC------------Threshold Effect Concentration

PEC------------Probable Effect Concentration

In table 5 above, the concentration values of the heavy metals in the river were all above the concentration values recorded in the dam.

Table 6: The mean concentrations of heavy metals at different depths using a coring tubein a sediment column during the dry season.

SAMPLE ID	CONCENTRATION OF HEAVY METALS (mg/kg)				
	Cd	Zn	Pb	Cu	Cr
YRS1	0.99	96.26	8.79	54.73	21.59
YRS2	0.98	96.75	10.25	4.80	23.49
YRS 3	0.96	94.87	10.13	50.00	23.80
YRS4	0.98	95.00	9.00	7.70	21.00
DDS 1	0.87	61.75	7.65	0.26	18.10
DDS 2	0.80	20.98	8.51	5.19	18.53
DDS 3	0.81	30.89	3.90	7.69	14.80
DDS4	0.78	33.00	8.50	8.80	14.80
BLANK	0.00	0.00	0.00	0.00	0.00
Maximum	0.99	96.76	10.13	54.73	23.80
Minimum	0.78	20.98	3.90	0.26	14.80
Arith. Mean	0.90	66.19	8.34	17.40	19.51
TEC.	0.99	120	36	32	43
PEC.	5.0	460	130	150	110
Max.contamin.	0.1	10	0.1	5.0	0.1

~~Key for~~ the codes

YRS1 ----------Yinyaa River Site 1

YRS2 ----------Yinyaa River Site 2

YRS3 ----------Yinyaa River Site 3

YRS4 ----------Yinyaa River Site 4

DDS1 ----------Dungu Dam Site 1

DDS2 ----------Dungu Dam Site 2

DDS3-----------Dungu Dam Site 3

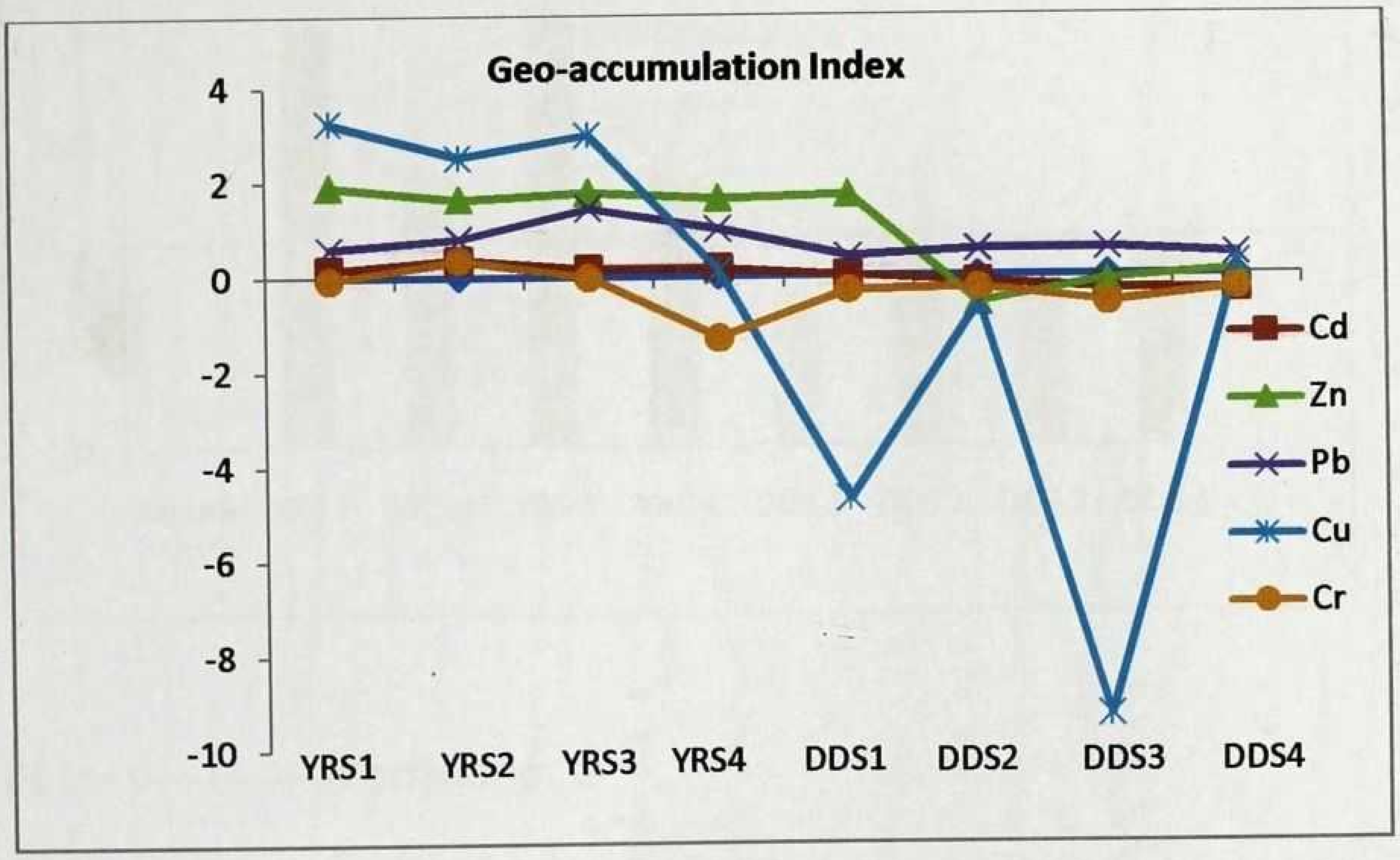
DDS4-----------Dungu Dam Site 4

TEC------------Threshold Effect Concentration

PEC------------Probable Effect Concentration

In table 6 above, the concentration values of heavy metals in the river far exceeded that of the dam.

