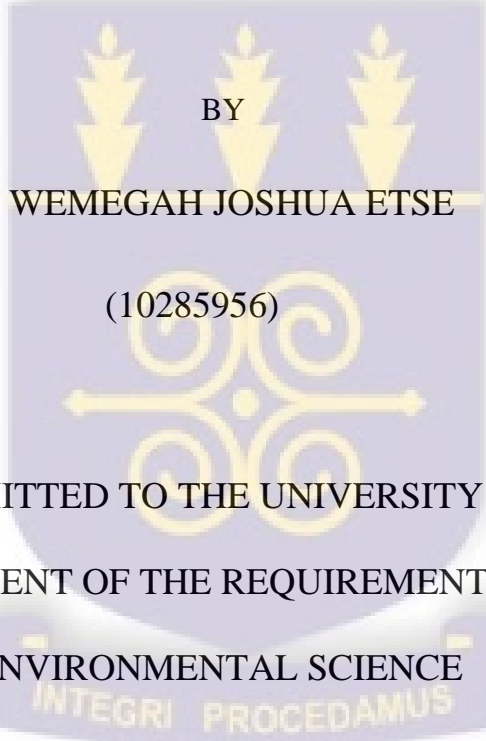


**NUTRITIONAL COMPOSITION OF AQUATIC PLANTS AND THEIR
POTENTIAL FOR USE AS ANIMAL FEED: A CASE STUDY OF THE
LOWER VOLTA BASIN**

The crest of the University of Ghana is a shield-shaped emblem. At the top, there are three golden stalks of grain. Below them, the word 'BY' is written in a serif font. Underneath 'BY' is the name 'WEMEGAH JOSHUA ETSE' in a larger serif font. Below the name is the identification number '(10285956)'. The central part of the shield features a golden decorative motif consisting of two horizontal bars with curved ends, intersected by a vertical line. At the bottom of the shield, there is a banner with the Latin motto 'INTEGRI PROCEDAMUS' written in capital letters.

BY
WEMEGAH JOSHUA ETSE
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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON
IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF
M.PHIL. DEGREE IN ENVIRONMENTAL SCIENCE

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DECLARATION

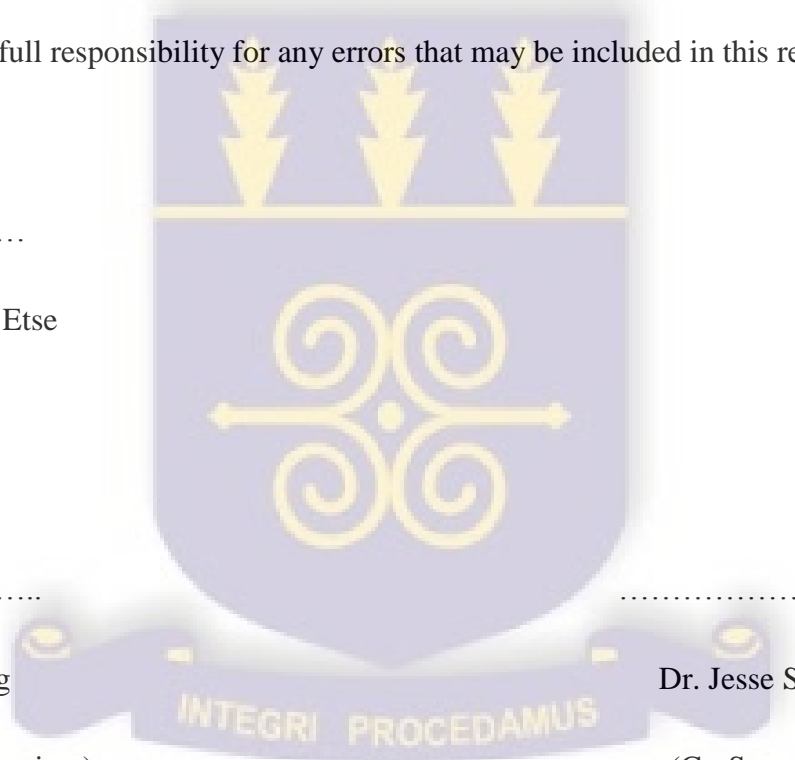
I, Wemegah Joshua Etse, hereby declare that this study is my original piece of research conducted between November 2014 and June 2015 under the supervision of Dr. Ted Annang and Dr. Jessey Ayivor both at the Institute for Environment and Sanitation Studies, University of Ghana, Legon.

Full acknowledgement has been made for all references of other people's work that have been cited. No part of this thesis has either been presented whole or in part to any other institutions for any award. I take full responsibility for any errors that may be included in this report.

.....
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(Student)

.....
Dr. Ted Annang
(Principal Supervisor)

.....
Dr. Jesse S. Ayivor
(Co-Supervisor)



DEDICATION

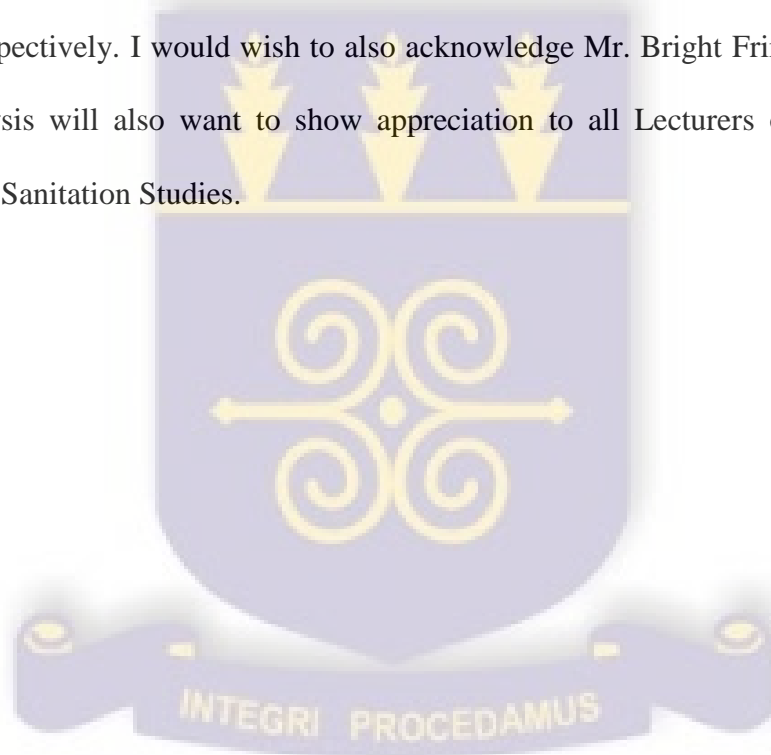
This work is dedicated to my lovely parents Mr & Mrs Wemegah whose invaluable support and prayers have brought me this far. I also dedicate this work to the very special person Baaba Sagoe.



ACKNOWLEDGEMENT

This work was made possible by the Almighty God who worked through persons on earth. Glory to Him. I would like to express my sincere gratitude to my supervisors, Dr. Ted Annang and Dr. Jessey S Ayivor both of the Institute for Environment and Sanitation Studies (IESS), University of Ghana for their immense contribution.

I also thank Mr. Ansah of the Ecological Laboratory, IESS and also Madam Joyce Essumang of the Food Science Department of University of Ghana who helped me analysed my water and plant samples respectively. I would wish to also acknowledge Mr. Bright Frimpong who guided me in data analysis will also want to show appreciation to all Lecturers of the Institute for Environment and Sanitation Studies.



ABSTRACT

An investigation was carried out to determine the nutritional composition of some selected dominant aquatic plants and their significant effect on chemical and physical characteristics of the water. Four aquatic plants namely *Nymphaea lotus*, *Ipomoea aquatica*, *Typha australis*, and *Scirpus cubensis* were sampled, identified and authenticated at the Ghana Herbarium. The proximate nutritional compositions of the plants were determined using standard procedure outlined in Association of Official Analytical Chemist (AOAC 2002). Water and sediment quality analyses of some physico-chemical variables were also carried out using processes outlined in the standard methods for the examination of water and wastewater. The results indicated that nutrient composition such as the crude protein, ether extracts, ash content and nitrogen free extracts were significantly higher than the corresponding constituents in *Panicum maximum* used as control for the study ($p < 0.05$). The results also indicated that levels of heavy metals in the plants were all within the WHO/FAO standards for metals in vegetables and in food. The results of the physicochemical parameter of water also revealed that pH, turbidity, nitrate, DO and BOD levels were found to differ significantly from the control site. The heavy metal concentrations in the sediment samples revealed significant variations in the distribution of the metals, with Zn showing the greatest variation and Pb the least with a mean concentration of 7.5 ± 0.86 mg/l and 0.4 ± 0.03 mg/l respectively.

The results indicate that these plant species have high nutritive potential and it is an indication of possible use as ingredients in animal feed. Exploitation of these aquatic plants for animal feed would be a step towards better utilization of these plants and subsequently help in management of aquatic plants within the basin.

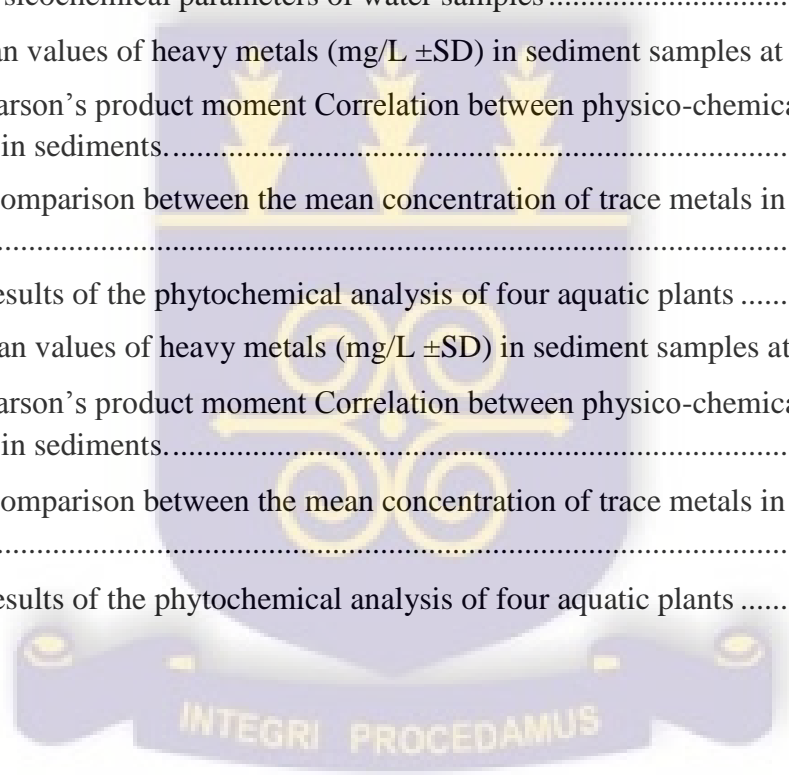
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CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND

Aquatic plants are plants that are adapted to aquatic ecosystems. They are referred to as hydrophytes or macrophytes (Sculthorpe, 1967). Aquatic macrophytes are important to the aquatic ecosystem. They are the primary producers in the aquatic ecosystem. For instance, they provide food and habitat for other organisms in the aquatic ecosystem. Submerged macrophytes, for example, are essential for the stabilization of the clear water state in shallow, mesotrophic and eutrophic lakes (Perrow *et al.*, 1997 ; Scheffer, 1998). Aquatic plants are also known to remediate heavy metal concentration in water (Keskinan *et al.*, 2004; Kamal *et al.*, 2004). Alternately, the proliferation of aquatic plants has significant negative impact on water bodies all over the world. (Mohamad *et al.*, 2013). For years, aquatic plants have been traditionally perceived as a nuisance rather than a useful resource (Shah *et al.*, 2010) due to the challenges they pose in the environment. Some of the challenges associated with the proliferation of aquatic plants include the blocking of waterways which causes navigation problems. Established stands of aquatic macrophytes of all life forms can prevent the passage of conventional boats. Submerged weeds will foul the propellers of conventional motor-driven craft, if they are close enough to the surface. The most serious problems are caused usually by floating masses of vegetation. Due to their mobility, these aquatic plants can be blown into a harbor or channel and completely fill it in a matter of hours thereby blocking waterways (El-Shinnawy *et al.*, 2000). The aquatic vegetation can cause alteration in the physicochemical characteristics of both water and hydrosol thereby altering the quality of water (Petosa *et al.*, 2010). They can also provide both habitat and food for the larval stage of animal vectors of human diseases such as malaria

caused by the parasite, *Plasmodium sp* thereby posing as a health hazard (El-Shinnawy *et al.*, 2000). In addition to the specific effects and disadvantages of excessive growth of aquatic plants described above, aquatic plants may interfere with the programs of water resource utilization and management (Malik, 2007). Water hyacinth, for example, has flourished in many tropical lakes including Lake Victoria, in East Africa where it caused several of the above described problems such as reduction in fishing output, interference with transportation and water supply and breeding of snails, mosquitoes and snakes (Mailu, 2001; Mironga, 2004). In Egypt, there is an aquatic weed infestation in the Nile River with *Ceratophyllum demersum* and *Potamogeton crispus* being the dominant species (El-Shinnawy *et al.*, 2000)

In Ghana, apart from the Volta system, several major river systems like the Tano, Ankobra, Pra, Kakum, Ochi, Ayensu and Densu which have been dammed for portable water production, irrigation, and fisheries have been affected with serious aquatic macrophyte infestation that has resulted in the improper use and management of the impoundments (deGraft-Johnson, 1991). Annang (2008) opined that the regulation of the flow regime of the Volta River due to the creation of Akosombo dam in 1963 and Kpong dam in 1981 have created ideal conditions for the rapid growth of aquatic plants in the Lower Volta Basin of Ghana (LVB). Therefore, he noted that this has resulted in some of the above mentioned problems. Meanwhile, varieties of aquatic plants including *Nymphaea lotus*, *Ipomoea aquatica*, *Typha australis*, *Scirpus cubensis*, *Ceratophyllum demersum* species are abundant in the Volta basin. The existence of the aquatic vegetation in the lower Volta has undoubtedly contributed to the level of poverty in the basin communities specifically because it has limited the mobility of fishing boats in the waterways along the basin communities (Annang, 2008). Consequently, the Volta River Authority (VRA)

purchased four mechanical weed harvesters at a total cost of US\$ 830,000 (Ghana Bulletin, 2013) that are positioned at Kpong for the physical and mechanical harvesting of the aquatic plants at huge cost and dumped the harvested plants as waste without considering utilizing these plants. The cost benefit of this initiative is however subject to much controversy because elsewhere in other part of the world, aquatic plants are used as biofuels, compost, medicine, animal feed and even as a source of food for humans.

Despite all these negative effects of aquatic plants, several studies have documented the possibilities of using these plants as a source of animal feed (Anon, 1984; Lata & Dubey, 2010). Shal *et al.*, 2010 carried out a study on aquatic plants in Sringar and found out that animals fed with the studied aquatic plants produced about 3 liters of milk per day per animal more than animals fed with straw. These studies ultimately explore all the possible ways to use these plants as an ingredient in animal feeds so as to continuously harvest and use the nuisance plants which will subsequently reduce the detrimental effects caused by aquatic plants in the aquatic ecosystem. deGraft-Johnson & Akpabey, (2015) stated that to efficiently manage aquatic plants in Ghana, the use of the plants as a leafy vegetable, green manure, medicine, or in other applications should be documented so that the social and economic factors contributing to the spread of the plants can be addressed and potentially reduced.

