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DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

EFFECTS OF INDUSTRIAL WASTE EFFLUENTS DISCHARGED INTO SAKUMO II LAGOON IN ACCRA GHANA

THESIS SUBMITTED TO THE DEPARTMENT OF THEORITICAL AND APPLIED BIOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN ENVIRONMENTAL SCIENCE

BY

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DECLARATION

I hereby declare that this submission is my own work towards the award of the M.Sc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this work to my wife Christiana Agbemehia and my little boy, Edem Agbemehia.

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ABSTRACT

Wetlands are among the most productive life support systems in the world and are of immense socio-economic and ecological importance to mankind. Despite the ecological and environmental services they provide, urbanization, and over–exploitation of resources are taking a serious toll on wetland resources within urban areas. The aim of this study was to establish the current pollution status of the Sakumo II Lagoon, as well as investigate the influence of effluent discharge from industrial activities on the quality of water in the lagoon. Social survey was also conducted to assess people's awareness and knowledge on the lagoon and wetland importance. Water samples were collected from three sections (South, Mid and North) of the Sakumo ll lagoon for a period of six (6) months and industrial effluents from three industries (Coca Cola Bottling Company, Kasapreko and Printex) for three (3) months and analyzed for temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), turbidity, electrical conductivity, NO_3-N, PO_4-P, NO-N and NH_4-N. Results obtained were compared with the Environmental Protection Agency (EPA)-Ghana permissible guideline values of 2002 for effluents discharged into water bodies and mean values from similar studies on the lagoon. One way ANOVA test indicated that the pH and turbidity of the lagoon water were the parameters of the water quality most significantly affected ($p< 0.05$) by pollution in both seasons. TSS (112.1 mg/l), TDS (371.2 mg/l) and conductivity (741.1 µS/cm) were however not affected by pollution and values were statistically similar ($p>0.05$). Compared to EPA–permissible values, concentrations of nitrate and ammonia for both water and effluent samples were high. Based on these results, the Sakumo II lagoon could therefore be described as relatively polluted with nutrient load and the influence of anthropogenic activities. It is therefore recommended that there should be improvement in sanitation facilities and enforcement of regulations on the protection of the lagoon and wetland resources.

ACRONYMS

APHA- American Public Health Association

BOD-Biological Oxygen Demand

BMA-British Medical Association

CSIR-Centre for Scientific and Industrial Research

DO – Dissolved Oxygen

EPA – Environmental Protection Agency

FoE-Friends of the Earth

KVIP-Kumasi Ventilated Improved Pit

MLF – Ministry of Lands and Forestry

STP- Sewage Treatment Plant

TMA – Tema Development Corporation

UNEP – United Nations Environmental Programme

UNESCO – United Nations Education and Cultural Organization

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of study

In recent years, there has been a remarkable growth of interest in environmental issues especially in sustainability and the better management of development in harmony with the environment. Though nature is admired and adored by most people, they do not appreciate the role the various components of nature play in their lives. Lagoons for instance, have been subjected to all kinds of abuse because of people's lack of appreciation of their usefulness. Some argue that, "Wetlands are waste areas that must be reclaimed for important purposes" while others hold the view that, "Wetlands breed mosquitoes," and so must be reclaimed for other uses.

Various definitions and descriptions have been assigned to wetlands in literature. Mitsch and Gosselink (1993) refer to wetlands as *"a habitat which occupies a position somewhere between dry land and deep aquatic ecosystem".* The Convention on wetlands of International Importance especially as water fowl habitat (Ramsar Convention, 1972), defined wetlands as *"areas of marsh, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters (6m).*

Wetlands cover an estimated six percent (6%) of the world's land surface and have generally been described as wastelands (Williams, 1991). In Africa, wetlands constitutes only around percent (1%) of the total surface area excluding coral reefs and some of the smaller seasonal wetlands (Kabii, 1997). However, in Ghana, wetland ecosystem constitutes about ten percent (10%) of the country's total land surface (National Wetlands Conservation Strategy, 1999). The Sakumo wetland is one of the five coastal wetlands in Ghana that have been already declared as Ramsar site under the International Ramsar Convention on wetlands. It is rated the third most important area for seashore birds on the Ghanaian coast (Agyepong *et al.*, 1999).

Wetlands are among the most productive life support systems in the world and are of immense socio-economic and ecological importance to mankind (Halls, 1997). According to the *"Ramsar Guidelines on Wise Use"*, benefits and values of wetlands include sediment and erosion control, flood control, maintenance of water quality and abatement of pollution, maintenance of surface and groundwater, water supply, support for fisheries, grazing and agriculture, outdoor recreation, education for human society, provision of habitat for wildlife especially water fowl and contribution to climatic stability. Other ecological services derived from wetlands include food and water, regulation of floods, drought, land degradation, and disease, soil formation, nutrient cycling as well as recreation and eco-tourism (Halls, 1997).

Despite the ecological and environmental services provided by wetlands, they are under severe threat as a result of unsustainable utilization. Wetlands around the world continue to experience immense pressure from human activities; the most important of these include agriculture and settlement, excessive exploitation by local communities, and other improperly-planned development activities. Wetland ecosystems are still being reduced in size as modern technology draining techniques make them even more attractive as potential agricultural land, and their flatness and coastal location make them obvious locations for large plants, harbours and waste disposal sites (Williams, 1991). Water is one of the main wetland resources. The availability and quality of such a resource always play important roles in determining not only where people can live, but also their quality of life (Solley *et al.*, 1995). Human activities particularly irrigated agriculture and urban development instigating water diversions from rivers and stream have often altered the hydrology of most wetlands (Khan *et al.*, 2009). The discharge of various forms of wastes into the wetland also creates fertile environment for microbiological and biological agents to flourish and spread disease pathogens leading to various health problems for humans and aquatic organisms (UNEP, 2006).

Urbanization, urban encroachment and associated pollution and over – exploitation of resources are taking a serious toll on wetland resources within urban areas. According to a research by friends of the Earth (FoE) in 1994 on wetlands in Ghana, most wetlands close to urban areas have been degraded through anthropogenic activities and the Sakumo ll lagoon is not exonerated from this abuse. The research emphasized that the current degradation of wetland ecosystem in Ghana is significant and reveal that management of these areas has been complex and challenging because of the threat of environmental degradation. Studies, therefore, need to be conducted to facilitate the processes towards long-term usage or conservation.

1.2 Problem statement

Ghana is rapidly urbanizing and is not different from other countries in sub-Saharan Africa. Recent statistics indicate that 43% of the populations were urban dwellers in 2000 as against 9% in 1931. With the current national growth rate of 2.6% per annum, the

Ghanaian urban population is expected to double in 17 years (Ghana Statistical Services, 2000). In Accra more pressure is being brought to bear on land for housing provision as population grows at an estimated 4.2%. In the quest for more lands for residential and other livelihood activities, wetlands have become natural targets and are being heavily encroached upon (Ghana Statistical Services, 2002).

The Sakumo II lagoon is located in an urban area in the Greater Accra Region of Ghana where access to domestic and industrial waste disposal facilities is limited. Only 4.5% of households in the region have access to adequate liquid waste disposal facilities (Ghana Statistical Service, 2000). The remaining 95.5% of households discharge their untreated liquid waste unto the streets, other surroundings or gutters and they are eventually discharged into various water bodies via storm water drains. In addition, 44.2% of households in the catchment area have no access to any form of toilet facility and therefore resort to the use of the lagoon fringes, seashores and bushes as places of convenience (Ghana Statistical Services, 2002).

Rapid urban growth through the activities of real estate developers and the expansion of settlements through housing projects in the Tema Metropolitan Assembly (TMA) as well as agricultural activities in the watershed of the wetland are equally of much concern. The Sakumo lagoon is the final recipient of all the domestic, municipal, agricultural and industrial waste from the Sakumo catchment which is transported by the streams and drains into the lagoon. These discharges carry large influxes of nutrients, suspended and dissolved organic matter, contaminants and other toxic materials into the wetland thereby affecting flora and fauna in and around the lagoon. These developments have resulted in reduced water quality and self-purification properties of wetlands as seen in the disappearance of key fish species from the wetland (Asmah *el al.,* 2008). Additional pressures in the urbanized coastal area which includes loss of natural habitat through physical alterations to the system, discharge of potentially toxic materials into the wetland can change both aquatic species diversity and ecosystems due to their toxicity and accumulative behavior (Heath, 1987; Allen, 1995).