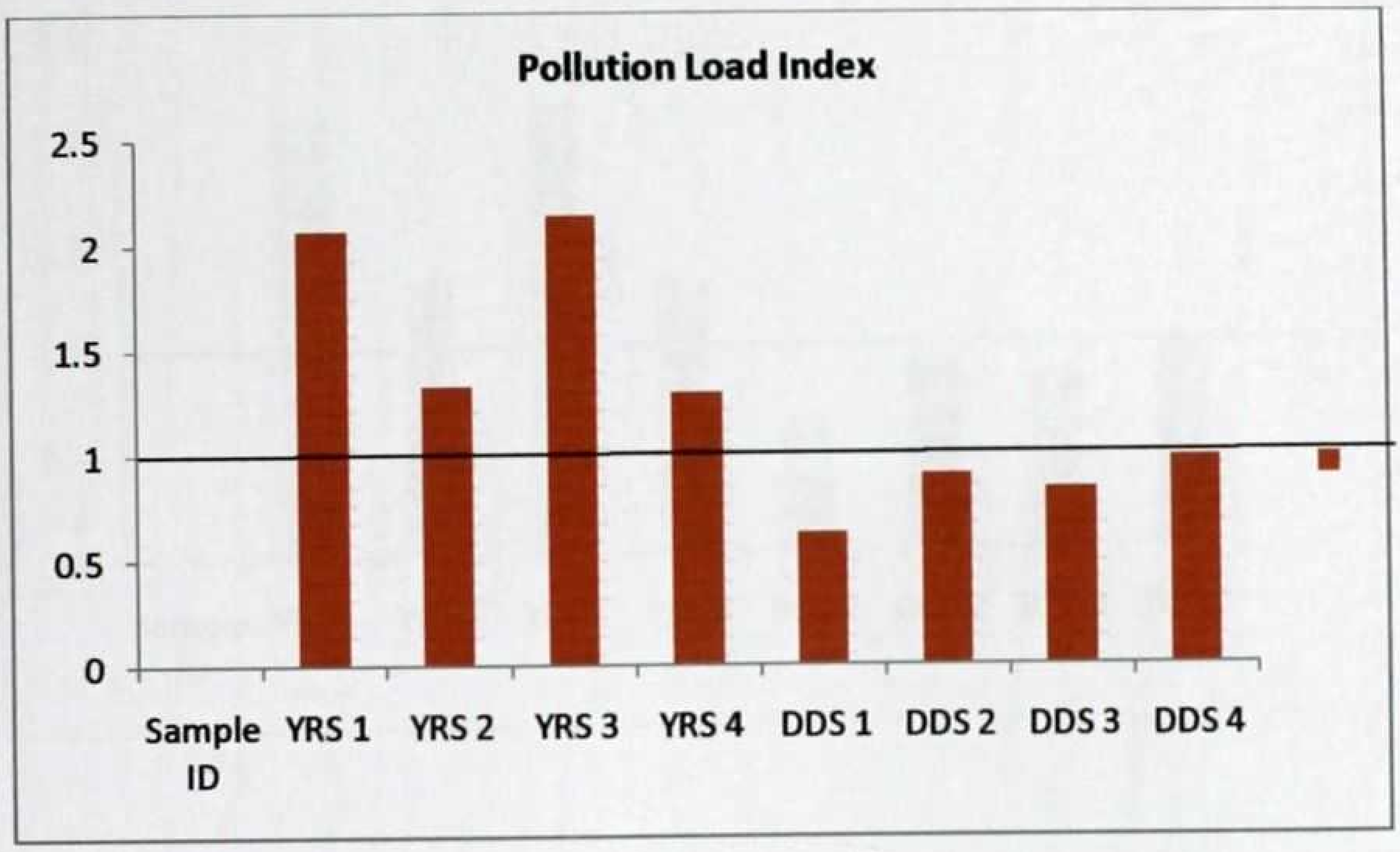
Figure 3 Shows the line graph of the results of Geo-accumulation index of the heavy metals in the sediment samples of both the Yinyaa Kobliga River and the Dungu dam.



From figure 3 above, the river sediment quality was moderately polluted to strongly polluted while the dam sediment quality were unpolluted to moderately polluted

Pollution load index

Figure 4 Calculated Pollution Load Index of the indicated sites during the dry season (Tomilson *et al.*, 1980).