Therefore these studies suggest that the potential use of aquatic plants as animal feed may serve as an efficient, effective and environmentally friendly means of controlling and managing aquatic plants within the Lower Volta Basin.

1.1 Problem Statement

The creation of the Akosombo dam in 1963 and Kpong dam in 1981 have created ideal conditions for the rapid growth of aquatic plants in the Lower Volta Basin of Ghana. As a consequence, there has been the proliferation of aquatic plants in the Lower Volta (Annang, 2008). Floating aquatic plants such as *Nymphaea lotus* and *Pistia stratiotes* form dense mats which completely cover water surface thereby clogging waterways, making boating, fishing and other recreational activities almost impossible (deGraft-Johnson and Akpabey, 2015). At Avadiwoekome Island, the biggest island on the Lower Volta Basin at the Lower Manya District, for instance, the weeds have made it impossible for fishermen and women who use canoes to cross the Volta to other communities to trade (Ghana Bulletin, 2013). The weeds have also made it impossible for people to pick oysters, which hide under the water hyacinth. The aquatic plants also affect the quality of water and increase the risk of waterborne diseases (El-Shinnawy *et al.*, 2000). They also reduce water flow, increase siltation and evapotranspiration. The aquatic plants disrupt hydroelectric installations (deGraft-Johnson and Akpabey, 2015) and also interfere with recreational activities such as swimming, boating and fishing. Current efforts aimed at controlling aquatic plants using mechanical harvesters in the Lower Volta River by the VRA and the Environmental Protection Agency (EPA) appear to be expensive, ineffective and unsustainable. Given this context, alternative methods of controlling aquatic plants sound as a laudable venture. One of such measures is using aquatic plants as animal feed so that factors contributing to the spread of the plant can be addressed and potentially reduced (deGraft-Johnson & Akpabey, 2015). There are an estimated 50,000 livestock particularly ruminants (cattle, sheep and goats) within the Basin (Veterinary Service, 2015). However, one of the major constraints of these ruminant productions in Ghana particularly in the Lower Volta Basin is the unavailability of forages all year round. It has been observed that, livestock around the basin have abundance

of pasture to feed on in the rainy season when animals are well fed and fattened. However, in the dry season, farm animals suffer from loss of weight as a consequence of low quality and quantity of feed. They therefore have to travel long distances in search of fodder. Paradoxically, there are some unexplored aquatic plants in the LVB that remain green throughout the year waiting to be tapped for animal use. Therefore, owing to the acute shortage of fodder in the basin especially during the dry season, the utilization of these aquatic plants as animal feed could be considered as a means of managing the growth of the aquatic vegetation within the basin and to supplement animal feed after evaluating their nutritional potential. Anon (1984) noted that aquatic plants differ widely in their chemical composition depending upon species, season and location. Meanwhile, limited studies have been conducted to assess the nutritional value of the predominant aquatic plants in the Volta basin. Therefore this study will fill the gap in literature as it intends to use a proximate analysis to evaluate the nutrient composition of some dominant aquatic plants in the lower Volta.

1.2 Objectives

The main objective of the study is to evaluate the nutritional potential of four dominant aquatic plants within the Lower Volta Basin

Specific objectives are:

- ❖ To assess the nutrient composition of some dominant aquatic plants using proximate analyses.
- ❖ To determine the phytochemicals present in the selected samples.
- ❖ To measure heavy metal concentration in the water, plant material and sediment.
- ❖ To find out the social perception on the use of aquatic plants in feeding animals.

1.3 Research Questions

- ❖ What are the nutrients present in the selected aquatic plants?
- ❖ What phytochemicals are present in the selected aquatic plants?
- ❖ What are the minerals present in the aquatic plants?
- ❖ Are people making use of the plants?

1.4 Hypotheses of the study

- ❖ Null hypotheses (H_0): There is no significant difference in the nutrient composition of aquatic plants to that of *Panicum maximum* (Guinea grass) in the lower Volta
- ❖ Alternative hypotheses (H_1): There is significant difference in nutrient composition of aquatic plants to that of *Panicum maximum* (Guinea grass) in the lower Volta.

1.5 Justification of the Study

There is an extensive growth of aquatic plants which has assumed levels that is seen as a nuisance and thus prevents some of the uses of the river like transportation and navigation. The Volta River Authority (VRA) continues to spend resources to manage the aquatic vegetation in the Basin by using mechanical harvesters to control these plants. However, the current methods used by the VRA appear to be ineffective, unsustainable and capital intensive because the aquatic plants will continue to grow as long as the Akosombo and Kpong dams exist and also nutrient inflow from both natural and anthropogenic sources. One viable alternative is to convert these harvested nuisance plant into a more useful purpose, specifically as animal feed as a means of controlling or managing the growth of plants within the basin. There is an estimated 50,000

livestock particularly ruminants in the Volta basin which lack forage especially in the dry season. Meanwhile vegetation within the basin remain green throughout the year. Several studies have been done on utilization of aquatic plants in feeding animals all over the world but there is however a limited study done on evaluating the nutritional composition of the aquatic plants in the Lower Volta Basin in Ghana. This gap in literature and the possibility of turning these seemingly “destructive plants” into animal feed after studying their nutritional composition have informed this study. It is expected, the findings of the study can improve livelihoods as inhabitants and others can invest in farm animal production as they will be assured of alternative feed for their animals during the dry season. Moreover, the findings of the study will be useful for the VRA in that it will provide an alternative source of revenue if the aquatic plants harvested are sold to farmers. The study will also assess the social perception of turning aquatic plants into animal feed and this can serve as the basis of educating farmers on the need to exploit the aquatic vegetation as animal feed. Finally, this study can serve as the foundation for future studies into the nutritional composition of other aquatic plants elsewhere in Ghana.

CHAPTER TWO

LITERATURE REVIEW

Aquatic plants play very important roles in the ecology of water bodies as they provide many benefits for fish, wildlife and people. In lakes, life depends directly or indirectly on water plants as they are seen as the primary producers in the aquatic ecosystem. They restock oxygen content in a waterbody. Submerged macrophytes, for example, are essential for the stabilization of the clear water state in shallow, mesotrophic and eutrophic lakes (Perrow *et al.*, 1997 ; Scheffer, 1998). The roots of many aquatic plants help keep soft sediments from being suspended. This reduces turbidity of the water, and hence increases the amount of sunlight that can reach the plant leaves for optimal growth. Once the plants grow, the water clears up and they grow even better. Consequently, vegetated waters often remain vegetated because water clarity promotes more plant growth (Sheffer 1998).

Several studies have documented the role of aquatic plants in reducing the heavy metal concentration of water (Keskinan *et al.*, 2004; Kamal *et al* 2004). Some aquatic plants such as *Pistia stratiotes* (water lettuce), *Spirodela polyrrhiza* (duckweed) and *Eichhornia crassipes* (water hyacinth) have the capacity to accumulated heavy metals in its body without the production of any toxicity or reduction in growth (Mishra & Tripathi, 2008; Mishra & Tripathi, 2009) . These studies highlight the potential role of using aquatic plants for large scale removal of heavy metals from polluted water.

Aquatic plants also influence food webs (Moss, 1990; Scheffer, 1998; and van Donk, 2002). For example, macrophytes compete for nutrients and other resources with phytoplankton and

periphyton (Ozimek *et al.*, 1990; van Donk *et al.*, 1993). Macrophyte also promote denitrification (Weisner *et al.*, 1994), contributing to a decreased availability of nitrogen for phytoplankton growth. These effects on phytoplankton may subsequently affect higher trophic levels-zooplankton and fish.

Underwater and emergent plants also protect shorelines of waterbodies from erosion due to wave action or currents (Madsen *et al.*, 2001). They help stabilize the sediment which can increase water clarity further. Aquatic plants, like rushes and cattails, dampen the force of waves and help prevent shoreline erosion. Submerged aquatic plants also weaken wave action and help stabilize bottom sediment

Despite the benefit of aquatic plants in the ecosystem, their excessive growth may be seen as a nuisance in the same ecosystem. Excessive plant growth in many water bodies is due to the fact that the water bodies are shallow, which allows sunlight to penetrate to the bottom and support photosynthesis (Harman & Albright, 2002). Also, water bodies rich in nutrient such as nitrates and phosphate enhance plant growth. Excessive growth of aquatic vegetation impairs recreational activities such as swimming, fishing, and boating (Hammitt *et al.*, 2015). It can also trap sediment and debris, gradually filling in bodies of water. It also impact power generation and irrigation by clogging equipment. It also degrade water quality by raising pH, decreasing oxygen and increasing temperature (Lembi, 2009)

Aquatic plants cause loss of water due to evapotranspiration. It has been stated in literature that a dense stand of aquatic weeds will lose more water to the atmosphere by transpiration than will

normally be lost by evaporation from an open water surface occupying the same area (Timmer & Weldon, 1967; Brezny *et al.*, 1973). However, it is very difficult to make direct measurement of water loss by plants in natural situation as any interference with the plants will certainly affect their rate of transpiration. Several researchers have carried out direct measurements in a variety of natural and artificial conditions in which they compared water lost from stands of aquatic plants with that lost from a comparable open water surface. While these may not be regarded as absolute values, it is possible that they indicate the factors which increase or decrease the difference between evapotranspiration from a stand of aquatic plants and evaporation from an open water surface (El-Shinnawy *et al.*, 2000).

Aquatic plants also slow the flow rate of water in channels. Submerged plants do not affect water losses from water ways as a result of transpiration but may trap silt, impair the flow in canals or drains, and may occupy useful volumes of water in small reservoirs. Water flow is affected when plants reduce the cross section of a channel. (El-Shinnawy *et al.*, 2000).

Established stands of aquatic macrophytes of all life forms interfere with navigation. They can prevent the passage of conventional boats. Submerged plants will foul the propellers of conventional motor-driven craft, if they are close enough to the surface. For this reason, mechanical paddles and other special methods of propulsion for water-weed-cutting boats have been developed. The most serious problems are caused usually by floating masses of vegetation. Because of the mobility of floating aquatic plants, they can be blown easily into a harbor or channel and completely fill it in a matter of hours.

Aquatic plants can also cause alteration in the physicochemical characteristics of both water and hydrosol. The macrophyte communities provide an important source of nutrients that are

released into the water column during decomposition. Abundance of the blue green algae may cause great problem such as oxygen depletion to the waterbody and their users. (Brix, 1994). The organic matter oxidation may introduce out products that can change the water quality. Also, under very low oxygen levels, some bacteria such as sulphur bacteria become very active (El-Shinnawy *et al.*, 2000).

Aquatic plants provide both habitat and food for the larval stage of animal vectors of human diseases such as malaria caused by the parasite, *Plasmodium sp.* This disease can be spread by mosquitoes (Patz *et al.*, 2000). Larval stages of mosquito can breed in the calm, still pockets of water created among stands of floating vegetation and emergent weeds. Schistosomiasis (bilharzia) is also a parasitic disease which is caused by two parasitic species, *Schistosoma haematobium* and *Schistosoma mansoni*. The parasite, *Schistosoma* depends on the snails as intermediate host in order to complete its life cycle. These snails live in the microhabitats provided by aquatic vegetation in which they find both shelter and food. With a certain combination of presence of permanent water, slow water velocity, and aquatic vegetation, the snails will be able to colonize the parasite. Their eggs are laid on the surface of plants and the life cycle of the animal thus depends to a considerable extent on the presence of suitable aquatic vegetation (El-Shinnawy *et al.*, 2000; Lembi, 2009).

There are several factors that support the growth of aquatic plants in a water body including nutrient intake, water depth, water clarity, salinity and flow rate of a water body (Carr, *et al.*, 1997). During periods of heavy rainfall, increased runoff brings more nutrients particularly nitrates and phosphates, from fertilized farms into a river body (Lembi, 2009). Nitrogen and

phosphorous enrichment from fertilizer runoff, sewage discharge and other anthropogenic disturbances are often cited as important factors in promoting overgrowth of aquatic plants. For floating plants such as water hyacinth and water lettuce, rises in dissolve nutrient concentration associated with anthropogenic loading have consistently shown to trigger increases in growth rate, thereby leading to invasive proliferation (Williams *et al.*, 2005). For rooted plants such as *Hydrilla sp* and water milfoil, sediment nutrient enrichment is a major contributor to overgrowth problems (Smith & Barko, 1990).

Aquatic plants like many other plants undergo photosynthesis. Photosynthesis is a process used by plants and other organisms to convert light energy, normally from the sun, into chemical energy that can be later released to fuel the organisms' activities (Brayant & Frigaard, 2006). Water of good clarity allows enough light to penetrate and reach submersed aquatic plant during the day for photosynthesis. It is for this reason why many red-water or black-water lakes have few submersed plants.

The flow rate of a waterbody is mostly affected by factors such as dam construction and flooding at high tides. Dam construction slows down the flow rate of a waterbody downstream (Friedl & Wüest, 2002) Aquatic plants thrive well in a slow flowing waterbody such as lakes or impeded flowing River like the case of the Lower Volta River in Ghana. The construction of Akosombo dam in 1963 and the Kpong dam in 1981 has created favourable growth conditions like the reduced flow rate of the Volta River which makes it suitable for aquatic plant growth (Annang, 2008). Before damming, the river had an average flow of $4,890\text{m}^3/\text{s}$ but with marked variability. After the construction of the dams, the flow rate could be as low as $30\text{m}^3/\text{s}$ in the driest month

whilst a peak flow of $3,750\text{m}^3/\text{s}$ to be recorded in the months of September and October (Halcrow, 1956). This explains why there is a massive aquatic vegetation within the Lower Volta Basin (LVB). This situation needs to be managed or controlled.

Most fresh water aquatic plants do not thrive well in saline conditions. The degree of salinity is apparently the reason why there are no or little vegetation around estuaries of rivers. This explains why there are few aquatic plants around estuaries of river where sea water intrusion increases the salinity. In recent times, areas around the estuary of the LVB have been invaded by water hyacinth and must be controlled sooner than later.

Nutrient intake in a waterbody could be natural through the decomposition of dead plant and animal materials (Alexander *et al.*, 1997). Human activities can also accelerate the process of nutrient inflow with urban construction, sewage discharges, agricultural practices, and residential development (Nelson & Booth, 2002).

Recommendations to utilize harvested nuisances aquatic plants for fertilizer, compost, paper-making, animal feed, fuel production and other purposes date back to at least the early 20th century. One of the major reasons for utilizing aquatic plants is the fact that they show primary productivity rates much higher than terrestrial plants. Utilizing aquatic plants controls aquatic plant growth and also generates resource that can aid in the management of aquatic plants. Aquatic plants have the potential for exploitation as animal feed, fertilizers, paper making, biofuels, medicine and waste water treatment.

Anthropogenic climate change, dwindling oil supplies and rural underdevelopment are some of the many examples that have sparked global interest in harnessing renewable energy sources. Biofuels such as ethanol and other forms of biomass-based energy are widely regarded as the most promising renewable energy pathways (Goldemberg, 2006). There is a growing urge to identify and develop bioenergy feedstock that can be harnessed in ways that do not require major land-use intensification or use of food crops. Although aquatic plants have long been regarded as an intriguing potential feedstock because of their growth rate in natural waterbodies, most contemporary management is based on plant control rather than utilization. Since aquatic plants produce large amounts of biomass and affect the natural environment adversely, for example water hyacinth has been shown to produce annual crop yields of 100 dry tons per hectare in natural environment (Hronich *et al.*, 2008), sustained removal of this biomass will have benefits for the nutrient balance and native ecology of affected aquatic ecosystems.