The present situation where 25% of the population in Ghana lives in the coastal areas (EPA/ World Bank, 1997) has brought about an increase in the amount of domestic waste discharged (untreated) into the coastal environment through concurrent faecal and nutrient pollution of the coastal environment especially in high-pollution areas such as Accra, Tema and Takoradi (Afoakwa *et al.*, 1998).

With the rate of urban expansion and its toll on wetlands, Ghana may completely lose some of its wetland if the public is not continuously made aware of the dangers such as ecological, social and the economic imbalances resulting into flooding, poverty and livelihood vulnerability incidences associated with turning wetlands into residential areas. Even though there have been a lot of research and writings on lagoon conservation, addressing the problem of effluents discharge on lagoon resources are not adequate. It is therefore necessary to determine the current pollution status of the Sakumo ll lagoon ecosystem and identify socio-economic factors affecting the long-term sustainability and conservation of the lagoon.

1.3 Justification of the study

Pollution phenomenon is a continuous process and affects the environment if care is not taken to address them. The Sakumo ll lagoon, as a coastal lagoon, is a habitat for migratory and resident birds and for that matter must be protected. Ghana is a signatory to two international conventions which seek to protect wetland habitats and migratory animals. These conventions seek to protect waterfowl habitat (Ramsar Convention) and migratory species of wild animals (Bonn Convention). Under the Ramsar Convention, Ghana is obliged to designate "suitable wetlands" within her territory for inclusion in the list of wetlands of international importance (Ramsar sites) to protect such listed wetlands and to ensure their wise use. The Bonn Convention obliges Ghana to protect migratory species and specifically, to provide strict protection for species in danger of extinction (Ntiamoah, *et al*., 1991). Sakumo ll lagoon is designated as Ramsar site and has to be protected from degradation such as pollution in order to sustain the resources that it provides to the society and the nation as a whole.

There is an acute lack of information and empirical data on the extent of pollution of the Sakumo II lagoon based on which policies aimed at reducing pollution could be formulated. This study is a response to this gap and would be of immense importance to regulatory bodies such as the EPA and CSIR.

1.4 General objective

The general objective of this study was to assess the effects of effluents discharged on Sakumo II lagoon.

1.4.1 Specific objectives;

The specific objectives are to:

1. Determine the effects of effluent discharge on the water quality of Sakumo II lagoon.
2. Assess the possible effect of industrial effluents discharge on Sakumo lI lagoon
3. Determine seasonal variation of pollution on Sakumo II lagoon.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 WETLAND RESOURCES

"Wetland" is a collective term applied to a broad range of inland, coastal and marine habitat*s* which share a number of common characteristics. The International Ramsar Convention defines wetland as *"areas of marsh, fern, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh brackish or salty, including areas of marine water, the depth of which at low tide does not exceeds six meters (6m)"*. Wetlands exist at the interface between terrestrial and aquatic environments. They constitute an important fish habitat and supports large populations of fish. Many local communities depend on fish sources from wetlands for their livelihood. They also serve as sources, sinks and transformers of materials. They generally act as sinks for sediments and wetlands that are connected to adjacent aquatic ecosystems (e.g. rivers) may trap more sediment as compared to wetlands that lack such connectivity). Mainly human pressures engineered by over-exploitation, drainage, conversion, pollution and other conflicting land- use practices threaten many wetlands, (Fryirs *et al*., 2007; Mitsch and Gosselink, 2000; Dune and Leopold, 1978).

The combination of timing of inputs of sediments and nutrients relative to peak biological activity has great implications for filtering ability. To be effective filters, wetlands need to be spatially distributed and linked to the hydrological processes occurring in the catchment (Mitsch and Gosselink, 2000). Mitsch and Gosselink (2000) suggested that 3-

7% of the catchment should be wetlands to provide flood control and water quality benefits for the catchment in temperate-zones.

In Africa, wetlands cover just about 1% of the total surface area (about 345,000 km^2). Some important wetlands include; the Zaire swamps, the Sudd in the upper Nile (Egypt and Sudan), those of the Lake Victoria basin, the floodplains of the Rivers Niger and Zambezi, the Chad basin and the Okavango Delta (Botswana), (Mitsch and Gosselink, 2000).

Wetland ecosystems in Ghana constitute about 10% of the country's total land surface. Ghana's 550km coastline includes over 90 lagoons. According to Ramsar Convention, wetlands in the country fall into three main groups: marine/coastal wetlands, inland/freshwater wetlands and man-made wetlands. The Sakumo Ramsar site is the smallest of the five listed wetlands of International importance in Ghana situated in the light industrial area which is experiencing high population growth and rapid industrialization. The wetland is an important economic resource to the country and also acts as nature conservation site whose continued degradation may be jeopardized by anthropogenic pollution (William, 1990).

2.1.2 CLASSIFICATION OF WETLANDS

There are five major divisions or systems of wetlands. Each of them shares similar locational-geomorphological, hydrological and biological characteristics. The five divisions made up of *coastal and inland wetlands.* The former comprise of: ***a) marine b)***

estuarine wetlands whereas the latter is composed of ***c) riverine d) lacustrine*** and ***e) palustrine wetlands***.

Williams (1990) has given the following definitions for the various types of wetlands:

1. **Marine:** are coastal wetlands such as coastal lagoons, rocky shores and coral reefs.
2. **Estuarine:** for example deltas, tidal marshes and mangrove swamps.
3. **Riverine:** are wetlands along rivers and streams
4. **Lacustine:** examples marshes, swamps and bogs
5. **Human-made wetlands:** such as reservoirs, fish pond, flooded mineral workings, salt pans, sewage farms and canals (Levin, 2001).

In these classifications/definitions, the first four systems include wetland, land deep-water habitats but the palustrine includes only wetlands. It is the estuarine and palustrine system that account for the bulk of the world and the two give the most familiar and popularly known types of marshes and fens/swamps (William, 1990).

2.1.3 Wetland of Ghana

Based on the criteria of the Ramsar convention, three major types of wetlands are identified in Ghana (MLF, 1999). These are:

(1) Marine /coastal

(2) Inland

(3) Man-made.

2.1.4 Marine/coastal wetlands

The wetlands within the coastal zones of Ghana namely salt water ecosystem which are primarily associated with flood plains of estuarine large rivers and water courses. The major coastal wetlands or salt water ecosystems are;

(1) Rocky Marine shores, example are Senya Bereku and Cape Three Points beaches.

(2) Estuarine waters, which can be found at Volta, Pra, Butre and Ankobra Rivers.

(3) Mangrove/Tidal forest, situated at lower reaches of Volta, Oyibi, Kakum and Ankobra.

(4) Brackish/saline lagoons which could be open or closed. Examples are:

Open: Sakumo, and Amisa lagoons.

Closed: Songor and Muni lagoons (MLF, 1999).

Inland wetlands are mainly fresh water ecosystems. They occur whenever ground water, surface springs, streams or runoffs caused by saturated, frequent flooding or create temporary and or permanently shallow water bodies. The following are the examples of inland wetland in Ghana:

1. Perennial rivers/streams caused by Densu, Afram, Oti and Ankobra rivers.

2. Permanent freshwater lakes as found at Bosumtwi.

3. Freshwater swamp forest as observed at Amansuri.

4. Freshwater marshes as seen at black, red and white Volta flood plains. Inland or fresh water wetlands are wide-spread and important worldwide. It is the most extensive natural drainage system in Ghana (MLF, 1999).

2.1.6 Man-made wetlands

The Ramsar convention also recognizes wetlands as man-made or artificial wetlands. These are wetlands constructed for: aquaculture agriculture, salt exploitation, water-storage and urban/industrial purposes.