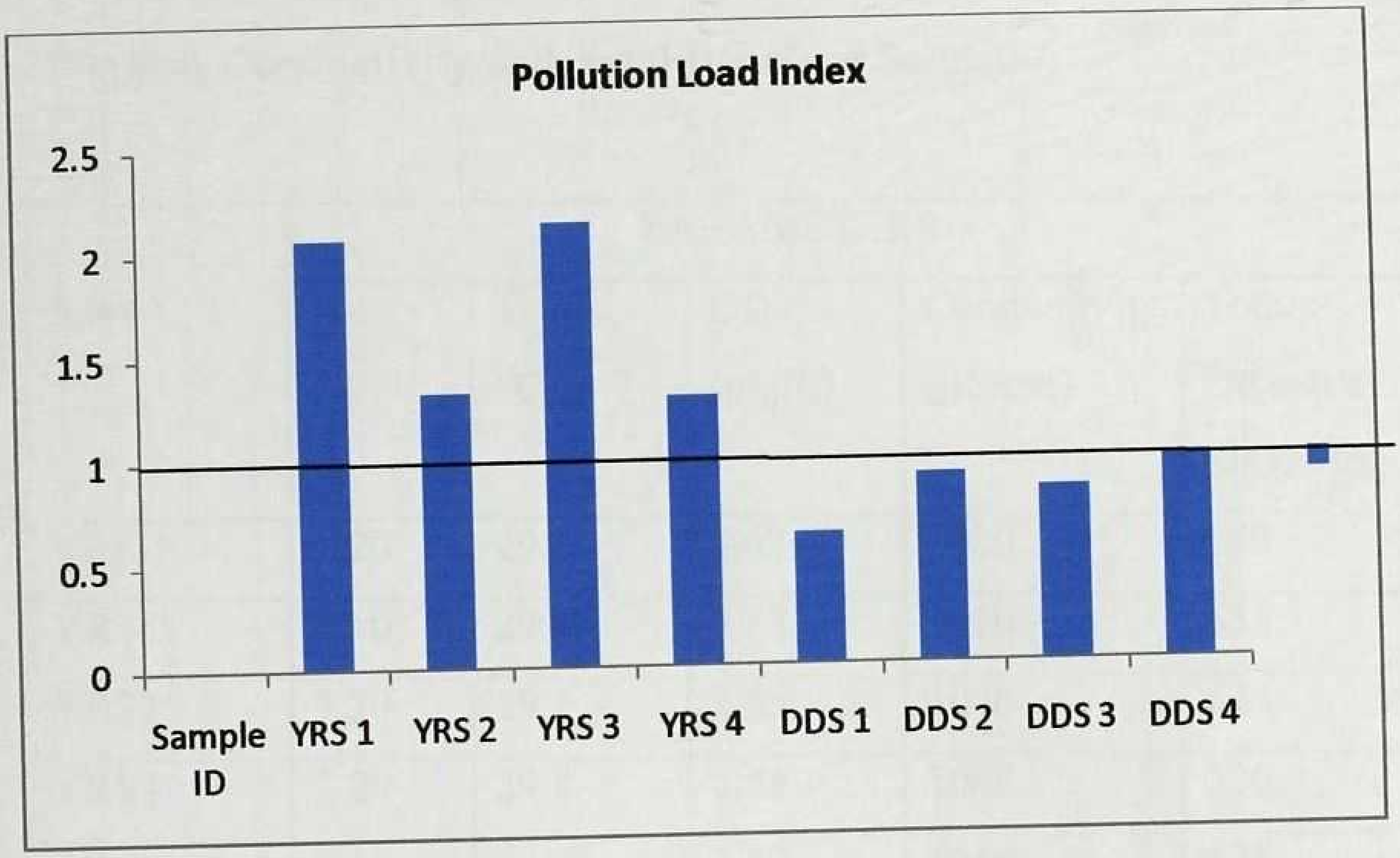
PLI = 0-----------Perfection

PLI = 1---------------Baseline levels of pollutants present

PLI > 1---------------progressive deterioration of the site quality

From figure 4, the Dungu dam had baseline levels of pollutant present while the Yinyaa Kobliga River was progressively deteriorating in quality.

Figure 5 Calculated pollution load index of the indicated sites during the Rainy season (Tomlinson *et al.*, 1980).



PLI = 0-----------Perfection

PLI = 1----------------Baseline levels of pollutants present

PLI > 1----------------progressive deterioration of the site quality

The Dungu dam had baseline levels of pollutants present while the Yinyaa Kobliga River had progressive deterioration of the site quality.

Table 6: The values indicate some physico-chemical characteristics of the Yinyaa Kobliga and the Dungu dam during the dry season (pH, Temperature, Dissolved Oxygen, Conductivity and Total Dissolved Solids).

Sites	PARAMETERS				
	pH	Temp ^{o}C	DO (mg/L)	Conductivity (μS/cm)	Total Dissolve Solids(mg/L)
YRS 1	7.20	29.6	3.67	1080	540
YRS 2	7.10	29.4	2.57	1070	535
YRS3	7.30	29.3	2.55	1040	525
YRS4	7.20	29.8	2.58	1060	520
DDS 1	7.10	30.0	2.62	1050	525
DDS 2	7.40	30.1	2.70	1080	540
DDS 3	7.20	30.0	2.60	1040	520
DDS4	7.50	30.0	2.64	1030	540
Arithmetic mean	7.25	29.78	2.74	1056	531

Key for the codes

Temp-------------Temperature

DO----------------Dissolved Oxygen

Maximum pH was recorded in the Dam and the minimum was recorded both in the dam and the river. Maximum temperature was recorded in the dam the minimum was recorded in the river. Maximum Dissolved oxygen was recorded in the river minimum was also recorded in the river. Maximum Conductivity values were recorded in both the river and the dam and the minimum Conductivity values were recorded only in the dam. Maximum Total Dissolved Solids were recorded in both the river and the dam while the minimum Total Dissolved Solids value was recorded in only in the dam.

Table 7: The values indicate some physico-chemical characteristics of the Yinyaa Kobliga and the Dungu dam during the rainy season

Sites	PARAMETERS				
	pH	Temp ^0C	DO (mg/L)	Conductivity (µS/cm)	Total Dissolve Solids(mg/L)
YRS 1	7.12	30.4	2.43	1090	530
YRS 2	6.88	30.1	2.42	1090	525
YRS3	7.25	30.2	2.42	1070	525
YRS4	7.14	30.7	2.40	1060	510
DDS 1	6.90	30.0	3.56	1060	500
DDS 2	7.35	30.0	3.56	1050	450
DDS 3	7.15	30.0	3.68	1050	420
DDS4	7.24	30.0	3.67	1040	415
Arithmetic mean	7.13	30.18	3.02	1064	484

Key for the codes

Temp------------Temperature

DO---------------Dissolved Oxygen

Both the maximum and the minimum pH values were recorded in the Dungu dam. Maximum temperature was recorded in the river while the minimum temperature value was recorded in the dam. Maximum Dissolved Oxygen was recorded in the dam while the minimum Dissolved Oxygen was recorded in the river. Maximum Conductivity values recorded were in the river while the minimum Conductivity value was found in the dam. Maximum Total Dissolved Solids value was recorded in the river while the minimum Total dissolved Solids value was recorded in the dam.

CHAPTER FIVE

DISCUSSION

5.0 Comparative study of sediment samples of Yinyaa Kobliga River and the Dungu dam.

A change in environmental condition as a result of the accumulation of heavy metals in sediments could be a secondary source of water pollution (Cheung *et a*l., 2003).

An assessment of heavy metal contamination in sediments is an indispensable tool to assessing the risk of an aquatic environment. In assessing heavy metal concentrations in the sediments of Yinyaa Kobliga River and the Dungu Dam, numerical Sediment Quality Guidelines (SQGs) were applied. (Appendix A). SQGs included a threshold effect concentration (TEC) and a probable effect concentration (PEC). If the metals in sediments are below the TEC, harmful effects are unlikely to be observed. If the metals are above the PEC, harmful effects are likely to be observed.

Mac Donald et al., (2000) noted that most of the TECs provided an accurate basis for predicting the absence of sediment toxicity and most of the PECs provided an accurate basis for predicting sediment toxicity.