The United Nations and Food and Agricultural Organization (FAO) has stressed that mineral fertilizers seem too expensive and harmful to the soil and the environment at large in developing countries. Thus there is the need to reassess organic fertilizers (FAO, 1975). The presence of large quantities of unwanted aquatic plants necessitates the need to find prudent economic use in order to change a nuisance into beneficial product at low cost and labour-intensive venture. Biochemical analysis of aquatic plants in the Lower Volta Basin revealed appreciable amount of nutrients necessary for plant growth (Annang, 2008). Research carried out by the Volta Research Basin Project (VBRP) showed significant increase in the yield of maize cultivated with compost prepared from aquatic plants compared to inorganic fertilizer. Composting aquatic plants effectively reduces the viability of the plants and allows for the safe re-use of the nutrients and organic matter contained in the weed material.

Aquatic plants have the potential to be used for metal phytoremediation. Phytoremediation is an emerging technological concept aiming to accumulate and translocate toxic metals in the environment into plant cells. There are several phytoremediation processes of which include, phytodegradation, rhizofiltration, phytostabilization and phytovolatilization. This technology uses various types of plants to degrade, extract, contain, or immobilize contaminants in soil and water (Vidali, 2001). Phytoremediation techniques are gradually receiving increasing attention due to cost-effective, non-intrusive nature and are a safe alternative compared to conventional cleanup techniques. Floating aquatic plants accumulate contaminants by its root. Submerged plants accumulate metals by their whole body. The ability of plants to hyperaccumulate metals and metalloids in plant mass has led to the idea that sustainable and ecofriendly remediation strategies could be developed based on this characteristic. Some aquatic plants that have been used for removal of toxic metals(lead) include *Lemna minor* (Duckweed), *Eichhornia crassipes* (Water hyacinth) and *Hydrilla verticillata* (Hydrilla) etc. Heavy metals are accumulated in different components of the environment in different ways and are being controlled by various mechanisms. Aquatic plants absorb heavy metals from the water, the rooted ones also from the bed material. Generally, aquatic plants can accumulate high amounts of heavy metals. In such a way, they reflect the toxicity of the water environment, and may serve as a tool for the bio-monitoring of contaminated waters(Jamnická *et al.*, 2006). With this regard, specific aquatic plants within the basin can be transported to areas with high toxicity to aid in the remediation of the environment.

The main goal of a management of aquatic plants in a water body is to achieve ecological balance (Lembi, 2009). There are three main methods of controlling aquatic plant growth. They

are physical, biological and chemical methods. The rapid proliferation of aquatic plants growth in the Lower Volta Basin has necessitated the management of these plants.

Physical control includes the removal of the weeds by manual labour or by mechanical harvesters (Madsen, 1997). The principle behind these harvesters is the same as mowing a lawn: the weeds will not be eliminated, but they can be prevented from growing to the surface and becoming a nuisance (Lembi, 2009). In Ghana, particularly the Volta Basin, manual removal has been the first control option practiced (deGraft-Johnson, 1991).

Biological control methods involve using beneficial organisms to control pest organisms (McFadyen, 1998). Biological controls have received considerable publicity and research attention. For example, certain insects have been released in the Midwest to control Eurasian water milfoil and purple loosestrife populations. Results with Eurasian water milfoil have been mixed, and the insect introductions for purple loosestrife are part of a long-term management plan (Lembi, 2009). In addition to insects, waterfowl such as swans can keep small ponds weed-free, but they require husbandry and protection from predators. The most widely used biological control agent is the grass carp (also known as the white amur). This fish is native to China and Russia and can live 15 to 20 years (Zhuang *et al.*, 2002). Grass carp consume most submersed plants, however it prefer certain plant species to others. Often the fish consume native species (such as pondweeds) before feeding on truly troublesome weeds such as Eurasian water milfoil or mat-forming algae. The grass carp is not effective on duckweed.

Chemical control involves the use of aquatic herbicides to control targeted weeds. The herbicides are target specific and are of low toxicity to fishes and wildlife when used according to guidelines (Lembi, 2009). Chemical control has its limitations. Applying herbicides may require

specialized equipment and expertise. Some herbicides can be very expensive, and some may not provide prolonged weed control. One important disadvantage of chemical control of aquatic weeds is that, senescence of plant materials after herbicide application has often been shown to result in a pulsed increase of dissolved nutrients and mass loading of organic matter into sediment layers. Near term consequences from this control method include major algal blooms, explosive growth of other invasive aquatic plants and in severe cases, hypoxia-induced fish kills (Newbold, 1975).

There has been a global effort to find possible ways of using aquatic plants as animal feed so as to continuously harvest the weeds to reduce their nuisance levels. Several studies have been carried on aquatic plants to evaluate their nutritional potential. For instance, Shal *et al.*, (2010) studied the nutritional potential of three local aquatic plants in Srinagar. The plants were *Nymphaea lotus*, *Nymphoides peltata* and *Hydrilla sp* which grow abundantly in the Dal and other lakes and water bodies of Kashmir. Proximate analysis revealed that all the three species had dry matter below 10%. Crude protein content of *Hydrilla*, *Nymphaea* and *Nymphoides* was 17.10%, 20.28% and 21.87% respectively. Ether extract level of *Hydrilla* (2.79%), *Nymphaea* (1.5%) and *Nymphoides* (3.5%) were also estimated. Ash content varied from 8% in *Nymphaea* to 19.45% in *Hydrilla*. Calcium content was 1.29%, 1.10% and 1.56% in *Hydrilla*, *Nymphae* and *Nymphoides* respectively. Fiber content was lowest (13.34%) in *Hydrilla* and highest (21%) in *Nymphoides*. Animals fed with aquatic plants (Group A) produced about 3 liters of milk per day per animal more than animals fed with straw (Group C). There was however no significant difference in daily milk yield of Group A and Berseem fed (group B) animals.

Lata & Dubey, (2010) studied the feed potential of an aquatic macrophyte *Eichhornia crassipes* which is considered as the world's worst aquatic plant species. They analysed the elemental minerals in plant samples. It was revealed that the samples were characterized by its high values of nitrogen, potassium, iron and manganese content. The Ca/P ratio that constitutes an important parameter when plants are considered for use as feed source was found to be within range.

Kalita *et al.* (2007) also conducted a study to evaluate the nutritional potential of four commonly available but unexplored aquatic weeds namely, *Salvinia cuculata*, *Trapa natans*, *Lemna minor* and *Ipomoea reptans* from northeast India to ascertain their suitability for use as supplementary fish feed. The aim was to reduce the cost of commercial feeds and also to reduce the detrimental effects of aquatic weeds in the ecosystem. Results of proximate analysis showed that the crude protein content of the aquatic weeds ranged between 11.0% and 32.2% (w/w), whereas crude fibre and ash contents varied between 4.2% and 20% (w/w), and 13.3% and 31.2% (w/w), respectively

Another study carried out by Akmal *et al.* (2014) at Head Baloki on the Ravi river in Pakistan nutritional potential of some selected aquatic plants including water hyacinth (*Eichhornia crassipes*; Emergent), water primrose (*Ludwigia peploides*; Emergent), Phragmites (*Phragmites australis*; Emergent), water Lilly (*Nymphaea lotus*; Floating), *Dalla* (Cape Cod Grass; Submerged) and Vallisneria (*Vallisneria spiralis*; Submerged) were evaluated through proximate analysis. Protein content was highest in leaves (11.85%) for water hyacinth, in stem (20.12%) for phragmites, in whole plant (25.4%) for water lilly and in whole plant (12.11%) for water primrose. Ash content was highest in roots (21.33%) for water

hyacinth, in whole plant (12.24%) for phragmites, in leaves (13%) for water lilly and in whole plant (6.4%) for water primrose. Fiber content was highest in stems (20.80%) for water hyacinth, in whole plant (13.73%) for phragmites, in leaves (15.23%) for water lilly and in whole plant (11.13%) for water primrose. Fat content was highest in roots (4.01%) for water hyacinth, in leaves (5.4%) for phragmites, in leaves (4.32%) for water lilly and in whole plant (0.39%) for water primrose. Highest moisture was observed in leaves (6.46%) for water hyacinth, in roots (7.2%) for phragmites, in leaves (6%) for water lilly and in roots (4.3%) for water primrose. The study suggests that these aquatic plants can be incorporated as a good source of protein and other nutrients in animals' feed. Exploitation of these aquatic plants will not only be of economic importance but would be a step toward better utilization of these plants for additional feed production. This will also help in solving the weed eradication problem.

Benjam & Masniyom, (2011) conducted a similar study from the Pattani Bay in South Thailand. They studied the chemical composition, amino acid, and element contents, as well as some physicochemical properties of *Ulva pertusa* and *Ulva intestinalis* in the rainy and summer seasons of 2007–2008. They found that the two green seaweed species contained high level of protein (14.6–19.5% DW), lipid (2.1–8.7% DW), ash (25.9–28.6% DW), soluble fiber (25.3–39.6% DW), insoluble fiber (21.8–33.5% DW) and total dietary fiber (51.3–62.2% DW). Comparing the element contents of the two species, *U. pertusa* was rich in Mg, K and Ca, while *U. intestinalis* was rich in Mg, K, Cl, Na, and Ca. The essential amino acids of the two species were rich in leucine, valine, and arginine contents. The most limiting essential amino acid of both species was lysine. However, the nutritional composition of the two seaweeds varied depending on seasonal change. As for the physicochemical properties of both seaweeds, their

swelling capacity (SWC), water holding capacity (WHC), and oil holding capacity (OHC) ranged from 4.0 to 6.4 ml/g DW, 7.8 to 15.0 g/g DW and 1.4 to 4.8 g oil/g DW, respectively. WHC and OHC of *U. intestinalis* was higher than those of *U. pertusa* ($P < 0.05$). This study suggested that both species could be potentially used as raw materials or ingredients to improve the nutritive value and texture of functional food and healthy products for human beings.

Omar *et al.*, (2013) also conducted a study to investigate the physicochemical properties of Red Sea water and the chemical composition of commonly occurring seaweeds along the Southern Coast of Jeddah, Saudi Arabia. The different parameters of the surface water such as temperature, salinity, pH, dissolved oxygen and dissolved nutrients were measured. Seaweeds viz. *Halimedaopuntia*, *Gracillariacorticata* and *Turbinariatriquetra* were analyzed for mineral content, moisture, ash, carbohydrate, protein and lipid. The bioaccumulation of heavy metals in the samples was within the corresponding range. Total carbohydrate was the abundant in the seaweeds. The vitamins, phytohormones, alginic acid, agar, carrageenan, amino acid profiles and fatty acids of seaweeds were also studied. The seaweed samples were enriched in essential amino acids, $\omega 3$ and $\omega 6$. The results exposed that these seaweed species contain high nutritive value and are promising in the field of pharmaceuticals and industry.

Mohamad, Uka and Yauri, (2013) also Evaluated the nutritional composition of water lily (*Nymphaea lotus* Linn.) from Tatabu Flood Plain in Nigeria and observed that the moisture content was highest in rhizome (20.40 ± 1.24) and lowest in seed (4.18 ± 0.17). The highest value for ash content was found in the root (27.36 ± 1.26) and the seed gave the lowest (2.81 ± 0.49). Highest carbohydrate value was obtain from the seed (9.95 ± 0.64) while the petiole gave the lowest value of (2.27 ± 0.38). The crude protein and crude fibre content were highest in the leaves

19.54±0.78 and 15.53±0.45 respectively while the lowest was observed in the seed (3.27±0.11) and 1.6±0.2 respectively. There was a significant difference among the parts analysed for ash content

Banerjee & Matai, (1990) also studied composition of thirty species of Indian aquatic plants in relation to utilization as animal forage. Dry matter of the studied plant species ranged from 4-16% with twenty nine species having more than 10% crude protein. The studied plant had lower fibre and higher fat and ash content when compared to dry terrestrial roughages commonly used as animal feed. Eighteen plant species had ash value below 15%. Alkaloids, nitrates and polyphenol contents were determined. When compared to conventional animal forages, twelve of the studied plant species appeared to have more potential for use as animal forage

CHAPTER THREE

MATERIALS AND METHODS

3.0 Study Area

The study was conducted on the Lower Volta Basin (LVB) in Ghana. Three sang sites were chosen (Kpong, Amedeka and Big Ada). Ada and Kpong sites are the stretches on the Lower Volta that is densely populated with diverse aquatic plants. Water samples were taken from Amedeka where there are no weeds and served as a control site.

The LVB is situated below two big sub catchments of the Volta River, that is the Black Volta and the White Volta and the Oti river. Each of these major sub-cathment among other several small rivers serve as a tributary in the Lower Volta drainage area. The Volta Lake together with the three rivers i.e Black Volta, White Volta and the Oti account for about 80% of total fresh water bodies in Ghana (Barry *et al.*, 2005). Due to its immense expanse of space and as an ideal analytical unit for studying water resources, the sustainable management of the Lower Volta Basin is of very great importance in Ghana.

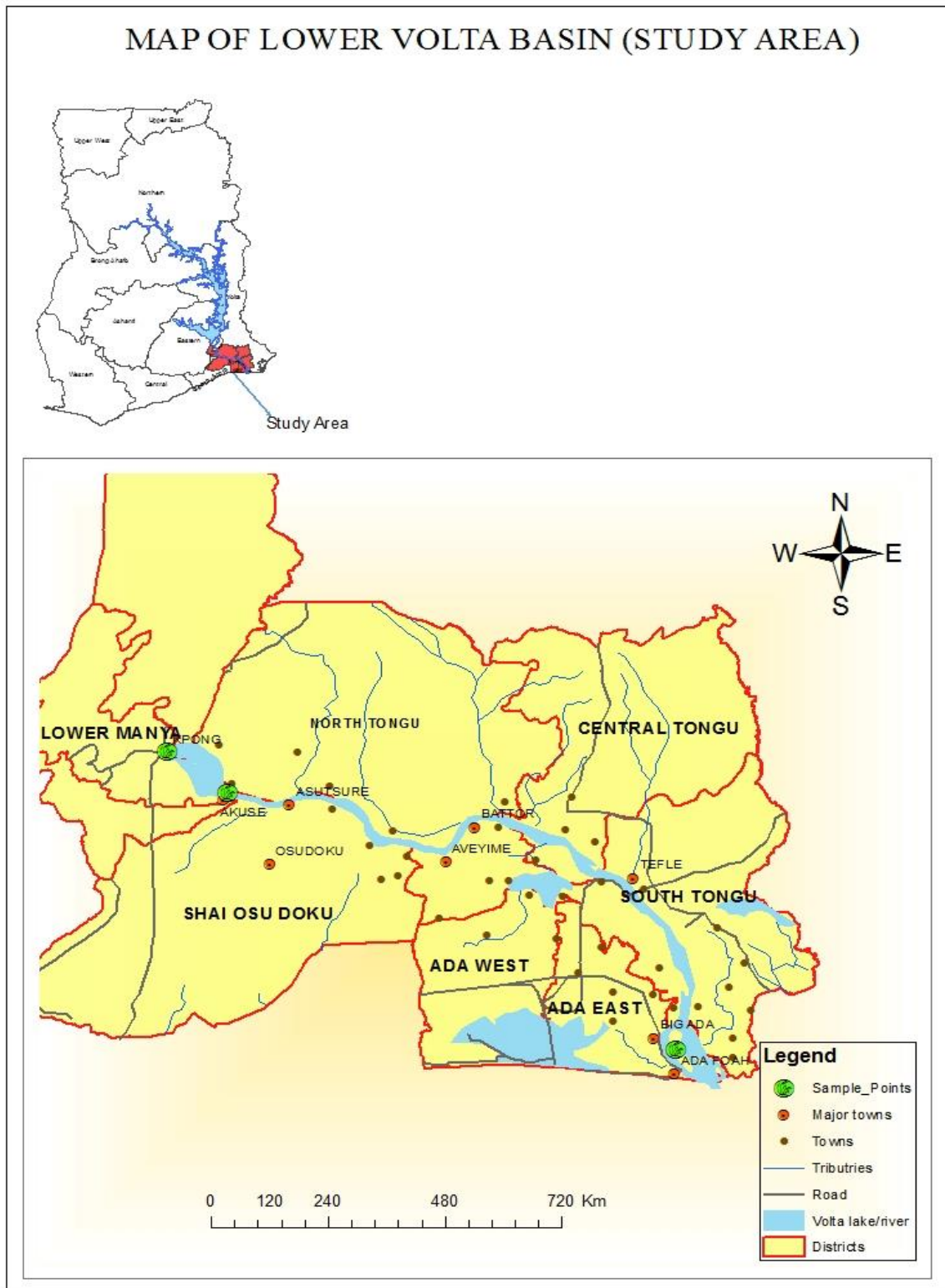


Figure 3.1; Map of the study area (Lower Volta Basin)