Examples of man-made wetlands in Ghana include the following:

1. Irrigated lands of Tano, Vea, Dawhenya and Anum valley

2. Salt pans of Elmina, Songor and Densu Delta

3. Water reservoir of Volta lakes, Kpong head pond and the Brimsu reservoirs

4. Urban/industrial wetland of Tema sewerage treatment plant.

5. Seasonally flooded arable land as of Sandema-Funbisi Rice Fields. Besides these, several other small man-made wetlands are found as mining pools (MLF, 1999).

Wetland Values

The values of wetlands are seen in the role wetlands play in natural ecosystem functioning. Wetlands are especially important because of their biological productivity and their production of oxygen. Wetlands are second only to rain forest as source of atmospheric oxygen. Globally, they provide habitat for more than 150 species of birds and 200 types of fish. The important roles of the Sakumo II wetland are divided into four broad categories of functions namely physical/hydrological, chemical, biological and socio-economic (MLF, 1999).

2.1.1 Physical /hydrological functions

i. Flood migration: floods areas, wetland temporarily localities such as Sakumo Township and Community 3 in Tema.

ii. Coastal protection: coastal marshes absorb wave energy and reduce erosion on estuarine shorelines, and so buffer the land from storms (MLF, 1999).

2.1.2 Chemical Functions

i. Pollution trapping

Some amount of phosphorus is taken up by plants and also reduced by being absorbed and setting in anaerobic sediments. Similarly nitrogen is removed by plant but more particularly by bacterial metabolism at the water-sediment interface which promotes nutrient denitrification (William, 1990).

ii. Removal of toxic residues

Toxic residues from products such as heavy metals, pesticides and herbicides, can be removed from the water by ion exchange and absorption in the organic and clay sediments (in effect they become buried in the sediments) and taken up by plants particularly the bull rush (*Schoenopletus lacustrus*), the common reed (*Phragmites australis*) and the water hyacinth (*Eichhornia crassipes*), which is an aggressive colonizer of warm still waters. The effectiveness and efficiency of these processes vary between 20 and 100% depending on the pollutant and the type of wetland, and can be enhanced by deliberate planting of absorptive vegetation (William, 1990).

iii. Waste Processing

A third and very practical chemical function of the wetland may be its ability to process human and animal waste material in an extremely efficient way. Its ability to do this may revolve around three factors.

a) It is very high in primary productivity, which means that its prolific growth takes from the water and substrates.

b) The absorption of pollutants by the high rate of sediments deposition and

c) The bacterial action in the sediments (William, 1990).

2.1.3 Biological Functions

i. Productivity: The Sakumo wetland is a spawning nursery ground and feeding site for marine species.

ii. Habitats: The wetlands provide habitat for a high concentration of birds, mammals, fishes and invertebrate species (MLF, 1999).

2.1.4 Socio-Economic Benefits and Values

Fish, fowl and faun fish and valuable mammals live in the wetland (William, 1995).

None consumptive benefits of the wetland include scenic, recreational, aesthetic, archaeological, scientific, heritage historical benefits (Williams, 1990).

2.1.5 Products of Sakumo wetlands

The products refer to those components that have been subjected to human exploitation, and therefore of socio-economic importance to the society. These include, plant products, fish, forage, water supplies, agricultural resources and recreation tourism. In the case of forage, the wetland grassland provides critical areas for livestock grazing, especially during the dry season. According to Agyepong (1999), five different plant communities have been identified within the Sakumo wetland. This is typha-cyperus association, (*Paspalum spp, Sesuvium spp, Sesuvium paspalum*). Association and mangroves with the plants communities is dominant. Koranteng (1995) has also stated that, the lagoon has fin-fish species belonging to 13 genera and 8 families with tilapias *Sarotherodon, and Melanothero* contributing about 97% of the total fish. In the same vein, there were 66 species of seashore birds recorded at the wetland (Ntiamoa-Baidu and Gordon, 1991).

2.1.6 Biological Diversity

The wetland supports wide variety of plants and animals. This attribute is of value in itself as it contributes immensely to the maintenance of its ecological processes for the benefit of the present and future generation (MLF, 1999).

2.1.7 Culture/heritage value

The Sakumo wetland is regarded as the abode of “gods”. It is therefore reserved and protected through various traditional practices (MLF, 1999).

2.2. Threats to wetlands

Anthropogenic inputs of nutrients and toxins drastically alter the chemical environment of wetlands and render many sites unsuitable for wetland plant and animals. Discharge of industrial and domestic sewage as well as agricultural run-off into wetlands increasing the organic loading of the wetland waters, and constitutes a threat of pollution. This increases the biochemical oxygen demands (BOD) of the water body, and leads to inadequate oxygen supply to support plant and animal life. If this situation persists, it destroys the wetland as a habitat. Extinction or loss of biodiversity of plant and animals is a grave concern to the world at large. It is for this reason that, the international law for conservation of Biological diversity (Biodiversity) was well developed in 1995 which is referred to as the '1992 Biodiversity convention' Sands, (1995). Another serious threat that needs to be mentioned is over fishing. The continuous catching of fish from the

Sakumo ll lagoon poses a threat to the Ramsar site, this leads to reduction in the average size of tilapias (*Sarotherodon melanotheron),*Koranteng, (1995).

2.2.1 Water Pollution

Pollution of aquatic environment means the introduction by man, directly or indirectly, of substances or energy which result in such deleterious effect that are harmful to living resources. It is hazardous to human health, hindrance to aquatic activities including fishing and leads to the impairment of water quality with respect to its use in agricultural, industrial and often economic activities, and reduction of amenities (UNESCO/WHO/UNEP, 1992).

Although natural phenomena such as volcanoes, storm earthquakes etc. also cause major change in water quality and the ecological status of water, these are not deemed to be pollution. Water pollution causes increases in nutrient loading which may lead to eutrophication. Organic wastes such as sewage organic farm waste impose high oxygen demands in the receiving water leading to oxygen depletion with potentially severe impacts on the whole ecosystem. Industries discharge a variety of pollutants in their waste water including heavy metals, organic toxins, oils nutrients and solids (http://en.wikipedia.org/wiki/water pollution).

2.2.2 Pollution of coastal environment of Ghana

The coastal and marine environment of Ghana is polluted with faecal material, leading to microbiological pollution of the coastal waters. This is becoming a serious environmental degradation problem of the coastal ecosystem (Wellens–Mensah *et al.*, 2002).

One of the most serious indirect impacts of coastal developments is that of a decline in water quality. Polluted effluents are often the most common source of adverse effects on coastal and marine ecosystem (Clark, 1992).

2.2.3 Source of coastal water pollution

Pollution of water may result from point source or diffuse source (non -point sources). Sources identified are all dry weather pollutants that enter water courses through pipes or channels whereas the latter comes from farm runoff, construction site and other land disturbances. Point source pollution comes mainly from industrial facilities and municipal wastewater treatment plant. The point sources or diffuse sources could be classified as physical, chemical, and biological pollution depending on the nature and source of pollutants (Peirce *et al.*, 1998).

The physical pollution takes place when solid debris is put into streams, smothering life on the streams bed, or when relatively hot water from factories and power station is discharged into a river. The rise in temperature of river water lowers the available dissolved oxygen which supports life that is critical for the self-purification processes taking place in the stream (Arnold, 1992).

Biological pollution arises when living things for example disease causing organism of faecal origin are added to water, In sewage effluent discharge, biodegradable organic chemicals may also upset natural balance of organisms in a stream and promote excess growth lowering oxygen content to critical levels.

Chemical pollution on the other hand is addition of chemical contaminants to water. The major cause is discharge of wastewater from urban areas. Other important sources are spillages of oil and industrial chemicals, disposal of sludge to the sea, solid waste on landfill sites, and the uses of fertilizers and pesticides in agriculture (Arnold, 1992). On the other hand, sources of water pollution can also be classified, based on the origin of the pollutants. For convenience, these sources of contamination of natural waters are classified here as natural, agricultural, mining, municipal and industrial (Arnold, 1992).