The arithmetic means of all the heavy metals fell below the TEC and PEC values (Tables 3, 4, 5 and 6) for both the rainy and dry seasons signifying harmful effects are unlikely to be observed. This may be due to the fact that the concentrations of the Heavy metals in the dam were far less than those in the river hence taking average concentrations of the river and the dam would further result in low concentration values.

Considering the individual heavy metals site by site, it was observed that Cadmium (Cd) exceeded the TEC values in Yinyaa Kobliga River Site 1 (YRS1), Yinyaa Kobliga River Site 2 (YRS2), Yinyaa Kobliga River Site 3(YRS3), and Yinyaa Kobliga River Site 4 (YRS4) (Table 3). This signified a potential risk of Cadmium (Cd) toxicity. On the other hand, the Dungu dam values for Cadmium (Cd) fell below the TEC and PEC values (Table 3) signifying harmful effects are unlikely to be observed.

The low values of Cadmium (Cd) in the dam may be due to the fact that the wastes produced by the vehicular mechanics at the point of sampling did not contain Cadmium (Cd) or during dispersion, Cadmium (Cd) was not dispersed to the dam but remained in the river.

Zinc (Zn) values in both the Dam and the river fell below the TEC and PEC values (Table 3). This implies that harmful effects are unlikely to be observed. This could mean that the anthropogenic contribution of Zinc (Zn) to pollution was negligible or did not occur at all.

The values of Lead (Pb) and Chromium (Cr) were below the TEC and PEC values (Table 3) showing no harmful effects are likely to be observed. This could be due to the fact that the wastes generated by the mechanics did not contain Lead (Pb) and Chromium (Cr) or their levels were not in such proportions so as to cause harmful effects.

The concentration of Copper (Cu) on the other hand, exceeded the TEC values in YRS1 and YRS3 (Table 3 and 5). This signified that the sampling sites in the Yinyaa Kobliga River stand a high risk of potential Copper metal toxicity. This may be possible because the sediment contribution of heavy metals from anthropogenic sources was high in these sites. However all the values of Copper (Cu) were below the PEC values indicating harmful effects are unlikely to be observed. Presumably the concentration of Copper (Cu) in the wastes generated was not high enough to cause any harm.

Analysis of sediment samples by the Atomic Absorption Spectrometer (AAS) Thermo Scientific ICE 3000 Model showed increased concentrations of the heavy metals from the dry to the rainy seasons. (Tables 3, 4, 5 and 6). This may be due to surface runoff water carrying wastes from the industrial area and households into the water bodies, (River and Dam). This finding agrees with the report of Okweye *et al.*, (2007).

Zinc (Zn) and Copper (Cu) concentrations increased from the dry Season to the Rainy season in all the sampled sites in the Yinyaa Kobliga River (Tables 3, 4, 5 and 6). This may be due to wastes generated in the industrialized area by the vehicle mechanics, domestic wastes from homes and the farming activities around the river and the dam during the rainy season.

Lead (Pb) had its concentrations increased in sampled sites YRS3 and YRS4, Cadmium (Cd) and Chromium (Cr) in sampled Sites YRS3 and YRS2 respectively (Tables 3 and 5). The concentration of Copper (Cu) in all the sampled Sites in the Dungu Dam (DDS) increased from the dry season to the rainy season (Tables 3 and 5). Zinc (Zn) and Chromium (Cr) also had their concentrations increased from the dry season to the rainy season in DDS1 and DDS4 respectively (Tables 3 and 5).

The following activities of the vehicle mechanics in the Tamale South Sub-Metropolitan Area could be the reason for the increased in concentration of heavy metals in their wastes; the discharged of leaded gasoline, lubricating oil, grease and the wear and tear of tyres could increase the concentration of lead (Pb) in their wastes. The indiscriminate discarded engine parts and discharged break emissions together with bearing wear could lead to a pile up of copper (Cu) in the wastes generated.. The release of all these heavy metals together with Zinc (Zn) from galvanized roofs and lead (Pb) from old house/car paint might have been washed off by surface runoff storm water into the Yinyaa Kobliga River and subsequently into the Dungu dam during the rainy season thereby increasing the concentration of these metals in the rainy season.

The following sampling sites had their concentrations in the dam and river sediments unchanged from the dry season to rainy season; YRS1 Chromium (Cr) (21.60mg/kg – 21.60mg/kg), YRS2 Pb (10.25mg/kg – 10.25mg/kg), DDS2 Cadmium (Cd) (0.89mg/kg – 0.89mg/kg), DDS2 Chromium (Cr) (18.60mg/kg – 18.60mg/kg) and DDS3 Cadmium (Cd) (0.80mg/kg – 0.80mg/kg) (Tables 3 and 5).

Heavy metals adsorbed to particulate matter may be dispersed as surface runoff storm water flows from the industrial area into the Yinyaa Kobliga River. Yinyaa Kobliga Site1 (YRS1) is the point at which the waste water from the industrialized area entered the river. YRS 1 and YRS2 are fast flowing sites during the rainy seasons. The Site becomes turbulent and most of the sediments would have been carried past the site before dispersion of the heavy metals occurred. It is also possible that the activities of the vehicle mechanics within the given period (rainy season) did not involve the use of the Chromium (Cr), Lead (Pb) and Cadmium (Cd).

The following sampling sites had their metal concentrations in the dam and river sediments decreased from dry season to the rainy season; YRS1 Lead (Pb) (8.86mg/kg – 8.85mg/kg), DDS1 Cadmium (Cd) (1.00mg/kg – 0.99mg/kg) and DDS4 Cadmium (Cd) (0.79mg/kg – 0.78mg/kg) (Tables 3 and 5).

The concentrations of lead (Pb) and Cadmium (Cd) decreased in YRS1 and DDS1 most probably because, the activities of the vehicle mechanics did not involve the use of Lead(Pb) and Cadmium(Cd) at the time of sampling. The lead (Pb) and Cadmium (Cd) which might have been adsorbed on particulate surfaces would have been consumed by sediment Biota and or other aquatic organisms before being dispersed to the sites.. Cadmium in DDS4 is the farthest site in the dam water (Plate 4). The dam is not fast following hence by distance it had a dispersal site disadvantage as most of the sediments would have settled before reaching DDS4.