3.1 Brief description of the sampling sites

Kpong head pond

The Kpong head pond is the name given to the reservoir created between the Kpong and the Akosombo dams, primarily for the generation of hydroelectricity. It was completed in 1981 with a surface area of about 37.4 km². It has a maximum depth of 15m and a mean depth of 5m (Ansa-Asare and Asante, 1998). The mean annual flow of water through the reservoir is 1183 m³/s and water retention time is 5 days (Ansa-Asare and Asante, 1998). The Kpong head pond has about 85 % of its total surface infested with aquatic weeds. Among the numerous plant species present are *Typha australis*, *Nymphaea lotus*, *Scirpus cubensis*, *Ipomoea aquatic* and *Vossia*. There is a high level of human activity mostly through fishing at the site



Plate 1: Photograph of a section of Kpong sampling site

Big Ada

The area of Ada sampling site has vegetation typical of savanna transition zone. On the banks of the river are species such as *Typha australis*, *Ipomoea aquatica*, *Scirpus cubensis* and some terrestrial plant species. Fishing is a major activity in the area. Recreational activities such as swimming and boating are common practices within the area



Plate 2: Photograph of a section of Ada sampling site.

3.2 Brief Description of Plants under study

***Typha australis* Schumach.**

Typha australis is a monocotyledonous flowering plant in the family *Typhaceae*. The plant has many common names such as Cattail, Reedmace, bulrus, Punks, corn dog grass, etc. The rhizomes are edible.

Typha leaves are alternate and mostly basal on a simple, jointless stem that bears the flowering spikes. The plants are monoecious, with unisexual flowers that develop in dense racemes. The numerous male flowers form a narrow spike at the top of the vertical stem.

Typha is often among the first wetland plant species to colonize areas of newly exposed wet mud, with its abundant wind dispersed seeds. Buried seeds can survive in the soil for long periods of time. They germinate best with sunlight and fluctuating temperatures, which is typical of many wetland plants that regenerate on mud flats. The plants also spread by rhizomes, forming large, interconnected stands. *Typha* is considered to be the dominant competitors in wetlands in many areas, and it often excludes other plant species with its dense canopy. In the bays of the Great Lakes, for example, it is among the most abundant wetland plants. Different species of cattails are adapted to different water depths. Although *Typha* is native wetland plants, it can be aggressive in their competition with other native species. It has been problematic in many regions in North America, from the Great Lakes to the Everglades. Native sedges are displaced and wet meadows shrink, likely as a response to altered hydrology of the wetlands and increased nutrient levels. An introduced or hybrid species may be contributing to the problem. Control is difficult. The most successful strategy appears to be mowing or burning to remove the aerenchymous stalks, followed by prolonged flooding. It may be more important to prevent invasion by preserving water level fluctuations, including periods of drought, and to maintain infertile conditions (Gott, 1999)

***Nymphaea lotus* Linn.**

Nymphaea lotus belong to the family *Nymphaeaceae*. It is a species of water lily with lily pads which float on the water, and blossoms which rise above the water. It is a perennial plant which grows to about 45cm in height. The color of the flower is white and sometimes tinged with pink.

It is found in ponds, and prefers clear, warm, still and slightly acidic waters. It can be found in association with other aquatic plant species such as *Utricularia stellaris*. In some parts of Africa the rhizomes and tubers are eaten either boiled, roasted or ground to a flour after drying for the starch they contain. The young fruits are sometimes consumed as a salad. The seeds are turned into a meal. The plant is invasive of any stretch of undisturbed water. It has colonised parts of the Volta Lake (Wiersema, 1982).

***Ipomoea aquatica* Forsk.**

Ipomoea aquatica is a semiaquatic, tropical plant grown as a vegetable for its tender shoots and leaves. It is found throughout the tropical and subtropical regions of the world, although it is not known where it originated from. This plant is known as water spinach in English. It belongs to the family *Convolvulaceae*. It grows in water or moist soil. The stems are 2-3 meters or more long rooting at the nodes and they are hollow and can float. The leaves vary from typically sagittate (arrow head-shaped) to lanceolate, 5–15 cm long and 2–8 cm broad. The flowers are trumpet-shaped, 3–5 cm in diameter, and usually white in colour with a mauve centre. Propagation is either by planting cuttings of the stem shoots that will root along nodes or planting the seeds from flowers that produce seed (Prasad *et al.*, 2008).

***Scirpus cubensis* Poeppig & Kunth**

Scirpus cubensis is a leafy plant. It belongs to the family *Cyperaceae*. It is most of the time noticed as a large colony of medium-height grasses growing in water, with spherical

inflorescences only somewhat visible among the many leaves. It is a major duck food (Junk & Piedade, 1997)

3.3 General Methods

The study adopted both quantitative and qualitative approaches of data collection. Plant, water and sediment samples were analysed quantitatively in the laboratory using appropriate protocols. Four different plant species namely *Nymphaea lotus*, *Ipomoea aquatic*, *Typha australis* and *Scirpus cubensis* were sampled from each of the sampling sites (Ada, Kpong and Amedeka) from January to March. Each time the plants were sampled, water and sediment were also sampled from the same sites for analysis.

3.4 Reconnaissance survey

A reconnaissance survey was carried out on the 13th and 14th of January, 2015 to ascertain the problems in the various areas. Potential sampling areas were critically considered and selected. Two sampling sites were selected using a judgement sampling technique after the survey to identify major environmental challenges. GARMAN ETREX 20 Global Positioning System (GPS) was used to record the coordinates of the sampling sites.

3.5 Aquatic plants

3.5.1 Plant Samples collection

Plant samples were collected into black polyethene bags from the sampling sites to the laboratory. Dominant plants species were selected. In all, four different plant species were selected each from Ada and Kpong for the study. The plants were selected based on dominancy,

availability and accessibility of at the two sampling sites. This was to allow for comparison between the plant samples at the two sampling sites

3.5.2 Plant Sample identification

Plant Samples were identified and authenticated at the herbarium of the Botany Department, University Of Ghana, Legon as *Typha australis*, *Nymphaea lotus*, *Ipomoea aquatic* and *Scirpus cubensis*

3.5.3 Plant Sample preparation

Plant samples were rinsed with water and dried in an oven at a temperature of 50°C for one week. The dried samples were pulverized and stored for the analysis.

3.5.4 Plant Samples analysis

3.5.4.1 Proximate determination

Moisture content Determination

Moisture content was determined by the loss in weight that occurs when the sample was dried to a constant weight in an oven. About 2 g of the plant sample was weighed into a silica dish previously dried and weighed. The sample was then dried in an oven at 65 °C for 36 hours, cool in a desiccator and weighed. The drying and weighing continued until a constant weight was achieved.

$$\% \text{Moisture} = \frac{(\text{wt of sample + dish before drying}) - (\text{wt of sample+ dish after drying})}{\text{Wt of sample taken}} \times 100$$

Ether Extract

The ether extract represents the fat and oil in the plant sample. Soxhlet apparatus was the equipment used for the determination of ether extract. This equipment consists of 3 major components

An extractor which comprises the thimble which holds the sample; Condenser for cooling and condensing the ether vapour; and a 250 ml flask

Procedure: about 150 ml of anhydrous diethyl ether (petroleum ether) was placed in the flask. About 3 g of the sample was weighed into a thimble and the thimble was plugged with cotton wool. The thimble with its content was placed into the extractor; the ether in the flask was then heated. As the ether vapour reaches the condenser through the side arm of the extractor, it condensed to liquid form and dropped back into the sample in the thimble, the ether soluble substances were dissolved and were carried into solution through the siphon tube back into the flask. The extraction continued for 5 hrs. The thimble was removed and most of the solvent was distilled from the flask into the extractor. The flask was then disconnected and placed in an oven at 65⁰C for 4 hours, cooled in desiccator and weighed.

$$\% \text{Ether extract} = \frac{(\text{wt of flask + extract}) - (\text{tare wt of flask})}{\text{wt of sample}} \times 100$$

Crude Fibre

The organic residue left after sequential extraction of a sample with ether was used to determine the crude fibre. The fat-free material was transferred to a flask/beaker and 200 mls of pre-heated 1.25 % sulphuric acid (H₂SO₄) was added and the solution was gently boiled for about 30 mins, maintaining constant volume of acid by the adding hot water. The Buckner flask funnel fitted

with Whatman filter paper was pre-heated by pouring hot water into the funnel. The boiled acid sample mixture was then filtered hot through the funnel under sufficient suction. The residue was then washed several times with boiling water (until the residue is neutral to litmus paper) and transferred back into the beaker. Then 200 mls of pre-heated 1.25 % sodium sulphate (Na_2SO_4) was added and boiled for another 30 mins, filtered under suction and washed thoroughly with hot water and twice with ethanol. The residue was dried at 65°C for about 24 hrs and weighed. The residue was transferred into a crucible and placed in muffle furnace ($400\text{-}600^\circ\text{C}$) and ash for 4hrs, then cooled in desiccator and weighed.

$$\% \text{Crude fibre} = \frac{\text{Dry wt of residue before ashing} - \text{wt of residue after ashing}}{\text{wt of sample}} \times 100$$

Crude Protein

Crude protein was determined by measuring the nitrogen content of the plant sample and multiplying it by a factor of 6.25. This factor is based on the fact that most protein contains 16% nitrogen. Crude protein was determined by Kjeldahl method. The method involves: Digestion, Distillation and Titration.

Digestion: About 2g of the sample was weighed into Kjeldahl flask and 25mls of concentrated sulphuric acid, 0.5 g of copper sulphate, 5 g of sodium sulphate and a speck of selenium tablet were added. Heat was applied in a fume cupboard slowly at first to prevent undue frothing, continued to digest for 45 mins until the digester became clear pale green. It was then allowed to completely cool and 100 mls of distilled water was rapidly added.

Distillation: Markham distillation apparatus was used for the distillation. The distillation apparatus was stem up and about 10mls of the digest was added to the apparatus via a funnel and

allowed it to boil. Ten mls of sodium hydroxide was added from a measuring cylinder so that ammonia is not lost. It was then distilled into 50 mls of 2% boric acid containing screened methyl red indicator.

Titration: the alkaline ammonium borate formed was titrated directly with 0.1N HCl. The titre value which is the volume of acid used was recorded. The volume of acid used was fitted into the formula which becomes

$$\%N = \frac{14 \times VA \times 0.1 \times w}{1000 \times 100} \times 100$$

Where:

VA = volume of acid used

w= weight of sample

%N= Percentage nitrogen

%crude protein = %N x 6.25

Ash

Ash is the inorganic residue obtained by burning off the organic matter of a plant sample in muffle furnace at 400-600⁰C for 4hrs. Two grams of the sample was weighed into a pre-heated crucible. The crucible was placed in muffle furnace at 400-600⁰C for 4hrs or until whitish-grey ash was obtained. The crucible was then placed in the desiccator, allowed to cool and weighed.

$$\%Ash = \frac{\text{wt of crucible+ash} - \text{wt of crucible}}{\text{wt of sample}}$$

Nitrogen Free Extract (NFE)

NFE was determined by mathematical calculation. It was obtained by subtracting the sum of percentages of all the nutrients already determined from 100

$$\%NFE = 100 - (\%moisture + \%CF + \%CP + \%EE + \%Ash)$$

NFE represents soluble carbohydrates and other digestible and easily utilizable non-nitrogenous substances in feed.

3.5.4.2 Phytochemical screening

Plant samples for phytochemical screening were air dried at room temperature for two weeks. The samples were then pulverized into powder. About 5 g of the powdered material were dispersed in 50 ml of Methanol. The solution was left to stand at room temperature for 24 hrs and was filtered with Whatman No. 1 filter paper. The filtrate was used for the phytochemical screening using the following tests.

Test for Alkaloids (Wagner's reagent test)

A fraction of extract was treated with 3-5 drops of Wagner's reagent (1.27 g of iodine and 2 g of potassium iodide in 100 ml of water) and observed for the formation of reddish brown precipitate or colouration.

Test for Flavonoids (Alkaline reagent test)

About 2 ml of the extract was treated with a few drops of 20 % sodium hydroxide solution. Formation of intense yellow colour, which becomes colourless on addition of dilute hydrochloric acid, indicates the presence of flavonoids.

Test for Phenols (Ferric chloride test)

A fraction of the extracts was treated with 5 % aqueous ferric chloride and observed for formation of deep blue or black colour.

Test for Saponins (Foam test)

About 6 ml of water was added to 2 mls of the extract in a test tube. The mixture was shaken vigorously and observed for the formation of persistent foam that confirms the presence of saponins.

Test for Amino acids and Proteins (1% ninhydrin solution in acetone).

About 2 ml of filtrate was treated with 2-5 drops of ninhydrin solution placed in a boiling water bath for 1-2 minutes and observed for the formation of purple colour.

Test for Terpenoids (Salkowki's test)

About 1 ml of chloroform was added to 2 ml of each extract followed by 3 drops of concentrated sulphuric acid. A reddish brown precipitate produced immediately indicated the presence of terpenoids.

Test for Sterols (Liebermann-Burchard test)

About 1 ml of the extract was treated with drops of chloroform, acetic anhydride and conc. H_2SO_4 and observed for the formation of dark pink or red colour.

3.5.4.3 Mineral Analysis

One gram of the powdered sample was put in digestion flask followed by addition of 25 ml concentrated HNO_3 . The flask was then heated until evolution of brown fume stopped. One cm^3 of perchloric acid was added to the mixture and the content was further heated to a clear solution. After heating, 30 ml of hot distilled water was added to the digest and heated to boiling. The solution was then filtered hot into a clean 50 ml volumetric flask, cooled and made up to the mark with distilled water. Two more duplicate digest solutions and a blank were prepared. Na and K content were analysed by flame atomic emission spectrophotometer. Ca, Cu, Zn and As were analyzed with an atomic absorption spectrophotometer with standard air-acetylene flame.