2.2.4 Natural pollution

This type of pollution is either accidental or occasional, area contaminants, like gases and dust, get transferred to a body of water in the form of rainfall, soil silt, deposition of chemical through weathering of soil and rocks (Pandey, 1997).

2.2.5 Agricultural pollution

The use of fertilizers, insecticides and herbicides in agricultural practices, poses serious pollution problems as most of these chemicals are resistant to natural degradation. The use of insecticides in the cotton farms of northern Alabama resulted in fish kill (Pandey, 1997). The agricultural activities in the catchment areas of Sakumo Ramsar site possess threat to the aquatic ecosystems.

2.2.6 Mining pollution

Uncontrolled mining operations sometimes produce soluble toxic materials that pollute streams. Mining pollution is however not applicable to the Sakumo II lagoon, since mining activities are non existence in the catchment areas (Pandey, 1997).

2.2.7 Municipal Pollution

Municipal waste, mainly domestic sewage includes the discharges from the toilets, bathrooms, kitchens and similar areas in dwellings, institutions, commercial and industrial buildings. Its principal pollution characteristics are pathogenic bacteria, suspended solids and oxygen consuming organic matter (Pandey, 1997). Sakumo ll lagoon may be polluted from materials due to increasing human population and inadequacy of sanitation facilities in the area (Edor, 2008).

2.2.8 Industrial pollution

Water is an essential raw material in almost all manufacturing plants, though only a small part of it may appear in the final product. The remainder becomes a waste material contaminant. Industries which are considered the principal sources of pollution may be classified as apparel, food and drugs, chemicals, materials and energy. The Sakumo Ramsar site has light industries in the catchment. Most of these are food processing and chemicals base, garment and drug manufacturers. The release of hot water from industries into streams may also constitute thermal pollution (Pandey, 1997).

2.3. Effect of water pollution

The effect of water pollution originates from primary and secondary pollution. The primary pollution is the entering into water or aquatic environment of solid waste, municipal sewage, runoffs from farms, etc. The secondary pollution on the other hand is the impacts that the pollutants may have on the aquatic ecosystem for example eutrophication (Oslo and Burgees, 1967). Some of these secondary impacts are: Silt bearing runoff from farms can inhabit the penetration of sunlight through the water column, hampering photosynthesis in aquatic plants.

Thermal pollution can include fish kill and invasion by new thermophyllic species (http:en.wikipedia.org/wiki/water pollution).

2.3.1 Effect on Aquatic and forms of life

Pollution of natural water may be disastrous to fish and other organisms naturally inhabiting the stream. This may suffocate the fish and other aquatic animals which require the presence of an appreciable concentration of dissolved oxygen. Within mild pollution, fish acquire a flavour that renders their flesh unfit for uses as food; whereas with more severe contamination; the fish sickens or die (Pandey, 1997).

2.3.2. Damage to property

Discharge of acid and occasionally of other industrial waste leads to damage of property through corrosive attack. Corrosion of object such as ships, damage to concrete structures in the stream and corrosion of piping, pumps, valves and other equipment in the plants, that use contaminated water as a cooling agent are examples of recorded damages to properties that result from pollution (Pandey, 1997).

2.3.3. Economics Loss

Economic losses are recorded when polluted streams which are used as the only source of municipal or industrial water require substantial treatment at considerable cost for the removal of suspended solids, taste, odour, colour, hardness and specific chemical present (Pandy, 1997). For example the Densu Delta, which is a source of potable water for the surrounding communities, is polluted. The Weija Dam which is constructed on the Densu River has its water to be intensively treated for domestic use by those in the Eastern corridor and parts of Accra. The treatment brings financial cost to the Ghana Water Company Limited which is the sole supplier and distributor of quality water in Ghana.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of study area

The Sakumo ll lagoon lies due east of Accra between Teshie-Nungua and Tema Township Ghana (Figure 1). The lagoon, covering about 35km² is the smallest coastal Ramsar site in Ghana and lies between latitude 5°35' N to 6°40' and longitude 0°00W with an altitude of 86.9m (286ft) and an average elevation of 45.7 m. The coastal lagoon is situated 3km west of Tema. The site has a total area of 1,364.35 hectares and located within 5°36'N and 5°38'N and longitudes 1°30'W and 0°30'W. The lagoon is separated from the sea by a narrow sand dune on which the Accra-Tema coastal area is connected to the sea by an old sluice.

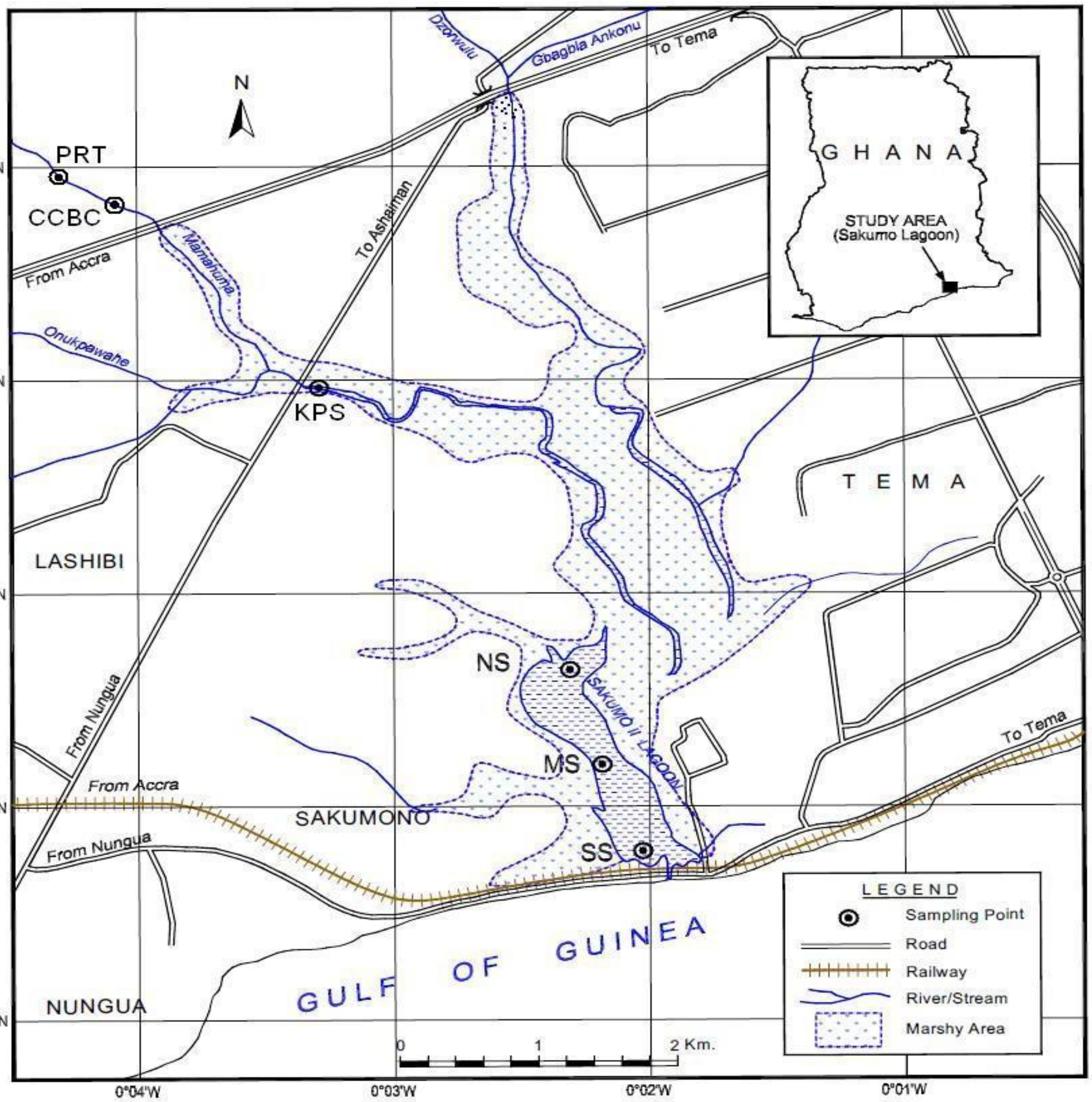

Figure 1: Map showing Sakumo II Lagoon and sampling points

3.1.1. Climate

The Sakumo Ramsar site lies in a semi-arid coastal savanna zone with mean annual rainfall of about 800mm occurring in two rainy seasons. The mean annual rainfall for the period 1954 to 1991 within the area was 734mm. Mean atmospheric temperature for the period 1958 to 1002 was 26.7°C (Tumbulto and Bannerman,1995) as cited by

(Agyepong, 1999).