The Arithmetic mean concentrations of the individual metals in both the rainy and dry seasons (Cd = 0.97/0.93, Zn = 67.33/66.75, Pb = 9.34/8.27, Cu = 18.05/17.55 and Cr = 20.96/19.84) far exceeded the maximum contamination permissible levels for fresh water ecosystem by USEPA (1991) (Tables 3 and 5). This indicated that the water quality is below the international standards and should not be consumed or used for domestic purposes.

5.1Assessing the sediments quality of Yinyaa Kobliga river and the Dungu dam.

The chemical contamination in the sediments was evaluated with the sediment quality guidelines proposed by USEPA. (Appendix A). Cadmium (Cd) and Lead (Pb) during the rainy season and Cadmium (Cd), Lead (Pb) and Chromium (Cr) during the dry season all belong to unpolluted sediments in all the sampling sites. Chromium (Cr) in sediments of sampling sites YRS2 and YRS3 during the rainy season is considered moderately polluted. Zinc (Zn) in the sediments of sampling sites YRS1, YRS2, YRS3, YRS4 and DDS1 and Copper (Cu) in sampling Sites YRS1 and YRS3 during the rainy season belong to heavily polluted sediments. On the other hand in the dry season, Copper (Cu) and Zinc (Zn) in the sediments of YRS1, YRS3 and YRS1, YRS2, YRS3, YRS4 and DDS1 respectively belong to heavily polluted sediments. Cadmium (Cd) and Lead (Pb) in both the dry season and the rainy season were unpolluted in the sediments. Taking the figures into consideration, it would be realized that even though Cadmium (Cd) and Lead (Pb) were unpolluted in the sediments, the concentration figures in the rainy season are relatively higher than that of the dry season. (Appendix A).

This could be due to the fact that surface runoff storm water from the industrial area where the vehicle mechanics operated could have caused the increased in the concentration figures during the rainy season. During the dry season it was found that

Chromium (Cr) belong to unpolluted sediments but in the rainy season it belonged to moderately polluted sediments in sampled sites (YRS2 and YRS3). Even though Zinc (Zn) and Copper (Cu) are heavily polluted in the sediments of sampled sites YRS1, YRS2, YRS3, YRS4 and DDS1 in both the rainy season and the dry season, the concentration of the sediment figures differ considerably with the rainy season figures being higher compared to the dry season figures.

The enrichment of these heavy metals concentration may be due to surface runoff water carrying pollutants from nearby industrial area (vehicular mechanics waste) into the Yinyaa Kobliga River and subsequently into the Dungu dam.

The rainy seasons figures being higher than those of the dry season figures agrees with the findings of Lokeshwary and Chanchappa, (2006). In their findings, the mean concentration of Iron(Fe) in sediments during the wet season was higher than that of the dry season probably due to rainfall and runoff.

5.2. Correlation analysis

~~Inter-el~~emental association has been evaluated by Pearson correlation coefficient and the results were presented. (Appendices B, C and D). Positive correlation existed between all the selected heavy metals. Correlation ranged from moderately correlated (as in Pb and Zn, Cu and Pb, Cr and Cu, Cu and Cd, Cu and Zn, Cr and Cd, and Cr and Zn) during the rainy season and (Pb and Cd, Pb and Zn, Cu and Cd, Cu and Zn) during the dry season to high correlation (as in Zn and Cd, Pb and Cd and Cr and Pb) during the rainy season and (Zn and Cd, Cr and Cd, Cr and Zn, Cr and Pb, and Cr and Cu) during the dry season. This indicated the same or similar input source. Elemental association may signify that each paired elements had identical source or common sink in the river and dam sediments. Furthermore these metals might have had the same anthropogenic and natural sources in the sediments of the study area.

5.3 Assessment according to anthropogenic factor

It was observed that all the metals had their Anthropogenic Factors (AF) either equal to 1 or greater than 1 except Cu in YRS4 during the rainy season and Zn and Pb DDS4 during the dry season.(Appendix E). This shows enrichment of the metals from anthropogenic sources. There are no waste bins in the Tamale south Metropolitan industrial area where the mechanics put in their waste. Most of their wastes are either discharged directly into the Yinyaa Kobliga River or onto the ground. (Plates, 1, 2 and 3).

During the rainy season, most of these wastes are carried away by runoff water into the river and subsequently to the dam. Most of the commonly discharged wastes in the runoff water from the industrial area included; leaded gasoline, worn out tyres, lubricating oil, grease, worn out bearings, motor oil, break emissions, corrosion of galvanized parts, auto body rust, engine parts, burnt fuels, worn out batteries, air conditioners, coolants, vehicular densities, glass etc. Most of these contributed to heavy metals pollution in the river and the dam. Mobility of heavy metals depends not only on the total concentration in the sediments, but also the properties of the sediments, metals and environmental factors. According to Shi *et al.*, (2009), Pb, Cu, and Zn are poorly to moderately dissolved in water and would adsorbed to particles in the runoff water to get into water bodies. Around the river and the dam are farms of the community members. During the rainy season they farm on the land around the river and the dam for the cultivation of vegetables and some cereals. They employed the services of a tractor to till the land. These tractors loosen up soil particles which were carried into the water bodies and contributed to the pollution of the water. Fertilizers applied to these farms contributed immensely to the pollution of the water and the introduction of heavy metals into the water bodies. It would be observed that Zn and Cu in sampling sites DDS1 and YRS2 respectively had the highest anthropogenic contribution into the dam and the river respectively. (Appendix E). The results indicated that the contribution of the heavy metal pollution during the rainy season is largely due to an anthropogenic origin in nature. The anthropogenic factor values during the rainy season were generally higher than the values in the dry season (Appendix E and F).This may be due to the rainfall and runoff water carrying heavy metals into water bodies. Cadmium generally had a very high anthropogenic factor during the rainy season as compared to that of the dry season. This may be due to the fact that the waste produced by the vehicle mechanics discarded ~~to on~~ the ground were carried by runoff surface water into the water bodies as suggested by Shi *et al*., (2009). During the rainy season, the Agricultural(anthropogenic) activities near the dam and the river could also be the point source contributing to the pollution of the water bodies. Although generally the anthropogenic factor contribution was higher during the rainy season compared to the dry season, anomalies were observed in Yinyaa Kobliga River Site 3 (YRS3), Dungu Dam Site 1 (DDS1) and Dungu Dam Site 2 (DDS2) (Appendix E and F). In Yinyaa Kobliga River Site 1 (YRS1) and Dungu Dam

Site 1 (DDS1). (Appendices E and F), the anthropogenic factor for the dry season was rather higher than for the rainy season. This may be due to dilution by rain water which influences concentration and heavy metal mobility. Mobility of heavy metals depends not only on the total concentration in the sediment but also on the sediment properties and metal properties. The anthropogenic factor values contributed by Zn were generally higher in the rainy season compared to the dry season.(Appendices E and F).