3.6 Water

3.6.1 Water Sample collection

A 500 ml plastic bottle (already washed and cleaned in the laboratory) was used to fetch water at each sampling point. This was subsequently used in the laboratory for analysis. The samples were kept on ice in chest to keep the temperature low in order to avoid microbial activity before transporting it to the laboratory. Three drops of nitric acid (HNO_3) were added to the water sampled for heavy metal analysis.

3.6.2 Physicochemical analysis of water samples

A 500 ml plastic bottle was used to take water at each sampling point. This was subsequently used in the laboratory for analysis. The samples were kept on ice in chest to keep the temperature low (about 10 °C) in order to avoid microbial activity before transporting it to the laboratory. Physicochemical parameters of the water samples were determined at the Ecological laboratory in the University of Ghana.

pH

The pH of each water samples was determined *in situ* using a potable pH meter. Measurement was carried out by immersing the cell of the meter in the water. The readings were then allowed to stabilize and the results recorded. The cell was rinsed with deionized water shaken to remove internal droplets and the outside wiped prior to immersion in the next water sample to avoid possible contamination from the previous samples.

Temperature

The temperature of the sample was taken using a mercury-in-glass thermometer. This was done *in situ* by placing the tip of the thermometer below the water surface of the sample to a depth of about four inches for about a minute. The readings were allowed to stabilize and recorded

Turbidity

Turbidity was measured using HACH 2100Q. The turbidity meter was powered on after which 20NTU (Nephelometric Turbidity Unit) cell was filled with the sample. The cell was then

cleaned and placed in the cell holder and covered with the lid. Reading was then done and recorded.

Total Dissolved Solids (TDS)

A glass fibre disc was prepared by placing it on a membrane filter and vacuum was applied to it. The disc was washed three times with distilled water. A clean dish was heated at 120°C for one hour in an oven and allowed to cool in a desiccator. It was weighed and recorded before being used. The water samples in the plastic bottles were vigorously shaken. One Hundred milliliter (100 ml) of the water sample was transferred into a volumetric flask by means of a graduated measuring cylinder. The sample was filtered through the glass fibre disc using suction pump. The total filtrate was transferred to a previously weighed evaporating dish and evaporated to dryness on a water bath. The sample was dried for two hours and cooled in a dessicator and weighed to a constant weight. The drying cycle was repeated until weight loss was less than 0.0005 g. The value was calculated using the formula below.

$$\text{TDS (mg/l)} = (A-B) / C \times 10^6$$

Where A = weight of residue + dish

B = weight of dish

C = Volume of water sample

Dissolved Oxygen (DO) by the sensor method

A DO sensor meter was used to measure dissolved oxygen of the water sample in the field. The electrode end of the meter was dipped into the water on the field. The reading of DO in mg/l was allowed to equilibrate and recorded. The temperature of the water was taken at the same time

Biochemical Oxygen Demand (BOD)

Water samples were collected into BOD bottles immediately after determining the DO content. This was carefully done to avoid air bubbles and by tilting the BOD bottles and gradually submerging it into the water. The bottle was allowed to overflow and covered with a stopper. Each bottle was labeled and kept in an ice chest and transported to laboratory. In the laboratory, the BOD bottles were kept in a dark cupboard to prevent light from getting in contact with the bottles and their content for a period of five days. The DO of the water was measured with the same meter after the fifth day. The difference in DO between day one and day five gave the BOD

$$\text{BOD in mg/l} = \text{DO}_1 - \text{DO}_5$$

Nitrate (NO_3^-)

The method used for the Nitrate analysis was the Cadmium Reduction Method. The nitrate level in each sample was measured using Nitrate Powder Pillows in direct reading Hach Spectrophotometer Model DR. 2010. This was achieved by measuring 10 ml of the sample into the sample cell of the Spectrophotometer and adding one NitraVer 5 Nitrate Reagent powder pillow. The solution was shaken. The mixture was then placed in the cell holder to determine the nitrate concentration in mg/l at 500 nm

Phosphate (PO_4^{3-})

About 10 ml of the water sample was placed in the sample cell. Phos Ver 3 Phosphate pillow was added to the cell content and swirled immediately to mix. The mixture was allowed to settle.

A blank sample was used to calibrate the spectrophotometer before the actual reading was determined at 890 nm. The spectrophotometer displayed the results in mg/l PO_4^{3-}

Sulphate (SO_4^{2-})

About 100 ml of the water sample was measured into a 250 ml Erlenmeyer flask and 5 ml of conditioning reagent was added and mixed by stirring. One g of BaCl_2 was added and stirred for 60 seconds. A blank sample was used to calibrate the spectrophotometer before the actual reading was determined at a wavelength of 420 nm.

Determination of Heavy Metals in water samples

An aliquot of 100 ml of water samples for metal determination was transferred in 125 ml conical flask. 5 ml of concentrated HNO_3 was added and evaporated on a hot plate to the lowest volume before precipitation occurs. Digestion was completed by the appearance of light-coloured clear solution. The solution was then filtered through 0.45 μm filter paper and transferred into a 100ml volumetric flask, cooled and top to the mark for analysis. A blank was also prepared through the same procedure. The concentration of Copper (Cu), Cadmium (Cd), lead (Pb), Arsenic (As) and Zinc (Zn) were determined using 240 FS Atomic Absorption Spectrometer by direct aspiration of water samples into an air acetylene flame and all into nitrous oxide acetylene flame.

3.7 Sediment

3.7.1 Sample collection

Sediments from the sampling sites were directly collected beneath the aqueous layer using a trowel. The sediment was placed in a plastic container and kept in ice chest. It was then transported to the laboratory for analysis.

3.7.2 Sample analysis

Sediment digestion and analysis

Sediment samples were digested by weighing 0.4 g of the sample in Teflon tubes. Exactly 4 ml of concentrated nitric acid (HNO_3) was slowly added to the content. The tubes were closed and placed in stainless steel bombs. The bombs were placed on a hot plate and heated at 150°C for 7 hours and then allowed to cool to room temperature before carefully opening the bombs to release pressure. The samples were transferred into the graduated polypropylene tubes and the Teflon tubes rinsed 3 times with distilled water and added to the content of the polypropylene tube. The content was diluted to the 50 ml mark of the tube with distilled water and mixed thoroughly. Analysis of sediment for the determination of heavy metals was carried out using the cold vapour atomic absorption according to Milner & Whiteside, (1981)

3.8 Social Survey

Sociological data and other relevant information on ethnobotanical use of aquatic plants and their effects on inhabitants' livelihood elicited using questionnaire. A total of 120 questionnaires were conveniently administered to targeted members within the two communities from 25th of February to the 6th of March 2015. Targeted members included fishermen and women, farmers, travelers on the lake, Traders along the lake and other community members very close to the

lake. All respondents were 18 years and above. Questions were made up of background information and general information on the lake and aquatic plants. The purpose was to assess inhabitant's perception on the use of aquatic plants in feeding animals within the community. The communities were Kpong and Big Ada. Sixty questionnaires were administered in each community

3.9 Statistical Analysis

The data were subjected to single factor analysis of variance (ANOVA) using SPSS software package version 16 for windows. Differences were declared significant at $p \leq 0.05$ and means found to be significantly different were separated using the least significant difference LSD (Post hoc test) at $p \leq 0.05$. The analysed data were expressed as means with their standard deviation ($X \pm SD$).

3.10 Experimental Precautions

- All glassware were thoroughly cleaned before use
- Identifiable and fixed landmarks at the various sampling sites were used to locate the same spot for sampling throughout the study
- Plant samples for phytochemical analysis were air dried at room temperature
- BOD bottles were used to collect water for BOD determination. The bottles were carefully filled to the brim to eliminate air bubbles

3.11 Limitation of study

The study considers only aquatic plant species that are dominant, available and accessible at the two sampling sites. Water samples were particularly taken from areas infested with aquatic plants and compared to an area without aquatic plants (Control).

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter analyses the data and statistical interpretation measure for the period of three months and are compared with their standard deviation and are presented as follows:

Table 4.1 Nutritional Composition of aquatic plants from Ada

Aquatic plants		Moisture (%)	Ether extract (%)	Crude protein (%)	Crude fibre (%)	NFE (%)	Ash (%)
<i>N. lotus</i>	Min	4.50	4.5	13.45	9.78	41.07	9.70
	Max	7.90	14.75	20.10	20.13	55.52	12.56
	Mean	6.30	8.08	15.17	16.53	46.06	11.27
	S.e	1.70	5.78	3.62	5.84	8.20	1.45
<i>I. aquatica</i>	Min	15.67	3.20	11.23	17.87	22.11	6.54
	Max	23.45	13.67	17.98	23.78	37.74	12.45
	Mean	19.56	9.92	14.96	20.40	26.20	8.95
	S.e	1.71	5.83	3.43	3.04	4.64	3.10
<i>T. australis</i>	Min	3.10	3.45	19.78	9.78	43.07	4.50
	Max	3.20	11.56	20.23	17.89	54.41	8.86
	Mean	3.17	7.27	20.04	15.15	48.06	6.32
	S.e	0.06	4.08	0.23	4.65	5.79	2.32
<i>S. cubensis</i>	Min	2.20	5.6	11.45	7.98	45.59	4.50
	Max	9.40	7.67	18.64	19.87	61.07	8.86
	Mean	5.37	6.29	16.53	14.51	52.24	7.09
	S.e	3.68	1.20	3.39	6.03	7.09	2.32

Table 4.2 Nutritional Composition of aquatic plants from Kpong

Aquatic plants		Moisture (%)	Ether extract (%)	Crude protein (%)	Crude fibre (%)	NFE (%)	Ash (%)
<i>N. lotus</i>	Min	6.20	5.63	15.10	13.60	31.41	12.31
	Max	7.10	6.31	18.62	17.76	40.53	15.32
	Mean	6.60	6.05	16.68	15.69	36.91	19.96
	S.e	0.45	0.36	1.79	2.08	4.84	1.53
<i>I. aquatica</i>	Min	17.63	11.62	12.30	19.64	10.15	9.63
	Max	20.36	13.16	15.63	24.30	25.64	10.73
	Mean	19.14	12.40	13.92	22.19	19.29	10.06
	S.e	1.39	0.77	1.67	2.36	8.11	0.59
<i>T. australis</i>	Min	1.80	5.30	18.43	11.61	45.40	6.32
	Max	2.60	6.21	26.30	14.63	49.32	12.31
	Mean	2.17	5.40	22.78	13.15	47.37	8.78
	S.e	0.41	0.80	4.0	1.51	1.96	3.14
<i>S. cubensis</i>	Min	1.80	4.70	14.30	10.20	52.89	6.32
	Max	3.20	6.30	16.32	12.70	58.20	12.31
	Mean	2.53	5.54	15.64	11.84	55.77	8.67
	S.e	0.70	0.80	1.16	1.42	2.68	1.41

Table 4.3 Mineral composition in plant samples from Ada.

Aquatic plants		Na (mg/L)	Ca (mg/L)	K (mg/L)	P (mg/L)
<i>N. lotus</i>	Min	0.10	0.35	0.23	0.11
	Max	0.23	0.45	0.43	0.20
	Mean	0.16	0.40	0.33	0.16
	S.e	0.06	0.05	0.10	0.05
<i>I. aquatica</i>	Min	0.20	0.02	0.23	0.11
	Max	0.32	0.41	0.43	0.34
	Mean	0.28	0.31	0.33	0.23
	S.e	0.07	0.11	0.10	0.11
<i>T. australis</i>	Min	0.21	0.21	0.16	0.14
	Max	0.30	0.34	0.27	0.20
	Mean	0.25	0.28	0.22	0.17
	S.e	0.05	0.07	0.06	0.03
<i>S. cubensis</i>	Min	0.31	0.23	0.28	0.31
	Max	0.43	0.43	0.32	0.65
	Mean	0.36	0.33	0.31	0.54
	S.e	0.06	0.10	0.02	0.19

Table 4.4 Mineral composition in plants samples from Kpong

Aquatic plants		Na (mg/L)	Ca (mg/L)	K (mg/L)	P (mg/L)
<i>N. lotus</i>	Min	0.01	0.27	0.19	0.03
	Max	0.16	0.41	0.43	0.11
	Mean	0.10	0.35	0.28	0.08
	S.e	0.08	0.07	0.13	0.04
<i>I. aquatica</i>	Min	0.16	0.41	0.42	0.05
	Max	0.23	0.56	0.51	0.16
	Mean	0.20	0.46	0.45	0.11
	S.e	0.04	0.08	0.05	0.05
<i>T. australis</i>	Min	0.10	0.32	0.34	0.05
	Max	0.23	0.56	0.52	0.16
	Mean	0.15	0.45	0.42	0.11
	S.e	0.07	0.12	0.09	0.05
<i>S. cubensis</i>	Min	0.23	0.46	0.12	0.54
	Max	0.43	0.65	0.32	0.67
	Mean	0.33	0.55	0.21	0.62
	S.e	0.10	0.09	0.10	0.07

Table 4.5 Heavy metal concentration in plant samples from Ada

Aquatic plants		Cu (mg/L)	As (mg/L)	Zn (mg/L)	Cd (mg/L)	Pb (mg/L)	Cr (mg/L)
<i>N. lotus</i>	Min	2.34	0.01	1.65	0.07	0.57	0.08
	Max	3.45	0.18	2.0	0.16	0.75	0.12
	Mean	2.71	0.08	1.8	0.12	0.66	0.10
	S.e	0.64	0.08	0.17	0.05	0.09	0.02
<i>I. aquatica</i>	Min	0.45	0.02	0.13	0.14	0.23	0.01
	Max	0.57	0.19	0.23	0.17	0.24	0.06
	Mean	0.52	0.12	0.18	0.15	0.23	0.03
	S.e	0.06	0.08	0.05	0.02	0.00	0.02
<i>T. australis</i>	Min	0.34	0.23	0.20	0.13	0.18	0.08
	Max	0.43	0.28	0.32	0.32	0.23	0.15
	Mean	0.39	0.25	0.27	0.23	0.21	0.12
	S.e	0.05	0.03	0.06	0.10	0.03	0.04
<i>S. cubensis</i>	Min	0.23	0.01	0.05	0.36	0.25	0.06
	Max	0.25	0.23	0.19	0.52	0.37	0.21
	Mean	0.24	0.14	0.11	0.44	0.32	0.15
	S.e	0.01	0.11	0.07	0.08	0.06	0.08

Table 4.6 Heavy metal concentration in plant samples from Kpong

Aquatic plants		Cu (mg/L)	As (mg/L)	Zn (mg/L)	Cd (mg/L)	Pb (mg/L)	Cr (mg/L)
<i>N. lotus</i>		2.61	0.01	0.72	0.08	0.67	0.01
	Max	6.41	0.06	2.81	0.15	0.97	0.23
	Mean	4.07	0.03	1.91	0.12	0.80	0.14
	S.e	2.04	0.02	1.10	0.04	0.15	0.11
<i>I. aquatica</i>	Min	0.26	0.06	0.06	0.10	0.23	0.07
	Max	0.43	0.20	0.21	0.13	0.30	0.16
	Mean	0.34	0.13	0.15	0.11	0.25	0.12
	S.e	0.09	0.02	0.08	0.01	0.04	0.05
<i>T. australis</i>	Min	0.17	0.14	0.26	0.13	0.17	0.13
	Max	0.63	0.20	0.42	0.23	0.23	0.32
	Mean	0.44	0.18	0.36	0.19	0.20	0.23
	S.e	0.24	0.03	0.09	0.05	0.03	0.10
<i>S. cubensis</i>	Min	0.08	0.16	0.25	0.32	0.25	0.02
	Max	0.12	0.34	0.63	0.47	0.38	0.19
	Mean	0.10	0.23	0.40	0.38	0.32	0.12
	S.e	0.02	0.09	0.20	0.08	0.06	0.08

Table 4.7 Physicochemical parameters of water samples from Ada, Kpong and Amedeka

Parameter		Ada	Kpong	Amedeka (Control)
pH	Min	6.4	6.20	6.5
	Max	7.0	6.53	6.9
	Mean	6.5	6.37	6.67
	S.e	0.1	0.16	0.15
Temperature (°C)	Min	28.40	30.10	29.2
	Max	30.20	32.60	32.3
	Mean	29.17	31.73	30.93
	S.e	0.93	1.42	0.68
Turbidity (NTU)	Min	2	13	2
	Max	17	17	3
	Mean	5.40	14.67	2.33
	S.e	1.28	2.08	0.58
DO (mg/L)	Min	17.6	8.6	22.3
	Max	19.2	12.7	26.6
	Mean	18.43	10.77	24.42
	S.e	0.80	2.06	2.50
BOD (mg/L)	Min	6.5	1.6	0.93
	Max	8.4	4.5	1.87
	Mean	7.57	3.10	1.13
	S.e	0.97	1.45	0.21
Nitrate (mg/L)	Min	1.25	2.2	0.76
	Max	1.84	2.4	1.23
	Mean	1.47	2.30	0.97
	S.e	0.32	0.10	0.01
Phosphate (mg/L)	Min	0.43	0.71	0.53
	Max	0.71	0.92	0.87
	Mean	0.55	0.81	0.73
	S.e	0.14	0.11	0.11
Sulphate (mg/L)	Min	4.0	5.0	4.12
	Max	4.0	6.0	4.67
	Mean	4.0	5.33	4.33
	S.e	0.00	0.14	1.53

4.1 Proximate analysis of the plant samples

Moisture content

The mean moisture content of the plant are shown in Table 4.1. They ranged from from a minimum of 3.1% in *T. australis* to a maximum of 19.6% in *I. aquatica*. Analysis of variance (ANOVA) at 95% family- wise confidence level showed that moisture content differed significantly ($P < 0.05$).