3.1.2. Hydrology

The catchment area of the Sakumo wetland is drained by a number of streams, which flow into the brackish waters of the Sakumo lagoon. A number of freshwater marshes are present along most of the river course within the wetland area. Four principal sub drainage basins have been identified in the area. The major ones are the Mamahum-Onukpahe (at the western side) and the Dzorwulu-Gbagbla-Ankonu (situated at the northern end) sub- basins. The Eastern and Southern sub-basins constitute the major ones. The catchment area has limited groundwater potentials because of low rainfall and the intermeadiability of the rocks (Agyepong, 1999).

3.1.3. Soil

Seven soils series have been delineated within the catchment area (Amatekpor, 1998 as cited by Agyepong, 1999). These are Oyarifa Mamfe complex (603 ha); Nyigbenya-Hatso complex (6047ha); Nyigbenya consociation (1402 ha); Simpa-Agawtaw complex (16788 ha) and Kuse-Ashaiman complex (1334ha). The others are Oyibi - Muni Complex (1,459ha) and Keta consociation (less than 0.5%). Five of the soil series are Simpa, Agawtaw, Akuse, Oyibi and Muni which are responsible for the supply of the greater part of the site to the lagoon (Agyepong, 1999).

3.1.4. Land use in the Wetland Area

The major land use activities comprise arable agriculture, animal grazing, fishing, fuel wood gathering, settlement and industrial development. An evaluation of the pattern of land use in the area was carried out in the 1974 and 1986 using aerial photography and topographical mapping (Amatekpor, 1998).Settlement and infrastructure development in the wetland area is made up of construction works including residential, commercial, and industrial and road construction. Significant developments have occurred in the road construction and residential buildings in the Sakumo/Lashibi and Regimanuel residential estates, and the wetland extension of Tema community 3 (Amatekpor, 1998). Other notable developments are the constructions of communities 18, 19 and 20 to the north. Additional developments such as the Celebrity Gulf course, a recreational land use which maintains continuous grass cover represents a compatible usage within the wetland ecosystem (Amatekpor, 1998).

Industrial and manufacturing developments comprise mainly food processing, metal products, textile, chemicals, oil refinery and garment industries extending to the Motorway and East industrial area which covers the KGM industries, Johnson Wax all at the Spintex area which threatens the survival of the wetland through pollution (Dadson, 1995).

Total agricultural land which comprises cultivated and fallow areas in the wetland area were estimated at 13,562.3ha, which account for 49.1% of the area (Amatekpor, 1998). This has decreased significantly as built up developments comprising residential, industrial and other constructional activities are on the increase. Arable agriculture include the cultivation of rice, cassava and vegetables occur on the northern outskirts of the lagoon, along the banks of the Dzorwulu, Gbagla-Akanu and Mamahuma streams which flow into the lagoon (Amatekpor, 1998). The farmers employ pesticides, fertilizers and other agro-chemicals in the cultivation process in order to increase the yield of their farm produce (Dadson, 1995). Pesticide residues, nitrate from fertilizers and microorganisms (Faecal Coli forms) from animal waste are sometimes found in the water bodies located near the farms (Williams and Langely, 2001).

The semi-nomadic grazing of cattle competes with arable agriculture in the available vacant areas. The urban expansion has decreased the pasture available for cattle, the waste generated from the cattle may pose a threat of pollution to the wetland.

Intensive marine and lagoon fishing is the main occupation of the people of Sakumono and the surrounding coastal communities. The catch comprises tilapias, *Sarotherodon melanothero*, the horse mackerel *Caranax hippopo*, the blue legged lagoon swimming crab *Calliectes latimaus* and other species (Amatekpor, 1998). Continuous fishing in the lagoon may lead to over exploitation of popular species and this could result in extinction of certain fish species.

3.1.5 Vegetation

The vegetation of the area is typical of the coastal zone of Ghana. Four habitat types exist in the Sakumo catchment; open lagoon, surrounding flood plains, freshwater marsh, and coastal savanna grassland. The main vegetation found in the freshwater marsh includes the succulent forbs, *Sessuvium portulacastrum* (90%) and the grasses: *Imperata cylindrica* and *Paspalum vaginatum*. *Avicennia africana* forms the main plant of the mangrove community associated with the surrounding flood plains, while *Paspalum vaginatum, Sesuviumpor tulacastrum* and *Philoxeru svermicularis* are associated with the coastal savannah grassland. The reed *Typhaaustralis* is associated mainly with the estuarine brackish-freshwater marsh (Atupra, 1993).

3.1.6 Description of sampling points

1. Section SS- is the southern part **(South-Sakumo)** of the lagoon and connects the lagoon to the sea via two culverts.

2. Section MS- is the middle part **(Mid-Sakumo)** of the lagoon and is densely populated and has a number of vegetable farms which depends on the lagoon as a source of irrigation. High fishing activity is concentrated in the middle parts of the lagoon.

3. Section NS- is the northern part **(North-Sakumo)** of the lagoon and receives effluents from industries, runoff from agricultural farms, storm water and domestic effluents through the streams.

4. Coca-cola Bottling Company(CCBC)- is a producer of soft drinks and other non-alcoholic beverages. The factory generates both liquid and solid wastes from its processes. Liquid waste from the factory includes spilled products, caustic soda and liquid soap for washing and cleaning, oil and grease from machine parts. Samples for this analysis were collected from the outlets of the factory before the effluents flow into the Onukpawahe stream and then into the Sakumo ll lagoon.

5. Kasapreko(KSP)- is a producer of alcoholic beverages and generates wastewater in the process. Sampleswere taken immediately from the outlets of the company before it flows into the onukpawahe stream and then into the Sakumo ll lagoon.

6. Printex company limited(PRT)- is a textile and garment industry. The main wastes generated from the factory's processes is dye-laden wastewater. Samples for analysis were collected from the outlet of the company before discharge into the onukpawahe stream which receives the effluents then into the Sakumo ll lagoon.

All the sites were selected based on accessibility using the map (Figure 1).

3.2 Field Work for Water Quality

3.2.1 Sample Collection and Analysis

Direct sampling method was used to collect water samples from three sampling points: upper, middle and downstream sections of the lagoon: Water samples were taken twice a month, three months (May, June and July) within the wet season and three months (January, February and March) within the dry season.

3.2.2 Water quality analysis

The following laboratory analysis was carried out on the water samples for selected physical and chemical parameters of the samples (table 3.1).

Table 1: Methods for the Determination of some Water Quality Parameters.

Water Quality Parameters	Methods and Instrument for Determination
pH	pH–Meter
Temperature	Thermometer
Turbidity	Turbidimeter
Conductivity	Conductivity meter
Total dissolved solids	Conductivity meter
Total suspended solids	Spectrophotometer
Biological oxygen dissolved	5day incubation
Dissolved oxygen	Dissolve oxygen meter

Source : field data 2012

3.2.3 Water sampling

A 1.5- liter polyethylene bottle was filled with water at each sampling site. This was subsequently used in the laboratory for off site analysis.

3.2.4 Laboratory analysis

Laboratory analyses were carried out in the Ecological Laboratory located at the Department of Geography and Resource Development, University of Ghana, Legon. Parameters analyzed were nitrogen-nitrate, phosphorus-phosphate and nitrate-ammonia. All analysis was done in triplicates and mean values calculated for each parameter.