5.4 Contamination factor assessment

Maximum value (12.40) of contamination factor was found in the sediment of Yinyaa Kobliga River Site 1(YRS1) for Cu (Appendix G) while the minimum contamination factor (0.05) for Cu was found in the sediment of Dungu Dam Site 1 (DDS1). DDS1, DDS2, DDS3, and DDS4 had low contamination factor values ranging from 0.05 to 0.98. DDS1 had low contamination factor values for Cu and Cr. (Appendix G). DDS2 had low contamination factor values for Zn, Cu and Cr. DDS3 had low contamination factor values for Zn and Pb. DDS4 had low contamination factor values for Zn and Cu. These low contamination values in the sediments of the dam may be attributed to dispersion and metal mobility. Metals adsorbed to particulate surface were dispersed by surface runoff water to other parts of the water body.

Apart from DDS4, all other sample sites had moderate contamination factor values for Cd according to the Hakanson's classification (Hakanson, 1980). Zn had moderate contamination factor values for YRS1, YRS2, YRS3, YRS4 and DDS1. Pb had moderate contamination factor values for all the sampling sites with the exception of

DDS3. Cu exhibited very high contamination factor values for the following sampling sites; YRS1, YRS2 and YRS3. Cu however demonstrated moderate contamination factor values in YRS4, DDS3 and DDS4 respectively. All the sample sites within the Yinyaa Kobliga River showed moderate contamination factor values ($1 \leq Cf \leq 3$) for Cr whereas all the Dungu Dam sapling sites showed low contamination factor values ($Cf < 1$) for Cr. Sample sites DDS1, DDS2, DDS3 and DDS4 that is all the sediment samples collected from the dam during the rainy season showed a low degree ($Cf < 1$) of contamination. YRS4 showed a moderate degree ($1 \leq Cf \leq 3$) of contamination while YRS2, YRS3 and YRS1 showed considerable degree ($3 = Cf < 6$) of contamination. The degree of contamination increased in the order; DDS3 < DDS2 < DDS4 < DDS1 < YRS4 < YRS2 < YRS3 < YRS1. This observation shows that the river is more contaminated with the heavy metals compared to the dam.

5.5 Assessment according to Geo-accumulation index

The quality of the sediment samples ranged between unpolluted to strongly polluted (i.e. 0-3). YRS1, YRS2, YRS3, YRS4 and DDS1 were unpolluted with Cd, DDS4 was moderately polluted with Zn, YRS1, YRS2, YRS4, DDS1 and DDS2 were unpolluted to moderately polluted with Pb, YRS4 and DDS4 were unpolluted with Cu. Cr was unpolluted to moderately polluted in sampled site YRS2 only. Zn and Pb were moderately polluted in the following sampled sites; YRS1, YRS2, YRS3, YRS4 and YRS3 respectively. Cu was moderately to strongly polluted in sampled sites YRS2 and YRS3 and strongly polluted in YRS1. The heavy metal enrichment could be as a result of surface water runoff from the industrialized area and the farms around the dam and the river.

5.6Assessment according to pollution Load Index (PLI)

The Pollution Load Index values in sampled sites YRS4, DDS1, DDS2, DDS3 and DDS4 indicated the presence of baseline level of pollutants.

The high values of pollution load index in YRS1, YRS2 and YRS3 indicated the progressive deteriorating of the quality of the river.

The pollution load index values for the dry season indicated that YRS2, YRS4, DDS1, DDS2, DDS3 and DDS4 had baseline levels of pollutants present. YRS1 and YRS3 had very high values indicative of progressive deterioration of the quality of the dam and the river.

There was a progressive increase in the values of the Pollution Load Index during the rainy season and the dry season alike. The values are indicative that the river is progressively deteriorating in terms of the quality of the river water compared to the dam which only indicated baseline levels of pollution. It was recorded that YRS1, YRS2, YRS3, YRS4, DDS1, DDS2 and DDS4 in the rainy season each had its value slightly higher than that of the dry season Figure 4 and 5). This may be due to the fact that surface runoff water from the industrial area of the Tamale South may have been washed into the river and subsequently to the dam. The farming activities near the river and the dam could also contribute to the pollution especially with the use of pesticide and herbicides on the farms and gardens.

5.7Physical and Chemical characteristics

The physico-chemical characteristics of water may be considered as one of the most important determinants in the identification of the nature, quality and type of water (fresh, brackish, saline) for any aquatic ecosystem (Addo, 2005). Temperature is a factor of great importance for aquatic ecosystems, as it affects the aquatic organisms and the physical and chemical characteristics of water (Delince, 1992). The temperature of the water recorded during the sampling period (October 2011and June, 2012) ranged between $29.4^{o}C$ to $30.10^{o}C$. The sampled site Yinyaa Kobliga Site 2 (YRS2) had the lowest temperature ($29.4^{0}C$) which was recorded on site. The highest temperature recorded on site was $30.10^{0}C$ at Dungu dam Site 2 (DDS2). The dry season in the Northern part of Ghana is characterized by very high temperatures during the day. The Dungu Dam Site 2 recorded the highest temperature. This may be due to the fact that, the water was not disturbed and the wind was not strong enough to cause upwelling. Higher temperatures diminish the solubility of dissolved oxygen and thus decrease the availability of this essential gas. Elevated temperatures increase the metabolism, respiration and oxygen demand of fish and other aquatic life, approximately doubling ~~the re~~spiration for a $10^{0}C$ rise in temperature. Hence the demand for oxygen is increased under conditions where oxygen supply is lowered (Gorden, 2012). The solubility of many toxic substances is increased as well as intensified as the temperature rises. Generally a rise in temperature corresponds to an increase in toxicity in heavy metals. For example a $4^{o}C$ rise in temperature increased the toxicity of Cu by 7% in fresh water (Khan *et al*., 2006).