The Least significant difference (LSD) multiple comparison test revealed that, there was no significant difference between the means between *T. ausralis*, *S. cubensis* and *N.lotus* but they were however significantly different from *I. aquatica*. The mean moisture content in the studied plants in a decreasing order of ranking are as follows; *I. aquatica* > *N. lotus* > *S. cubensis* > *T. ausralis*.

The mean moisture content in the plant samples from Kpong also ranged from a minimum of 2.1% in *T. ausralis* to a maximum of 19.1% in *I. aquatica*. The results of the analysis follow similar trends as that of the plants sampled at Ada.

Ether Extract

The mean percentage ether extract of the plant samples from Ada ranged from a minimum of 6.3% in *S. cubensis* to a maximum of 9.9% in *I. aquatica*. Analysis of variance (ANOVA) at 95% family- wise confidence level showed that percentage ether extract in the various plant samples did not differ significantly ($P>0.05$). However, the variation in percentage ether extract was highest in *I. aquatica*, followed by *N. lotus* and lowest recorded in *T. ausralis* and *S. cubensis*.

The mean percentage ether extract of the plant sample from Kpong however ranged from a minimum of 5.5% in *S. cubensis* to a maximum of 12.4% in *I. aquatica*. Analysis of variance (ANOVA) at 95% family- wise confidence level indicated that percentage ether extract in the various plants samples was statistically significant ($P<0.05$).

However, The LSD revealed that, there was no significant differences between the means of *T. ausralis*, *S. cubensis* and *N. lotus* but there were however significantly different from *I. aquatica*.

Ash content

The mean percentage ash content of the plant sample from Ada ranged from a minimum of 6.3% in *T. ausralis* to a maximum of 11.3% in *N. lotus*. *S. cubensis* and *I. aquatica* also recorded an ash content of 7.0% and 8.9% respectively. Analysis of variance (ANOVA) at 95% family- wise confidence level showed that, the ash content in the sampled plants were not statistically significant($P>0.05$)

The mean percentage ash content of the plant sample from Kpong also ranged from a minimum of 8.6% in *S. cubensis* to a maximum of 13.9% in *N. lotus*. Analysis of variance (ANOVA) at 95% family- wise confidence level indicated that the ash content in the sampled plants was statistically significant ($P<0.05$).

The least significant difference however revealed that there was no significant differences in means between *T. ausralis*, *S. cubensis* and *I. aquatica* but each was however significantly different from *N. lotus*. The mean percentage ash content in the studied plants in a decreasing order of ranking are as follows; *N. lotus* > *I. aquatica* > *T. ausralis* > *S. cubensis*.

Crude Fibre

The mean percentage crude fiber content of the plant sample from Ada ranged from a minimum of 14.5% in *S. cubensis* to a maximum of 20.4% in *I. aquatica*. The *T. ausralis* and *N. lotus* also recorded crude fiber content of 15.1% and 16.5% respectively .Analysis of variance (ANOVA) at 95% family- wise confidence level showed that, the crude fiber content in the sampled plants were not statistically significant($P>0.05$)

The mean percentage crude fiber content of the plant sample from Kpong also ranged from a minimum of 11.8% in *S. cubensis* to a maximum of 22.2% in *I. aquatica*. The *T. ausralis* and *N. lotus* also recorded crude fiber content of 13.1% and 15.6% respectively. Analysis of variance (ANOVA) at 95% family- wise confidence level indicated that, the crude fiber content in the sampled plants differ significantly($P < 0.05$).

The least significant difference however revealed that, there was no significant differences in means between *T. ausralis*, *S. cubensis* and *N. lotus* but there were however significantly different from *I. aquatica*.

Nitrogen free extract

The mean percentage NFE content of the plant sample from Ada ranged from a minimum of 26.2% in *I. aquatica* to a maximum of 52.0% in *S. cubensis*. The *T. ausralis* and *N. lotus* also recorded mean NFE content of 48% and 46% respectively (Figure 4.5). Analysis of variance (ANOVA) at 95% family- wise confidence level showed that, the NFE content in the sampled plants were not statistically significant($P > 0.05$).

The mean percentage NFE content of the plant sample from Kpong also ranged from a minimum of 19.2% in *I. aquatica* to a maximum of 55.7% in *S. cubensis*. The *T. ausralis* and *N. lotus* also recorded mean NFE content of 47.3% and 36.9% respectively(Figure 4.6).Analysis of variance (ANOVA) at 95% family- wise confidence level indicated that, the NFE content in the sampled plants were highly statistically significant($P < 0.05$).

The least significant difference however revealed that, there was no significant differences in means of NFE between *T. ausralis* and *S. cubensis* but were however different from and *N. lotus*

and *I. aquatica*. The mean percentage NFE content in the studied plants in a decreasing order of ranking are as follows; *S. cubensis* > *T. australis* > *N. lotus* > *I. aquatic*.

Crude protein

The mean percentage crude protein content of the plant sample from Ada ranged from a minimum of 14% in *S. cubensis* to a maximum of 20% in *I. aquatica*. The *N. lotus* and *T. australis* also recorded mean percentage crude protein content of 16.5% and 15.1% respectively (Figure 4.3). Analysis of variance (ANOVA) at 95% family-wise confidence level revealed that, the crude protein content in the sampled plants were not statistically significant ($P > 0.05$)

The mean percentage crude protein content of the plant sample from Kpong also ranged from a minimum of 13.9% in *I. aquatica* to a maximum of 22.7% in *T. australis*. The *N. lotus* and *S. cubensis* also recorded mean percentage crude protein content of 16.6% and 15.6% respectively (Figure 4.3). Analysis of variance (ANOVA) at 95% family-wise confidence level indicated that, the crude protein content in the sampled plants were statistically significant ($P > 0.05$)

The LSD however showed that, there was no significant differences in means of crude protein between *S. cubensis*, *N. lotus* and *I. aquatica* but were however significantly different from *T. australis*.

4.2 Mineral Composition

The sodium levels in plants sampled at Ada sampling site ranged from 0.10- 0.23mg/l, 0.20- 0.32mg/l, 0.21-0.30mg/l and 0.31-0.43mg/l for *N. lotus*, *I. aquatica*, *T. australis* and *S. cubensis*

respectively whilst that sampled at Kpong sampling sites ranged from 0.01-0.16 mg/l, 0.16-0.23 mg/l, 0.10-0.23 mg/l and 0.23-0.43 mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively.

The calcium levels in plants sampled at Ada sampling site ranged from 0.35- 0.45mg/l, 0.20-0.41mg/l, 0.21-0.34mg/l and 0.20-0.46mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively whilst that sampled at Kpong sampling sites ranged from 0.27-0.41 mg/l, 0.41-0.56 mg/l, 0.32-0.56 mg/l and 0.46-0.65 mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively.

The potassium levels in plants sampled at Ada sampling site ranged from 0.23- 0.43mg/l, 0.23-0.43mg/l, 0.16-0.27mg/l and 0.28-0.32mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively whilst that sampled at Kpong sampling sites ranged from 0.19-0.43 mg/l, 0.42-0.51 mg/l, 0.34-0.52 mg/l and 0.12-0.32 mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively.

The phosphorus levels in plants sampled at Ada sampling site also ranged from 0.11- 0.20mg/l, 0.11-0.34mg/l, 0.14-0.20mg/l and 0.31-0.65mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively whilst that sampled at Kpong sampling sites ranged from 0.03-0.11 mg/l, 0.11-0.21 mg/l, 0.05-0.16mg/l and 0.54-0.67 mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively.

4.3 Heavy metal concentration in plant samples

All the six heavy metals that were selected were detected in the plant samples both at Ada sampling site and Kpong sampling sites. These metals include copper (Cu), Zinc (Zn), Cadmium (Cd) , Arsenic (As) and Lead (Pb) (Figure 4.7).The copper concentration in plants

sampled at Ada sampling site ranged from 2.3-3.45 mg/l, 0.45-0.57 mg/l, 0.34-0.45 mg/l and 0.23-0.25mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively whilst that sampled at Kpong sampling sites ranged from 0.261-6.41 mg/l, 0.26-0.43 mg/l, 0.17-0.6 mg/l and 0.08-0.12 mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively.

The arsenic concentration in plants sampled at Ada sampling site ranged from 0.01- 0.18mg/l, 0.02-0.19 mg/l, 0.23-0.28mg/l and 0.01-0.23mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively whilst that sampled at Kpong sampling sites ranged from 0.01-0.06 mg/l, 0.06-0.20 mg/l, 0.14-0.20 mg/l and 0.16-0.34 mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively.

The zinc concentration in plants sampled at Ada sampling site ranged from 1.65- 2.0mg/l, 0.13-0.23mg/l, 0.20-0.32mg/l and 0.05-0.19mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively whilst that sampled at Kpong sampling sites ranged from 0.72-2.81 mg/l, 0.06-0.21 mg/l, 0.26-0.42 mg/l and 0.25-0.63 mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively.

The Cadmium concentration in plants sampled at Ada sampling site ranged from 0.07- 0.16mg/l, 0.14-0.17mg/l, 0.13-0.32mg/l and 0.36-0.52mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively whilst that sampled at Kpong sampling sites ranged from 0.08-0.15 mg/l, 0.10-0.13 mg/l, 0.13-0.23 mg/l and 0.32-0.47 mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively.

The lead concentration in plants sampled at Ada sampling site ranged from 0.57- 0.75mg/l, 0.23-0.30mg/l, 0.17-0.23mg/l and 0.25-0.38mg/l for *N. lotus*, *I. aquatica*, *T. ausralis* and *S. cubensis* respectively whilst that sampled at Kpong sampling sites ranged from 0.67-0.96 mg/l, 0.06-0.21

mg/l, 0.26-0.42 mg/l and 0.25-0.63 mg/l for *N. lotus*, *I. aquatica*, *T. australis* and *S. cubensis* respectively.

4.4 Physicochemical parameters of water

Temperature and pH

The water temperature sampled at Ada stretch of the river ranged from a minimum of 28.4°C to a maximum of 30.2°C with a mean value of $29 \pm 0.9^\circ\text{C}$, that of Kpong stretch of the river ranged from 30.1°C - 32.6°C with a mean temperature of $31.7 \pm 1.0^\circ\text{C}$ whilst that of Amedeka ranged from 29.2°C-32.3°C with a mean temperature of $30.93 \pm 0.68^\circ\text{C}$

Statistical analysis using Analysis of Variance (ANOVA) showed that there was a statistically no significant differences in temperature between the three sampling sites ($t=42.2$, $P<0.05$) at 5% level of significance (95% family- wise confidence level).

Pearson's product moment correlation matrix carried out to determine the degree, strength and direction of the interrelationship between the physicochemical parameters and heavy metal concentration in the water sample at the sites indicated that Temperature had a strong significant positive relationship with cadmium with a correlation coefficient(r) of 0.854. There was however a weak correlation between temperature and the following metals Zn, Cu, Cr and As.

The water pH sampled at Ada stretch of the river ranged from a minimum of 6.8 to a maximum of 7.0 pH units with a mean value of 6.9 ± 0.1 , that of Kpong ranged from 6.2 – 6.5 pH units with a mean pH of 6.37 ± 0.2 and that of Amedeka range from a minimum of 6.3 to a maximum of 6.9 with a pH of 6.70 ± 0.15 .

Statistical analysis using ANOVA indicate no significant difference in means of pH from the three sampling sites.

Pearson's product moment correlation matrix however showed that pH had a highly significant negative correlation with cadmium and zinc at 5% and 1% level of significant respectively (pH-Cd, $r=-0.776$, $p<0.05$), pH-Cr, $r=-0.669$, $P<0.01$). There was however a strong positive correlation between pH and Zn.

Figure 4.1 below illustrates the mean pH of the three sampling sites.

The dissolved oxygen in the water sampled at Ada ranged from a minimum of 17.6mg/l to a maximum of 19.2mg/l with a mean value of 18.4 ± 0.8 mg/l, that of Kpong stretch of the river also ranged from 8.6mg/l- 12.7mg/l with a mean value of 10.7 ± 2.0 mg/l and that of Amedeka ranged from a minimum of 22.3mg/l to a maximum of 26.6mg/l with a mean DO value of 24.40 ± 2.50 mg/l.

Statistical analysis using ANOVA indicate significant difference in means of DO from the three sampling sites.

Pearson's product moment correlation matrix indicated that there was generally a weak correlation between dissolved oxygen and the studied metals however, dissolved oxygen had a strongly positive correlation with zinc with a correlation coefficient of $r=0.770$ and a negative correlation with cadmium with a correlation coefficient of $r=-0.805$ at 5% level of significance.

The Biochemical oxygen demand in the water sampled at Ada ranged from a minimum of 6.5mg/l to a maximum of 8.4mg/l with a mean value of $7.5.4\pm 0.9$ mg/l, that of Kpong ranged from 1.6mg/l- 4.5mg/l with a mean value of 3.1 ± 1.4 mg/l and that of Amedeka ranged from a minimum of 0.93mg/l to a maximum of 1.87mg/l with a mean DO of 1.13 ± 0.21 mg/l

Statistical analysis using ANOVA test revealed that there was no statistically significant differences in dissolved oxygen between the water at Amedeka and Kpong. There was however a statistical significant difference in dissolved oxygen content between (Kpong and Amedeka) and (Amedeka and Kpong).