3.3. Measurement of Chemical parameters

3.3.1 Nitrogen- Nitrates

The nitrate level in each sample was measured using Nitrate Powder Pillows in a direct reading HACH spectrophotometer Model DR 2000. Twenty five (25) milliliters of the sample was measured into sample cell. One Nitraver, 5 Nitrate Reagent Powder Pillow was added to the sample and vigorously shaken for 1 minute. Nitrate was measured using the method proposed by (Asmah *et al.*, 2008).

3.3.2 Nitrogen- Ammonia

Ammonium-nitrogen was determined by direct nesslerisation and spectrophotometric determination at wave length of 425nm. Twenty-five (25) milliliters of the sample (the prepared sample) was measured using graduated mixing cylinder. Another graduated mixing cylinder was filled with the 25millilitres of dematerialized water (blank).Three drops of Mineral Stabilizer was added to each of the cylinders, this complexes hardness in the sample. The solutions were inverted several times to ensure thorough mixing. Three drops of Polyvinyl Alcohol Dispensing agent was added to each cylinder and inverted several times to mix and to aid the colour formation in the reaction of Nessler reagent with ammonia ions. 1.0 ml of Nessler Reagent was pipetted into each cylinder. Stopper and inverted several times to mix. A 1-minute reaction period was allowed during which each solution was poured into respective blank and prepared cells. The blank was placed into the cell holder to calibrate it then the prepared sample was placed into the cell holder to determine the Nitrogen ammonia level at 425nm. A yellow color is formed proportional to the ammonia concentration.

3.3.3 Phosphate – phosphorus

The sample cell was filled with 25ml of sample and one PhosVer 3 Phosphate Powder pillow reagent was added to the cell content (the prepared sample) and swirled immediately to mix. A two-minute reaction period was allowed. Another sample cell (the blank) was filled with 25ml of sample and placed into the cell holder to calibrate it. After the reaction period the prepared sample was placed into the cell holder and the level of phosphorus was determined at 890 nm.

3.4.0 Social questionnaire survey

Questionnaires were administered in some areas in the catchment in order to gather information on social issues of the Lagoon site. In all, hundred (100) questionnaires were administered at Lashibi, Klagon, Sakumono Village and Community 3 Tema based on accessibility. A sample of the questionnaire is attached (See appendix C).

Table 2: Selected Communities along the studied area of Sakumo ll Lagoon

Communities along the Lagoon	Number of Respondent
Sakumono Village	40
Lashibi	15
Klagon	25
Community 3	20
Total	100

(Source; Field data 2012)

3.4.1 Interviews

Interviews were also conducted by interacting with the Assembly man at the lagoon site including fishermen and livestock owners' car washing operators.

3.4.2 Data Analysis

The data were coded and entered directly into Statistical Package for Social Sciences (SPSS) Windows (version 16.0) and Microsoft excel used for data analysis. The results were presented in tables and bar charts.

3.4 .3 Ethical Consideration

Permission was sought from the Wild Life Division of the Forestry Commission and local chiefs in the study area. The consent of the respondents was sought verbally and they were assured of confidentiality.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

The results of physic-chemical analysis of the Lagoon water samples from Sakumo ll lagoon and effluents from three selected industries (CCBC, KPS and PRT) are presented in this section. The results were compared with the Environmental Protection Agency (EPA, 2002) guidelines values.

4.2. Physical and Chemical Parameters

The following physical and chemical parameters of the Lagoon water are presented in this section: temperature, pH, turbidity, total suspended solids (TSS), total dissolved solids (TDS), and conductivity and chemical parameters: dissolved oxygen (DO) and biological oxygen demand (BOD) and nutrients-nitrate, phosphate and ammonia. The summary statistics of (mean ±SE) values for the parameters are presented in (Table 3) below.

Table 3: Mean Concentrations of physical and chemical parameters of Sakumo ll Lagoon

	SAMPLING STATION OF SAKUMO II LAGOON			
PARAMETER	**BRIDGE**	**COMMUNITY 3**	**CELEBRITY**	**MEAN**
Physical parameters				
Temperature(°C)	28.92±0.24	29.77±0.32	28.75±0.59	29.2
pH	7.48±0.24	7.53±0.12	7.9±0.27	7.6
Turbidity(NTU)	17.02±3.69	27.60±6.66	24.7±3.71	23.12
TSS (mg/l)	21.33±2.89	102.83±47.14	75.5±30.18	66.55
TDS (mg/l)	6669.2±2531.1	779.25±63.96	3355.8±902	3601.42
Conductivity(µS/cm)	11672±5374.2	1391.2±157.65	6711.5±1803.1	6591.6
Chemical parameters				
DO (mg/l)	4.88±0.43	3.00±0.49	5.2±1.04	4.36
BOD (mg/l)	2.17±0.18	1.28±0.15	3.1±1.14	2.2
Nitrate-N(mg/l)	1.50±0.26	4.13±0.60	3.52±1.25	3.1
Phosphate-P (mg/l)	2.82±0.64	4.73±1.37	1.97±0.55	3.2
Ammonia-N (mg/l)	3.15±1.47	5.18±3.80	1.1±0.35	3.14

4.2.1 Temperature

The mean variations in water temperature of the sampling sites ranged between 28.8 °C and 29.77 °C for both wet season and dry seasons with a mean value of 29.2 °C. The highest monthly mean was 29.77±0.32 °C recorded at Mid-Sakumo and the lowest monthly mean recorded was 28.75±0.59 °C recorded at North-Sakumo (Table 3)

4.2.2 pH

pH values recorded during the entire study ranges from 6.1-8.7 with an average value of 7.6.The highest monthly mean pH value of 7.9±0.27 was recorded at Mid-Sakumo and the lowest monthly mean pH value of 7.48±0.24 was recorded at the South-Sakumo (Table 3).

4.2.3 Total Suspended Solids (TSS)

The suspended solid measured values ranged from 21.33 mg/l to 102.83 mg/l with an average mean value of 66.55 mg/l. The highest monthly mean was recorded at Mid-Sakumo with a value of 102.83±47.14 and the lowest monthly mean recorded was 21.33±2.89 at North-Sakumo. (Table 3)

4.2.4 Total Dissolved Solids (TDS)

The TDS distribution in the Lagoon ranged from 779.25 mg/l to 6669.2 mg/l with an average mean value of 3601.42 mg/l. The highest monthly mean recorded during the study was 6669.2±2531 mg/l at South-Sakumo whilst the lowest monthly mean TDS value of 779.25±3.96 mg/l was recorded at Mid-Sakumo (Table 3)

4.2.5 Dissolved Oxygen (DO)

The concentration of DO ranged from 3.0 to 5.2 mg/l with an average mean value of 4.36 mg/l The highest monthly mean was recorded at North-Sakumo with a value of 5.2±1.04 mg/l and the lowest DO value recorded was 3.00±0.49 mg/l at Mid-Sakumo (Table 3).

4.2.6 Biological oxygen demand (BOD)

BOD values varied between 1.28 and 3.1 mg/l with an average mean value of 2.2 mg/l. The highest monthly mean was recorded at North-Sakumo with a concentration value of 3.1±1.14 mg/l whilst the lowest monthly mean was recorded at Mid-Sakumo with the concentration value of 1.28±0.15 mg/l (Table 3).

4.2.7 Turbidity

Turbidity values for lagoon ranged from 17.02 to 27.60 NTU with an average mean value of 23.12 NTU. The highest mean value of 27.60±6.66 NTU was recorded in Mid-Sakumo the lowest value of 17.02±3.69 NTU was recorded at South-Sakumo (Table 3).

4.2.8 Conductivity

The values were between 1391.2 to 11, 6722 µS/cm with an average mean value of 6591.62 µS/cm. The highest mean conductivity value of 11672±5374.2 µS/cm was recorded at the South-Sakumo and the lowest mean value of 1391.2±157.65 µS/cm was recorded at Mid-Sakumo (Table 3).