According to Khan *et al*., (2006) heavy metals inhibit the rate of oxygen consumption at all temperatures. For example, 7^0C rise in temperature ($20-27^0C$) increased the inhibitory effect of Cu on oxygen consumption by up to 54%. It is therefore implied that if the temperature continues to increase, the inhibitory effects of certain heavy metals would also continue to rise leading to fatal consequences of the aquatic organisms. This would invariably pollute the water leading to a change in the water quality. Khan et al., (2006) explained that a rise in temperature can lead to hypoventilation (i.e. unusually slow and shallow way of breathing leading to a dangerous buildup of carbon dioxide in the blood) situation in the hemoglobin of aquatic worms.

The pH values for both the Dungu dam and the Yinyaa Kobliga waters were found to be between7.00-7.50 with a mean pH of 7.25. The mean value obtained lies very close to the neutral point 7.00. The maximum contamination levels as indicated by the USEPA, (1983) showed the following characteristics at a lower pH value (pH< 7.00); a bitter metallic taste of the water and corrosion of metals would be observed. At a high pH (pH > 7.00), the water has the following characteristics; slippery feel between fingers, soda taste, deposits of all kinds of particles. These characteristics were not found in both the Dungu dam and the Yinyaa Kobliga River.

Dissolved Oxygen (DO) levels varied from 2.57 to 3.67mg/L. According to Cunningham and Saigo, (1995), if DO falls below 2mg/L, it would affect biological respiration and most aquatic organisms would perish. The DO level in any water body depended on temperature (more oxygen can dissolved in colder waters than in warmer waters). It would be observed that the amount of dissolved oxygen does not differ much from the critical point of 2mg/L in all the sampling sites except for YRS1 which recorded 3.67mg/L.

The DO low values observed may be due to the discharged of organic and inorganic wastes from the anthropogenic sources (household waste and waste from the vehicle mechanics). The decay of these organic materials by chemical processes or microbial actions can severely reduce dissolved oxygen concentrations (http://www.freedrinkingwater_quality.com. Higher temperatures militate against DO by favouring the growth of sewage fungus and putrification of sludge deposites. The growth of sewage was however observed in the river but not in the dam.

The conductivity of the water samples ranged from 1040µS/cm to 1080µS/cm. These values are far below the local Environmental Protection Agency effluent guidelines limit of 1500µS/cm (Addo, 2005). These variations may be due to the fact that the presence of the electrolytes may not be evenly distributed throughout the water. This could be accountable for the variations in conductivity. There are currently no official guidelines as to what is considered safe level for conductivity of most freshwaters (Karikari, 2007). However, the conductivity of most freshwaters ranged from 10 to 1000µS/cm but may exceed 1000µS/cm especially in polluted waters, or those receiving large quantities of land run-off (Chapman, 1992). Conductivity is related to the concentration of Total Dissolved Solids (TDS). According to Chapman, (1992) TDS may be obtained by multiplying the conductivity by a factor between the ranges of 0.55 to 0.75. Given these low conductivity values, it is not surprising that the TDS which is an index of the amount of dissolved solids in water would be low as shown. (Table 5 above).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.0Conclusion

From the correlation matrix, it was demonstrated that the heavy metals were highly positively correlated suggesting that these metals were either associated with each other or were coming from a common source.

Anthropogenic factor analysis proved that all the heavy metals which were investigated were of an anthropogenic origin. ($AF > 1$). This could be traced to the disposal activitiesof vehicle mechanics and the domestic wastes discharged into the river.

Contamination factor analysis indicated that both the dam and the river were moderately to considerably contaminated. ($1 \leq Cf \leq 3$) to $3 = Cf$

The Modified Degree of Contamination indicated that the river ranged from moderately contaminated to highly contaminated with the heavy metals (Cd, Zn, Pb, Cu, Cr). However the dam ranged from uncontaminated to moderately contaminated.

Geo-accumulation Index Analysis proved that the dam was uncontaminated but the river ranged from moderately contaminated to strongly contaminated.

The Pollution Load Index revealed that the river was progressively deteriorating in the quality of the water. However, the dam showed the presence of baseline level of pollutants.

The results revealed that both the Yinyaa Kobliga River and the Dungu Dam; had low levels of dissolved oxygen DO. This implies that the decay (chemical and microbial action) on the wastes discharged into the river and the dam reduced the amount of dissolved oxygen (DO).

The concentrations of the arithmetic means of the heavy metals (Cd, Zn, Pb, Cu, and Cr) in the Yinyaa Kobliga River and the Dungu Dam far exceeded the USEPA and WHO guidelines for fresh water ecosystems Table 1 and 3). Hence the water does not meet international standards hence cannot be used by humans and animals.

6.1 Recommendation

1 To fully establish heavy metal pollution of the Tamale South Industrial area, soil samples from the vehicle mechanics shops/garages and farmlands together with other debris of surface runoff water should be collected and analysed.

2 A stricter environmental monitoring program should be enshrined in the Tamale Metropolitan Assembly's bye Laws to prohibiting and put a fine/sentenced on indiscriminate damping of waste into water bodies.

3 Integrated waste management systems should be put in place by the Tamale Metropolitan Assembly.

4 The Metropolitan Assembly should provide waste bins as well as give public education about the harmful effects of environmental (water, soil, land and air) pollution.

5 A large geochemical datasets (soil, birds, vegetation, food crops and rock samples) should be collected to cover the whole of the Tamale South Industrial area in order to determine the extent of heavy metal pollution.

6 Future works in the area should take into consideration flood areas either than the dams to determine heavy metals pollution in these water bodies.Flood plains should be sampled for more emphasis.