Pearson's product moment correlation matrix showed that biological oxygen demand correlates negatively with cadmium and Zinc. (BOD-Cd, $r=-0.831$, $P<0.05$), (BOD-Zn, $r=-0.763$, $P<0.05$). Figure 4.2 below illustrates the mean values of the BOD and DO at the sampling sites.

Nitrate, Sulphate and Phosphate

The nitrate concentration of the water sampled at Ada stretch of the river ranged from a minimum of 1.25mg/l to a maximum of 1.84 mg/l with a mean value of 1.47 ± 0.3 mg/l, that of Kpong ranged from 2.2 – 2.4mg/l with a mean value of 2.3 ± 0.1 mg/l and that of Amedeka ranged from a minimum of 0.76mg/l to a maximum of 1.23 mg/l.

Statistical analysis using ANOVA revealed no statistical difference between water from (Amedeka and Ada sampling sites). There was however a statistical difference between (Amedeka and Kpong) and (Ada and Kpong) sampling sites. ($P<0.05$).

The sulphate concentration of the water sampled at Ada stretch of the river recorded a mean value of 4mg/l, that of Kpong ranged from 5 – 6mg/l with a mean value of 5.3 ± 0.5 mg/l and that from Amedeka ranged from a 4.12mg/l to a maximum of 4.67mg/l with a mean 4.33mg/l. There was however no statistical significant differences in sulphate concentration between the three sampling sites ($P>0.05$). Figure 4.3 represent mean nutrient levels in the water samples

The Phosphate concentration of the water sampled at Ada stretch of the river ranged from a minimum of 0.43mg/l to a maximum of 0.71 mg/l with a mean value of 0.5 ± 0.1 mg/l, that of Kpong ranged from 0.71 – 0.92 mg/l with a mean value of 0.8 ± 0.1 mg/l and that of Amedeka ranged from a minimum of 0.53mg/l to a maximum of 0.87mg/l with a mean value of 0.73 ± 0.11 mg/l.

There was no statistical significant differences in phosphate concentration between the three sampling sites using ANOVA ($P < 0.05$).

4.5 Results of heavy metal Analysis in water and sediment

All the six heavy metals analyzed in sediments were detected at the three sampling sites (Ada, Kpong and Amedeka). This include copper (Cu), lead (Pb), Cadmium (Cd), Zinc (Zn) and Arsenic (As). The total concentrations of heavy metals in sediments and water at Ada sampling sites ranged from (3.73-4.82mg/l, 0.34-0.50mg/l), (0.44-0.49mg/l, 0.1-0.2mg/l), (1.2-1.7mg/l, 0.02-0.06mg/l), (6.8-8.5mg/l, 0.14-0.19mg/l), (0.9-3.2mg/l, 0.01-0.03mg/l) and 0.9-1.5mg/l, 0.01-0.02mg/l) for copper (Cu), lead (Pb), Chromium (Cr), Zinc (Zn), Cadmium (Cd), and Arsenic (As) respectively. The total heavy metal concentration in sediment and water sample at Kpong sampling site also ranged from 4.6-5.7mg/l, 0.38-0.46mg/l (Cu), 0.4-0.5mg/l, 0.112-0.113mg/l (Pb), 0.5-0.9mg/l, 0.05-0.06mg/l (Cr), 0.9-2.5mg/l, 0.05-0.06mg/l (Cd), 5.3-6.8mg/l, 0.09-0.14mg/l (Zn) and 0.1-0.6mg/l, 0.01-0.04mg/l (As). The control site (Amedeka sampling site) however recorded very low levels of heavy metal concentration in the sediments and water. It ranged from (0.8-1.2mg/l, 0.35-0.41mg/l), (0.1-0.18mg/l, 0.01-0.02), (0.9-1.2mg/l, 0.2-0.3), (4.1-4.8mg/l, 1.2-1.3), (0.1-1.5mg/l, 0.01-1.2mg/l) and 0.2-0.8mg/l, (0.01-0.04mg/l) for copper

(Cu), lead (Pb), Cadmium (Cd), Zinc (Zn) and Arsenic (As) respectively. The mean values and the standard deviations of the heavy metals concentration are illustrated in Table 4.6 below

Table 4.8 Mean values of heavy metals (mg/L \pm SD) in sediment samples at the study area.

Site	Cd	As	Pb	Cr	Zn	Cd
Ada	2.3 \pm 1.2	1.2 \pm 0.3	0.47 \pm 0.02	1.4 \pm 0.25	7.5 \pm 0.86	2.3 \pm 1.2
Kpong	1.8 \pm 0.8	0.3 \pm 0.02	0.4 \pm 0.03	0.7 \pm 0.02	5.80 \pm 0.8	1.8 \pm 0.8
Amedaka	0.8 \pm 0.02	0.1 \pm 0.01	0.2 \pm 0.001	0.4 \pm 0.001	2.3 \pm 0.02	1.2 \pm 0.03

4.6 Correlation between physico-chemical parameters and heavy metals in sediments.

Considerable numbers of significant positive and negative correlation were observed between the following physico-chemical variables and heavy metals concentration in the sediment sample; Temperature and Cadmium ($r=-0.960$, $P<0.01$), Temperature and Zinc($r=-0.722$, $P<0.05$), pH and Cr ($r=-0.543$, $P < 0.05$), As and Zn ($r=0.719$, $P<0.05$), Cr and As($r=0.935$, $P<0.01$), Pb and Cd ($r =-0.632$, $P<0.05$). The table below shows the person's product moment correlation matrix of the significant physico-chemical and heavy metal concentrations in sediments of the lower Volta basin.

Table 4.9: Pearson's product moment Correlation between physico-chemical parameters and heavy metals in sediments.

VAR	pH	Temp	Cu	AS	Pb	Cr	Zn	Cd
pH	1					-0.543*		
Temp		1	-0.558	-0.503	0.58	-0.543*	-0.722*	-0.960**
Cu			1		-0.692*			
As				1		0.935**	0.719*	
Pb					1			-0.632*
Cr						1		
Zn							1	0.662*
Cd								1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). Temp; Temperature.

Table 4.10: Comparison between the mean concentration of trace metals in water and sediment.

Site	sample	parameter	Cd	AS	Pb	Cr	Zn	Cd
Ada	water	F	7.5	24.1	244.5	51.4	118.7	7.5
	sediment	P-value	0.00*	0.00*	0.00*	0.00*	0.00*	0.10ns
Kpong	Water	F	8.5	32.3	185.9	47.2	114.3	11.2
	Sediment	P-value	0.00*	0.00*	0.00*	0.00*	0.00*	0.30ns
Amedaka	water	F	7.2	25.8	175.3	49.5	117.5	9.6
	Sediment	P-value	0.00*	0.00*	0.00*	0.00*	0.00*	0.20ns

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P<0.05 probability level; ns: Not significant

4.8 Phytochemical Screening

Results obtained from qualitative screening of plant samples are indicated in Table 4.11 below. Of the seven phytochemicals analysed, three were found in all the four plants samples. They are Flavonoids, Saponins and phenols. *Nymphaea lotus* had all the phytochemicals tested present. Alkaloids and proteins were not found in *Ipomoea aquatica*. Terpenoids were not present in *Typha australis*. Sterols were also not present in *Scirpus cubensis*.

Table 4.11 Results of the phytochemical analysis of four aquatic plants

Phytochemicals	<i>Nymphaea lotus</i>	<i>Ipomoea aquatica</i>	<i>Typha australis</i>	<i>Scirpus cubensis</i>
Alkaloids	+	-	+	+
Flavonoids	+	+	+	+
Saponins	+	+	+	+
Sterols	+	+	+	-
Phenols	+	+	+	+
Proteins	+	-	+	+
Terpenoids	+	+	-	+

All experiments were done in triplicate. Legend: += Present, - = Absent.

4.9 Social Survey

This section involves the analysis of the questionnaire administered to some individuals within selected communities in the study area. A total of 120 respondents from two communities namely; Kpong (50%), Ada (50%) were interviewed. With respect to sex of the individuals, 71

individuals representing 59.2% were males whilst 49 individuals representing 40.8% were females.

Forty –seven (47) people representing 39.2% of the respondent were between the ages of 20-29 years, 30 %, 20.8% were between the ages of 30-39 and 40-49 respectively whilst only 10% were 50years and above at the time the interview were sought.

Similarly, Thirty five (35 %) of the respondent engage in fishing whilst 28.3% engage in various trading activities with 11.7 %, 10% and 15 % engaging in farming, office work and handwork respectively.

The results showed that about forty -seven percent (47 %) of the respondents were indigenes whilst 53 % were settlers. The educational levels of the respondents were sought and it showed that 39.2 % of the population had JSS education whilst 1 5% had secondary/6th form education, Ten percent (10%) had tertiary education with 1.7% having vocational, 34.2% however had no formal education.

On the possible use of the river, 48 persons representing 40% use the water for domestic activities whilst 36.7% use the water for fishing. However, 11.7% and 10.8% use the water for irrigation and swimming respectively.

When the respondents were asked whether the plants that grow at the sampling sites are used to feed animals, 65.2% of them answered in the affirmative whilst 34.8% said they don't use the plant to feed animals.

Similarly 67.5 % of the respondents attested to the fact that the plants harvested have medicinal value whilst 32.5 % thought otherwise. When the views of the respondents were sought to ascertain whether the plants harbor some wild animals including snakes, 92.3 % answered in the affirmative. However, majority of the respondents had not been bitten by those snakes during the use of the water for their various activities.

When the respondents were asked whether they fish in areas densely populated with weeds, 32.7 % of them answered in the affirmative whilst 62.5 % said they do not fish in such areas. The respondents similarly confirmed that the abundance of weeds have reduced their fish catch as majority representing 79.2 % answered in the affirmative.

On the possible use of the water for drinking purposes, 43.3 % of the respondents drink the water directly from the river whilst the remaining 56.7 % use other sources such as wells and borehole as major source of drinking water. However, this same water used by humans are also a very good source of drinking water for animals such as cattle, goats, sheep and pigs as 74.2 % of the respondents affirmed to that fact.

When the respondents were asked whether the abundance of weeds have increased the cost of transportation on the river, 54.2 % answered in the affirmative whilst 45.8 % said it has not increase the cost of transportation. The respondents noted that the vector borne disease that is currently prevalent in the area is malaria as opposed to *Schistomiasis* which was the major disease in the area.

Also 78 % of the respondent attested that children no longer swim in densely infested areas.

When the respondents were asked which kind of livestock they have in their communities, 100 % indicate the presence of cattle, sheep, goat, pigs and poultry in their communities

CHAPTER FIVE

DISCUSSION

5.0 Introduction

This chapter analyses' and discusses the findings of the study made in the selected sampling sites. Some secondary sources of information are also included here.

The proximate composition of the selected plants were compared to proximate composition of fresh early bloom guinea grass (*Panicum maximum*). Guinea grass is the most productive forage grass in tropical Africa, valuable for pasture, green-silage, hay, and silage. Especially palatable in the younger stages, tending to become coarser and less readily eaten by cattle as it matures. However, because of its lack of good seed production, its use is limited (Reed, 1976). The proximate composition of *Panicum maximum* are as follows: crude protein (5.3%), crude fibre (39.6%), ash content (10.6%), ether extract (1.4%) and nitrogen free extract (43.1%).

Nymphaea lotus from Ada was the richest in ash content. Ash is considered as the total mineral or inorganic content of the sample. This implies *Nymphaea lotus* has the highest of total mineral or inorganic content. These minerals may be vital to animals and subsequently humans. The crude fibre, protein, ash, ether extract and nitrogen free extract were all higher than that of a fresh early bloom *Panicum maximum* from Tanzania. Higher protein content makes it suitable for animal feed and as human feed. It is for this reason that many humans around the world feed on *Nymphaea lotus* (Nordeide *et al.*, 1996). This trend was not different from that observed for *Nymphaea lotus* at Kpong. The results obtained in the proximate analysis of *Nymphaea lotus* were similar to that observed by Shal *et al.*, 2010 in Srinagar. The crude protein content and

Nitrogen free extracts of *Nymphaea lotus* are comparable to that of Alfalfa hay (C.P= 16.91%, NFE= 40.55%) (Banerjee & Matai 1990)

The crude protein, ash content, ether extract and nitrogen free extracts of *Ipomoea aquatica* from Ada were higher than the corresponding constituents in a Fresh early bloom *Panicum maximum* from Tanzania. This implies *Ipomoea aquatica* has a higher nutritional value than *Panicum maximum*. The high ash content of *Ipomoea aquatica* ($8.95 \pm 3.10\%$) is an indication that the plant contain nutritionally important mineral element. The value of ash content obtained in this study is low compared to 14.44% (on dry weight basis) in *Ipomoea aquatica* leaves grown in Vietnam (Ogle *et al.*, 2001) and 17.87% found in leaves of *Ipomoea* sp. grown in Swaziland. In contrast, the value is higher than that of *Ipomoea batatas* leaves (1.8 g/100 g dry weight) reported by Asibey-Berko and Taiye (1999).

The crude protein content in *Ipomoea aquatica* ($13.92 \pm 1.67\%$) was found to be higher than that reported in *Ipomoea aquatica* leaves (4.25% dry weight) found in Vietnam (Ogle *et al.*, 2001). When compared with other species such as *Ipomoea batatas* leaves with crude protein content of 8.0% (Asibey-Berko & Taiye, 1999), 11.67-18.00% and 24.37-29.46% (Monamodi *et al.*, 2003), the plant leaves analysed have low crude protein content. The value on the other hand, accord with the protein content for fresh vegetables (0.5-5.0%) as reported by Lintas (1992). The crude fibre was however lower than that of *Panicum maximum*. The results showed similar trend at Kpong.

Typha australis had the highest crude protein content (20.04%). The crude protein content of *Typha australis* is comparable to that of *Azolla Pinnata* (21.9%) and *Pistia stratiotes* (20.5%)

(Banerjee & Matai, 1990) which is an edible under water tuber. The crude protein content, ether extracts and nitrogen free extracts were higher than the corresponding constituents in *Panicum maximum*. Higher NFE indicates the presence of digestible carbohydrates, vitamins and other non-nitrogen soluble organic compounds which are essential for animal and human growth (Fao.org, 2015). Ash content was lower in *Typha australis* than *Panicum maximum* indicating lower mineral or inorganic content in *Typha australis*. The nutrient composition of *Typha australis* from Ada did not differ significantly from samples from Kpong.

Scirpus cubensis had the highest NFE (52.24%) indicating the presence of more digestible carbohydrates, vitamins and other non-nitrogen soluble organic compounds which are essential for animals and human growth. The NFE of *Scirpus cubensis* is comparable to the NFE of *Vallisneria Americana* (53.43%) which occurs naturally in Asia and America (Fao.org, 2015). The crude protein content of *Scirpus cubensis* is comparable to that of *Ceratophyllum demersum* (15.8%) which is a submersed aquatic plant (Banerjee & Matai, 1990). Ether extracts also and Nitrogen free extracts were higher than the corresponding constituents in *Panicum maximum*. Crude fibre and ash content were higher in *Panicum maximum* than *Scirpus cubensis*.

The mineral composition of the four aquatic plants presented in tables 4.2 and 4.3. showed significant variation. This variation may be due to differences in genus and species level of the plants (Kalita *et al.*, 2007). Among the four species, *Scirpus cubensis* showed relatively higher mineral content. Mineral elements play an important role in regulating many vital physiological processes in the body, such as regulation of enzyme activity (cofactor or metalloenzyme), skeletal structures (e.g., calcium and phosphorus), neuromuscular irritability and clotting of

blood (calcium). Non-availability of adequate quantities of minerals in diet affects animal growth and may cause irrecoverable deficiency diseases (De Silva & Anderson, 1994). Calcium and Phosphorus was particularly high in *Scirpus cubensis* at Ada.