4.2.9 Nitrate

Nitrate concentration ranged from 1.50 to 4.13 mg/l with a mean value of 3.1 mg/l. The highest monthly mean value of 4.13±0.60 mg/l was recorded at Mid-Sakumo and the lowest monthly mean value of 1.50±0.26 mg/l was recorded at Bridge (Table 3).

4.2.10 Phosphate

Phosphate concentrations of the lagoon were between 1.97 to 4.73 mg/l with an average mean of 3.2 mg/l. The highest monthly mean concentration during the study was recorded at Mid-Sakumo with a concentration of 4.73±1.37 mg/l whilst the lowest monthly mean concentration of 1.97±0.55 mg/l was recorded at North-Sakumo (Table 3).

4.2.11 Ammonia

The concentration of ammonia ranged from 1.1 to 5.18 mg/l with a mean value of 3.14 mg/l. The highest monthly mean of 5.18±3.80 mg/l was recorded at Mid-Sakumo whilst the lowest monthly value of 1.1±0.35 mg/l was recorded at Celebrity (Table 3).

4.3 Effluent Discharge

4.3.1 Physical and Chemical Parameters

The following physical and chemical parameters of effluents are presented in the table below: temperature, pH, turbidity, total suspended solids (TSS), total dissolved solids (TDS), and conductivity and chemical parameters: dissolved oxygen (DO) and biological oxygen demand (BOD) and nutrients-nitrate, phosphate and ammonia. The summary statistics of (mean ±SE) values for the parameters are presented in (Table 3) below.

Table 4: Mean concentration of physical and chemical parameters of industrial effluent from PRT, CCBC and KPS

	SAMPLING STATIONS OF INDUSTRIAL EFFLUENTS			
PARAMETER	**PRT**	**CCBC**	**KPS**	**MEAN**
Physical parameters				
Temperature(°C)	28.67±0.47	29.03±0.59	29.43±0.19	29.04
Ph	7.3±0.40	8.8±0.66	6.9±0.49	7.7
Turbidity(NTU)	439.67±28.71	57.0±4.93	18.9±2.18	171.9
TSS(mg/l)	123.00±56.52	138.3±14.84	75.0±2.52	112.1
TDS(mg/l)	288.33±22.02	625.0±77.0	200.33±55.89	371.22
Conductivity(µS/cm)	573.67±40.28	1247.7±153.6	402.0±111.80	741.1
Chemical parameters				
DO(mg/l)	5.5±0.85	2.8±1.14	1.93±0.44	3.41
BOD(mg/l)	2.6±0.42	1.2±0.22	1.0±0.38	1.6
Nitrate(mg/l)	2.53±0.63	8.5±4.2	6.47±0.72	5.83
Phosphorus(mg/l)	0.32±0.06	4.1±0.53	1.1±0.53	1.84
Ammonia(mg/l)	0.53±0.15	7.85±5.1	3.3±2.43	3.89

PRT-Printex, CCBC-Coca Cola Bottling Company, KPS-Kasapreko

4.3.2 Temperature

Effluent temperatures depended upon the process of production in the industry. The temperature values of various industrial effluents ranged from 28.67 to 29.43 °C with a mean value of 29.04 °C. The highest monthly mean of 29.43±0.19 °C was recorded at KPS and the lowest monthly mean recorded was 28.67±0.47 °C at PRT (Table 4).

4.3.3 pH

The pH value of various industrial effluents was between 6.9 and 8.8 with a mean value of 7.7 for the period of the study. The highest monthly mean pH value of 8.8±0.66 was recorded at CCBC station and the lowest monthly mean pH value of 6.9±0.49 was recorded at the KPS (Table 4).

4.3.4 Total Suspended Solids

TSS values varied from 75.0 to 123.00 mg/l with an average value of 112.1 mg/l. The highest monthly mean was recorded at CCBC with a value of 138.3±14.84 mg/l and the lowest monthly mean recorded value of 75.0±2.52 mg/l was at Celebrity (Table 4).

4.3.5 Total Dissolved Solids

The TDS values for the study ranged from 625.0 to 200.33 mg/l with a mean value of 371.22 mg/l. The highest monthly mean recorded during the study was 625.0±77.0 mg/l at the CCBC station whilst the lowest monthly mean TDS value of 200.33±55.89 mg/l was recorded at KPS station (Table 4)

4.3.6 Dissolved Oxygen

The DO levels measured during the study were generally low between 1.93 to 5.5 mg/l with a mean value of 3.41 mg/l. The highest monthly mean was recorded at PRT with a value of 5.5±0.85 mg/l and the lowest DO value recorded was 1.93±0.44 mg/l at KPS (Table 4).

4.3.7 Biological Oxygen Demand

The BOD values varied from 1.0 to 2.6 mg/l in the sampling points with a mean value of 1.6 mg/l. The highest monthly mean was recorded at PRT with a concentration value of 2.6±0.42 mg/l whilst the lowest monthly mean was recorded at KPS with the concentration value of 1.0±0.38 mg/l (Table 4).

4.3.8 Turbidity

Turbidity values for the study were between 18.9 to 439.67 NTU with an average value of 171.9 NTU. The highest mean value of 439.67±28.71 NTU was recorded in PRT whilst the lowest value of 18.9±2.18 NTU was recorded at KPS (Table 4).

4.3.9 Conductivity

Conductivity values increased steadily from 402.0 to 1247.7 µS/cm with an average of 741.1 µS/cm. The highest mean conductivity value of 1247.7±153.6 µS/cm was recorded at the CCBC and the lowest mean value of 402.0±111.80 µS/cm was recorded at KPS (Table 4).

4.3.10 Nitrate

The nitrate concentrations of the effluents were between 2.53 to 8.5 mg/l with an average value of 5.83 mg/l. The highest monthly mean value of 8.5±4.2 mg/l was recorded at CCBC and the lowest monthly mean value of 2.53±0.63 mg/l was recorded at PRT (Table 4).

4.3.11 Phosphate

The effluent values varied from 0.32 to 4.1 mg/l with an average of 1.84 mg/l. The highest monthly mean concentration during the study was recorded at CCBC with a concentration of 4.1±0.53 mg/l whilst the lowest monthly mean concentration of 1.1±0.53 mg/l was recorded at KPS (Table 4)

4.3.12 Ammonia

Ammonia concentration ranged from 0.53 to 7.85 mg/l with a mean value of 3.89 mg/l. The highest monthly mean of 7.85±5.1 mg/l recorded at CCBC whilst the lowest monthly value of 0.53±0.15 mg/l was recorded at PRT (Table 4).

4.4 SUMMARY OF MEAN RESULTS OF LAGOON WATER AND INDUSTRIAL EFFLUENTS COMPARED

Comparison of the mean physico-chemical parameters of the Lagoon water and industrial effluents is presented in (Table 5) below.

Table 5: Summary of means of Sakumo II Lagoon water and effluents

Parameters	Lagoon water	Effluent	Level of significance (p-value)
Physical parameters			
Temperature(°C)	29.2	29.04	>0.05
PH	7.6	7.7	<0.005
Turbidity(NTU)	23.12	171.9	<0.0013
TSS(mg/l)	66.55	112.1	>0.05
TDS(mg/l)	3601.42	371.22	>0.05
Conductivity(µS/cm)	6591.6	741.1	>0.05
Chemical parameters			
DO(mg/l)	4.36	3.41	>0.05
BOD(mg/l)	2.2	1.6	>0.05
Nitrate(mg/l)	3.1	5.83	>0.05
Phosphorus(mg/l)	3.2	1.84	>0.05
Ammonia(mg/l)	3.14	3.89	>0.05

4.4.1 Temperature

Comparing the mean temperature values of the entire study, the temperature of the effluent (29.04 °C) was slightly higher than that of the Lagoon water (29.2 °C), however there was no statistical significant difference between the values (Table 5).

4.4.2 pH

Comparing the mean pH values of the entire study, the pH of the effluent (7.7) was slightly higher than that of the Lagoon water (7.6), however the values varied significantly $p< 0.013$ (Table 5).