7 The Yinyaa Kobliga River and the Dungu Dam sediment concentrations and the physico-chemical parameters model developed should be validated.

8 The study would be informative for future scientific works as the results would serve as a baseline data for the (river and dam) aquatic environment.

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APPENDICES

APPENDIX A' (sediment quality guidelines of the United States Environmental Protection Agency (USEPA))

Metal	Not polluted	Moderately polluted	Heavily polluted	Present study concentrations
Cd	-	-	> 6	0.78-1.10
Cr	< 25	45– 75	>75	14.90-28.65
Cu	< 25	25 – 50	>50	0.30-74.86
Zn	<20	20 – 50	>50	22.50-127.50
Pb	<40	40 – 60	>60	3.95-10.25

APPENDIX B' (Correlation matrix between heavy metals in the sediment samples from the river and the dam during the rainy season)

Heavy metals	Cd	Zn	Pb	Cu	Cr
Cd	1				
Zn	0.90	1			
Pb	0.73	0.59	1		
Cu	0.63	0.66	0.50	1	
Cr	0.66	0.65	0.75	0.58	1

0.7-0.99 means highly positively correlated

0.4 – 0.69 means positively correlated

Below 0.1 means not correlated

APPENDIX C' (Correlation matrix between heavy metals in the sediment samples from the river and the dam during the dry season)

Heavy metals	Cd	Zn	Pb	Cu	Cr
Cd	1				
Zn	0.88	1			
Pb	0.57	0.62	1		
Cu	0.52	0.55	0.67	1	
Cr	0.75	0.88	0.75	0.80	1

APPENDIX D' (correlation coefficient between the river and the dam sediments).

Sediment samples	YRS	DDS
YRS	1	
DDS	0.75	1

APPENDIX 'E (Anthropogenic Factors during the rainy season)

Element	Cd	Zn	Pb	Cu	Cr
YRS1	1.10	1.31	1.11	1.36	1.08
YRS2	1.15	1.10	1.25	1.81	1.00
YRS3	1.00	1.21	1.10	1.21	1.00
YRS4	1.10	1.11	1.00	0.94	1.01
DDS1	1.12	1.81	1.13	1.07	1.13
DDS2	1.11	1.00	1.00	1.00	1.00
DDS3	1.01	1.00	1.01	1.01	1.00
DDS4	1.20	1.00	1.16	1.02	1.02

APPENDIX 'F(Anthropogenic factors during the dry season)

Element	Cd	Zn	Pb	Cu	Cr
YRS1	1.01	1.01	1.01	1.00	1.00
YRS2	1.01	1.00	1.00	1.00	1.01
YRS3	1.01	1.02	1.00	1.02	1.05
YRS4	1.00	1.00	1.02	1.01	1.05
DDS1	1.15	1.00	1.01	1.12	1.00
DDS2	1.11	1.07	1.00	1.01	1.00
DDS3	0.99	1.01	1.01	1.00	1.01
DDS4	1.01	0.97	0.91	1.01	1.00

APPENDIX G' (Contamination factor and Modified degree of Contamination duringrainy season)

Sample ID	Contamination Factor(Cf values)					Modified Degree of Contamination m(C_d)
	Cd	Zn	Pb	Cu	Cr	
YRS1	1.40	2.58	1.32	12.40	1.11	3.76
YRS2	1.30	2.16	1.52	7.43	1.47	2.78
YRS3	1.40	2.37	2.36	10.55	1.29	3.59
YRS4	1.40	2.14	1.73	1.41	1.14	1.56
DDS1	1.20	2.27	1.15	0.05	0.93	1.13
DDS2	1.10	0.46	1.27	0.87	0.96	0.93
DDS3	1.00	0.63	0.59	1.28	0.77	0.85
DDS4	0.98	0.73	1.16	1.52	0.94	2.67

APPENDIX H' (Contamination factor and Modified degree of Contamination during dry season)

Sample ID	Contamination Factors (Cf values)					Degree of Contamination (Cd)
	Cd	Zn	Pb	Cu	Cr	
YRS1	1.19	2.02	1.19	10.69	1.24	16.33
YRS2	1.18	2.00	1.37	0.94	1.36	6.85
YRS3	1.16	2.01	1.35	9.91	1.43	15.86
YRS4	1.17	1.97	1.23	1.52	1.26	7.15
DDS1	1.19	1.28	1.04	0.06	1.04	4.61
DDS2	1.06	0.47	1.14	1.02	1.07	4.76
DDS3	0.95	0.65	0.53	1.50	0.85	4.48
DDS4	0.94	0.66	1.03	1.74	0.85	5.22

APPENDIX I(Physico-Chemical Parameters during rainy season)

Sites	ANALYTICAL ITEM				
	pH	Temp	DO (mg/L)	Conductivity (µS/cm)	Total Dissolve Solids(mg/L)
YRS 1	7.20	29.6	3.67	1080	540
YRS 2	7.10	29.4	2.57	1070	535
YRS3	7.30	29.3	2.55	1040	525
YRS4	7.20	29.8	2.58	1060	520
DDS 1	7.10	30.0	2.62	1050	525
DDS 2	7.40	30.1	2.70	1080	540
DDS 3	7.20	30.0	2.60	1040	520
DDS4	7.50	30.0	2.64	1030	540
Arithmetic mean	7.25	29.78	2.74	1056	531

APPENDIX J (Physico-Chemical Parameters during dry season)

Sites	ANALYTICAL ITEM				
	pH	Temp	DO (mg/L)	Conductivity (μS/cm)	Total Dissolve Solids(mg/L)
YRS 1	7.12	29.6	3.67	1080	540
YRS 2	6.88	29.4	2.57	1070	535
YRS3	7.25	29.3	2.55	1040	525
YRS4	7.14	29.8	2.58	1060	520
DDS 1	6.90	30.0	2.62	1050	525
DDS 2	7.35	30.1	2.70	1080	540
DDS 3	7.15	30.0	2.60	1040	520
DDS4	7.24	30.0	2.64	1030	540
Arithmetic mean	7.25	29.78	2.74	1056	531