All the heavy metals analysed in the plants were lower than the WHO/FAO, 2007 guideline for metals in foods and vegetables (Table 5.1). Among the species studied, Copper and Zinc were particularly high in *Nymphaea lotus*. This observation may be due to the natural abundance of zinc and copper in the environment. Zinc is the 24th most abundant element in the Earth's crust and has been present ever since the planet was formed. Also the broad nature of the leaves of *Nymphaea lotus* gives the plant a large surface area to absorb metals from the water. Copper functions in the immune system of animals through the following: energy production, neutrophil production and activity, antioxidant enzyme production, development of antibodies and lymphocyte replication (Kim et al., 2005). Zinc also function in the immune system of animals through the following: energy production, protein synthesis, stabilization of membranes against bacterial endotoxins, antioxidant enzyme production, and maintenance of lymphocyte replication and antibody production (Nockels, 1994; Kidd, 1996). Therefore the presence of relatively higher content of Copper and Zinc in *Nymphaea lotus* makes it more suitable to be incorporated in animal diet as it will provide the animals with essential trace elements

All the plant species with the exception of *Ipomoea aquatica* have proteins, indicating that they can be used as good feed for animals thereby reducing their overgrowth as weeds. The presence of the secondary metabolites suggests that the plants can serve as good sources of pharmaceutical agents. This is due to the fact that plant secondary metabolites have been shown

to possess pharmacological activities and also are directly or indirectly involved in disease cure, prevention and general health of the human body. This is demonstrated by the folkloric use of plant parts for medicinal purposes.

Alkaloids generally present in the four plant species play some metabolic role and control development in living system. They are also involved in protective function in animals and are used as medicine especially the steroidal alkaloids. Flavonoids and phenolic compounds in the plants have been reported to exert multiple biological effects including antioxidant, free radical scavenging abilities, anti-inflammatory and anti-carcinogenic properties on the human body (Pandey & Rizvi, 2009). These plants can therefore be harvested and investigated for their pharmacological (biological) activities. More so recently there has been a renewed interest in plant-based medicine. Newer medicinal plants are being sought for. These plants have demonstrated from the presence of these phytochemicals that they have promising medicinal properties. Harvesting these weeds for animal fodder and medicinal purposes will drastically reduce the invasive effects of these weeds on the water body. Gbadamosi & Oloyede., (2014) reported similar trend of phytochemicals in *Nymphaea lotus* in Nigeria

The mean temperature of water sampled at Ada and Kpong did not differ significantly from the control site (Amedeka). There was however a slight difference in temperature at the sampling sites. The narrow differences in temperature could be attributed to solar radiation which depends on weather conditions and the mixing of the water (Kakari 2013). The temperature of the water at the three sampling site were however higher than the WHO guideline for drinking water. The difference in time of sampling also accounts for changes in temperature. Temperature plays an

important role, which governs the seasonal succession of the biota (Dhanalakshmi *et al.*, 2013). Karikari, (2013) and Ofori-Danson & Ntow (2005) made similar observation in the Volta River.

The pH of the water sampled at Ada and Kpong differed significantly from that of the control site (Amedeka). The relatively lower pH values at Ada and Kpong may be due to the numerous plants whose photosynthetic activities produce carbon dioxide into the water which subsequently forms carbonic acid (H_2CO_3) and hence reduce the pH. The pH values at the sampling sites were considered suitable for aquatic plant growth and fish survival which have been reported to range between 5.0 and 9.0 (Jobbling, 1995). Values of pH outside the expected range of 5.0 to 9 should be considered as indications of industrial pollution or some cataclysmic event. However, the pH of the water sampled at the three sites all fell within the range of WHO guideline of drinking water (6.5-8.5). Karikari, *et al.*, (2013) also observed similar trend in pH of water in the Volta River.

Ada and Kpong showed low levels of dissolved oxygen as compared to the control site (Amedeka). These results when subjected to one-way ANOVA showed significant differences at 5% level between the mean values of the sampling areas. The low DO recorded at Ada and Kpong reflect the high number of living organisms the plants accommodate in the water. These living organisms consume and make use of oxygen in the water. A similar study in Nigeria carried out by Mironko *et al.*, (2012) revealed that dissolved oxygen content in aquatic weeds infested areas is lower than uninfested areas. Karikari also reported a mean DO level of 7.3mg/l at Kpong. Antwi & Ofori-Danson (1993) reported average DO level of 7.78mg/l on the Volta River in Ghana. On the field, it was observed that the flow rate of water within infested areas was impeded by the aquatic plants. Dissolved oxygen is affected by flow rate,

mixing and aeration due to wind action (Straskaba & Tundisi, 1999). The DO levels recorded at the two sampling sites were however higher than the WHO standards for drinking water (7.5mg/l). This indicates that the waterbody is much oxygenated despite the presence of the numerous aquatic plants.

The DO recorded at Ada was higher than that of Kpong. The higher value recorded at Ada may be due to the relatively turbulent nature of the water body. It could also be ascribed to mixing and reaeration due to wind action as well as photosynthetic activity by the aquatic plants. Dissolved oxygen (DO) is very crucial for survival of aquatic organisms and it is also used to evaluate the degree of freshness of a river. The flow rate of the water at Ada was observed to be higher than the flow rate at Kpong.

BOD values in the three sampling sites were generally low. However, the BOD values obtained for Ada and Kpong were higher than that of the control site (Amedeka). Moderately polluted rivers have a BOD value in the range of 2 to 8 mg/l (Thakre *et al.*, 2010). The BOD values recorded at Ada and Kpong sampling point fell within the range of moderately polluted water body. This implies the aquatic plants exert some level of pollution on water. The BOD value of water at the control site was below the range of pollution (1.13mg/L). Asante *et al.*, (2008) reported a mean BOD value of 4.5mg/l on the Weija Reservoir and Karikari *et al.*, 2013 also reported a BOD value of 3.5mg/l on the Volta River which agrees with this study.

Nitrate levels at Ada and Kpong were relatively higher than nitrate levels at the control site (Amedeka). Nutrient levels were generally low in the waterbody of the study area. However, the nitrate grossly exceeded the global average of 0.1mg/L of nitrate in fresh water bodies (Meybeck & Helmer, 1989). This could be as a result of runoff from fertilized farm lands and domestic waste. Nitrates in the water samples at infested areas could be due to decomposition of dead plant and animals from the infested areas. This partly account for the high nitrate levels at infested areas of aquatic plants. The nitrate concentrations of the water at the three sampling sites were however within the WHO guideline of nitrate in drinking water (10mg/L)

The average concentration of sulphate in freshwater bodies is 4.8mg/L (Meybeck & Helmer, 1989). Sulphate concentration of water from Ada and the control site (Amedeka) fell below 4.8mg/L. Sulphate concentration in water at Kpong was higher than the average sulphate concentration in freshwater. There was however no statistical significant difference in means of sulphate concentration at the three sampling points. The concentration of sulphate in the water could be due to natural occurrence in the water as sulphur occur naturally in its reduced form in igneous and sedimentary rocks (Singleton, 2000). The sulphate concentration at the three sampling points was however within the WHO guideline of 250mg/L for drinking water.

Phosphate concentration of the water samples from the three sampling site did not differ significantly suggesting that the aquatic plants at the study area have no significant influence on phosphate concentration of the water. This observation contradicts that of Mironga *et al.*, (2012) in Lake Naivasha that phosphate concentration in infested areas is lower than uninfested areas. The natural background levels of phosphate ($P-PO_4^{3-}$) in inland waters usually range from 0.005 to 0.05 mg/L (Dunne & Leopold, 1978), the mean PO_4^{3-} contents at all the three sampling sites

were outside the range of 0.005 to 0.05 mg/L. This could be due to the washing of utensils, clothing and bathing by both children and adults in the river at each sampling site as witnessed during the study. The levels of phosphate concentration from the three sampling sites were not statistically different.

The turbidity values of the water sampled at Kpong and Ada were higher than that of Amedeka that is the control site. The mean turbidity of Ada and Amedeka is similar; however, significant differences appear in the turbidity between Amedeka and Kpong on one hand and Ada and Kpong on the other hand. The relatively high turbidity recorded at Ada and Kpong may be due to the high levels of suspended particles that result from debris from the numerous aquatic plants.

All the heavy metal concentration analysed in the water were found to be lower than the WHO guideline for drinking water with the exception of cadmium and lead. Cadmium concentration from all the three sampling point exceeded the WHO guideline of Cadmium concentration in drinking water. The relative high amount of cadmium concentration in the study area might be coming from runoff from farms that use phosphate fertilizers. Phosphate fertilizer contain cadmium (De Meeus *et al.*, 2002). Lead concentration exceeded the WHO guideline of lead in drinking water at Ada and Kpong where there are numerous aquatic plants. The main sources of lead in the environment is from lead batteries and lead paints. The improper disposal of lead in the environment may partly account for the relative higher lead concentration in the water (Rhue *et al* 1992). Heavy metals concentration in the water sample did not vary significantly from the three sampling area suggesting that the plants did not have significant influence on heavy metal concentration in the water.

The concentrations of all the studied metals in sediment samples were higher than the concentrations in the water columns. This confirms the fact that sediment has been described as a ready sink or reservoir of pollutants including trace metals, where they concentrate according to the level of pollution (Onyari *et al.*, 2003). The higher concentration of metals in the sediment compared to the water may be attributed partly to the fact that suspended heavy metals in the water column settle in the sediments and accumulate over time. There are several environmental factors that could influence the mobility of heavy metals from sediments into the water column. This may include pH, temperature and Redox potential (Siegel, 2002). The lower levels of heavy metals recorded in water compared to the sediments is an indication that the least of the heavy metals are binded to sites that are water soluble.

With the exception of cadmium which did not show any statistically significant differences ($P > 0.05$), the differences in the concentrations of copper (Cu), lead (Pb), Chromium (Cr), Zinc (Zn) and Arsenic (As) in water and sediment sample at the three sampling sites were statistically significant ($P\text{-value} < 0.05$). The corrosion of galvanized pipes on the canoes and other deposits, erosion of natural deposits, runoffs from waste batteries and paints from the town and nearby surroundings could probably be the main sources of heavy metal contamination in the water and sediments. The natural weathering of rocks at the bottom sediment could also be a potential source of heavy metal released into the sediments and the water column.

The results from the social survey indicate that some members within the communities often used some of the aquatic plants to feed animals. Animals in the communities include cattle, goats, sheep, pigs and poultry. Regular harvesting and feeding of animals with these plants could reduce the detrimental effects of these weeds on the water body. None of the respondent has ever

used any of the numerous aquatic plants as food. This observation contradicts what Shah *et al.*, (2010) studied in India that humans feed on aquatic. Again 67% of the respondent indicated that the plants have medicinal value. This was confirmed by the results obtained in the phytochemical analysis.

Other socioeconomic impacts of the aquatic plants indicate loss of earnings opportunities as fishermen could not access fishing and landing sites as well as interference of the weeds with fishing gear and clogging of pumps. Some fishermen have adopted to the use of fishing traps rather than the usual casting of nets to catch fishes. Casting of nets will harvest unintended aquatic weeds. The abundance of aquatic weeds has subsequently led to a reduction in fish catch.

A recreational activity along the two communities (Ada and Kpong) is also affected as children no longer swim in densely infested areas. Travelers on the River attested to the fact that cost of transportation on the river has increased due to blockage of waterways by aquatic vegetation, hence the use of alternatively longer route.

Again the aquatic weeds impede flow rate of the water and provide good breeding grounds for mosquitoes. This was evident in the two communities Kpong and Ada as respondent indicated the presence of numerous mosquitoes at night. However the respondent indicated a decline in schistomiasis which previously was a major water health related issue in the communities.

Although 92.3% of the respondent attested to the vegetation harbouring wild animals such as snakes, there has not been any incidence of snake bites in the communities from the river.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 CONCLUSION

The conclusions of the study are presented as follows:

The present study has indicated that *Nymphaea lotus* Linn., *Ipomoea aquatica* Forsk. , *Typha australis* Schmach. and *Scirpus cubensis* Poeppig & Kunth. could be important sources of proteins and minerals suitable for incorporation into animal diet. The results indicate that all the four plant species investigated have higher nutritive value than *Panicum maximum* Exploitation of these aquatic plants will not only be of economic importance but would be a step towards sustainable and effective way of managing aquatic vegetation within the Lower Volta Basin.

The studied plants particularly *Nymphaea lotus* Linn., *Typha australis* Schumach. and *Scirpus cubensis* Poeppig & Kunth. have demonstrated from the presence of the phytochemicals that they have promising nutritional and antioxidant properties. Harvesting these plants for animal fodder and medicinal purpose will drastically reduce the invasive effects of these weeds on the water body and also aid in the management of aquatic plants within the LVB.

Concentration of all the heavy metals analysed in the plants were found to be lower than the WHO/FAO, 2007 guideline for metals in foods and vegetables. Copper and Zinc were relatively higher in *Nymphaea lotus* than in all the other plants. The relatively high levels of copper and zinc

in *Nymphaea lotus* makes it suitable to be incorporated in animal diet due to the vital role of copper and zinc animals.

The physicochemical parameters of water were examined to evaluate the quality of water in which the plants grow. The results revealed that most of the parameters of water differed significantly from the control site. These parameters include pH, Nitrates, BOD and DO. The concentrations of heavy metals in the water were all within the WHO guideline for drinking water with the exception of lead (Pb) and Cadmium (Cd). The measure concentrations of all the studied metals in the sediment samples were higher than the concentrations in the water columns.

In order to completely ascertain the concentrations of heavy metals in each fraction of the sediment, heavy metals fractionation should have been done.

From the survey, responses from the respondents indicated that some group of people use some of the plants particularly *Nymphaea lotus* to feed animals. Consistent harvesting of this plant will aid in management of aquatic plants within the LVB.

6.1 RECOMMENDATIONS

The following recommendations are made with reference to the results, and overall findings obtained from the research in order to help improve management of aquatic plant within the Basin

There is the need for the Volta River Authority (VRA) to improve land use management in the catchment and along the river so as to reduce silt and nutrient loads as a mechanism for controlling the proliferation of aquatic plant growth within the Basin. Runoff from fertilized farms can be reduced by planting trees such as *Tarchonantus cambhoratus*, *Acacia*

drepanolobium and indigenous grasses, like star grass (*Aletris farinsa*) along the banks of the river. This can improve the quality of the land cover, grass availability and thus reduce surface runoff.

Different plant species should be evaluated for their nutritional value by research institutions such as the universities and the Council for Scientific and Industrial Research (CSIR) to identify species that are rich in nutrient to be used as fodder for animals so as to continuously harvest to feed animals as a means of controlling or managing the vegetation within the basin.

Some livestock should be tested by feeding them with *Nymphaea lotus*, *Ipomoea aquatic*, *Typha australis* and *Scirpus cubensis* to monitor the effect of the plants on their health by veterinary officers.

Based on the phytochemicals present, further studies should be conducted to isolate the active phytochemical constituents in the plants and investigate their biological activities.

To efficiently manage aquatic plants in Ghana, the use of aquatic plants as a leafy vegetable, green manure, medicine, or in other applications should be documented so that the social and economic factors contributing to the spread of the plants can be addressed and potentially reduced.

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APPENDICES