4.4.3 Total Suspended Solids

The TSS mean value of the effluent (112.1 mg/l) was higher than that of the Lagoon water (66.5 mg/l), but there was no statistical significant difference between the values (Table 5).

4.4.4 Total Dissolved Solids

Comparing the mean TDS values of the entire study, the Lagoon water (3601.42 mg/l) mean was higher than that of the effluent (371.22 mg/l), however they did not differ significantly (Table 5).

4.4.5 Dissolved Oxygen

The DO mean value of the Lagoon water (4.36 mg/l) was higher than that of the effluent (3.41 mg/l), but the mean values did not differ significantly (Table 5).

4.4.6. Biological Oxygen Demand

Comparing the mean BOD values of the study, the BOD of the Lagoon water (2.2 mg/l) was higher than that of the effluent (1.6 mg/l), but both were however not statistically varied (Table 5).

4.4.7 Turbidity

Turbidity mean value of the effluent (171.9 NTU) was higher than that of the Lagoon water (23.12 NTU), however the mean values were significantly different ($p<0.0013$) (Table 5).

4.4.8. Conductivity

Comparing the mean conductivity values of the study, the mean value of the Lagoon water (6591.6 µS/cm) was higher than that of the effluent (741.1 µS/cm), however mean values did not differ significantly (Table 5).

4.4.9 Nitrate

Nitrate mean values of the effluent (5.83 mg/l) was higher than that of the Lagoon water (3.1 mg/l), however the mean values did not differ significantly (Table 5).

4.4.10 Phosphate

Comparing the mean phosphate values of the study, the mean of the Lagoon water (3.2 mg/l) was higher than that of the effluent (1.84 mg/l), but values did not differ significantly (Table 5).

4.4.11. Ammonia

Ammonia mean value of the effluent (3.89 mg/l) was higher than that of the Lagoon water (3.14 mg/l), however there was no statistical significant difference between the mean values. (Table 5).

Table 4: Test of Significance Difference of Physico-Chemical Parameters Subjected to Anova

Physico-chemical Parameter	Mean Jan	Feb	Mar	Jun	July	August	lsd
pH	8.100^{a}	7.967^{a}	8.167^{a}	7.267^{b}	7.233^{b}	7.100^{b}	0.6177
Turbidity	33.400^{a}	30.200^{a}	31.700^{a}	21.000^{ab}	$15.300b^{c}$	7.000^{c}	14.950

Means in the same row that have different superscripts are significantly different at $\alpha = 5\%$ *(i.e.* $p < 0.05$*)*

Monthly differences in pH were not significant from January- March and from June to August. However pH was significantly higher ($p = 0.005$) in January, February and March compared with June, July and August. In the case of turbidity, differences were not significant from January- March and June. However turbidity was significantly higher ($p = 0.013$) in January, February, March and June compared with July and August. For the other physical and chemical parameters (temperature, DO, BOD, TDS, TSS, conductivity and nutrient concentrations such as ammonia, phosphate and phosphorus) differences were not significant ($p > 0.05$).For the seasonal analysis, mean turbidity and pH values for the rainy season (June, July and August) and dry season (January, February and March) were significantly different ($p < 0.001$)

4.5 Social Questionnaire Survey

4.5.1 Fishing

Fifty percent (50%) of the respondents fish in the Bridge area, whilst the rest of the respondents fish at Community 3 and Celebrity areas respectively. Interviews conducted among the fisher folks reveal that, there were reductions in fish sizes and quantities. This could be attributed to human activities like agriculture, poor waste disposal systems. This may be due to the continuous fishing and large number of the fishermen at work at the lagoon. The knowledge of the indigenous people in reference to conservation of resources in the lagoon by Ramsar convention (1987) is rather low with only 13% of the respondents having some knowledge about it. Eight-seven percent (87%) of respondents had little or no knowledge of any regulation/laws/taboos that are used to protect fish and other aquatic resources. According to them, fishing is not allowed in the lagoon on

Fridays and during close season. The closed season is usually February to April which will allow fishes to spawn and grow well.

4.5.2 Livestock rearing

Thirty-three (33%) of the respondents confirmed that they reared various livestock including cattle sheep, goat and chicken whilst the remaining 77% keep pig and pets such as dogs and cats. Most respondents graze the animal close to the lagoon.

4.5.3 Farming and land cover change

Acreages of farm lands cultivated by the respondent ranged from 1-2 acres (56%), 3-4 acres (22%) and 5 acres (11%) of farm lands. Only 41% of the respondents applied fertilizer to their crops. Out of this percentage, 35% used inorganic fertilizer whilst (6%) used organic fertilizer. Fifty nine (59%) use neither of the two. Arable crop farming was dominant among the farming activities. With respect to the use of pesticides, twenty-eight percent (28%) of the respondents use them to control pests.

4.5.4 Public health and sanitation

Nineteen percent (19%) of the respondents used KVIP, (8%) pit latrine, (15%) used water closet, (55%) engage in free range whilst the remaining (3%) dispose their liquid waste into channels (Table 4.5). Sixty-four (64%) of the respondents confirmed that they throw their refuse close to the lagoon. Malaria and cholera accounts for (44%) of the commonest diseases affecting the residents whilst the rest include tuberculosis and fever. Forty-seven (47%) of the respondents seek for treatment in clinic and hospitals. The remaining (53%) resort to traditional medicine and self-medication for treatment.

Sanitation in the communities along the lagoon was not the best. There were inadequate sanitation facilities such as KVIP, refuse collectors, sewage treatment plant (STPs). This has resulted in indiscriminate disposal of solid waste and municipal sewage into the environment. The absence of KVIP or public place of convenience at Lashibi and Klagon resulted in defecation in the surrounding bush by some residents in the communities.

The prevalent disease noticed in the communities during the period of study was typhoid fever, malaria and cholera. According to the respondents, community members report to Tema General Hospital, Ashaiman Health Centre and other private hospitals such as "Raphal and Narh Bita" for treatment.

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Physical and chemical parameters

5.1.1 Temperature

The mean temperature value (29.04 °C) in all the effluents of the three industries was relatively above the permissible limits of EPA (29 °C). The high mean value may be due to the usage of water for steam production and cooling processes which causes thermal pollution (Roven *et al*., 1998).Mean value for the lagoon water was higher (29.2 °C) than the mean value (25.50 °C) recorded by Biney (1990) at the same study area. This can be due to varying weather conditions around the time the data was taken. However this mean temperature compares favourably with the EPA permissible guideline value of 29 °C for effluent discharge into water bodies and is within permissible limits for tropical shallow waters.

5.1.2 pH

Comparing with EPA guideline values, the pH value in the effluents of KPS and PRT were within the permissible limit and may not adversely affect aquatic life. These results are in line with the findings of Edor (2008). The high pH value (8.8) of CCBC industries may be due to the excessive use of carbonated water in the production of soft drinks.

Mean pH value for Lagoon water (7.6) was found within the permissible limits compared with the EPA guideline value (6-9). Hamill and Bell (1986) reported that the pH of most natural waters ranges from 6.0 to 8.5. So the pH values recorded during the study will provide conducive environment for the life of coastal water fishes and bottom dwelling organisms.

5.1.3 Total Suspended Solids (TSS)

The high mean value (112.1 mg/l)) of TSS in all three industries could be due to the water used in the crushing processes that carries away the solid particles. Results suggest that these effluents may cause problems, if directly applied to agricultural field or if discharged into the lagoon. This may not be suitable for aquatic life (Cunningham and Saigo, 1997) as particles prevent sunlight from reaching plants for photosynthesis that may result in oxygen depletion in the lagoon (UNESCO, 2006). High TSS in the lagoon may also results in loss of fish biodiversity (Armah and Amlalo, 1998). Mean value of the lagoon water (66.55 mg/l) was beyond the permissible limits compared with the EPA guideline value (75 mg/l). The presence of TSS in the lagoon water, even in a small amount does indicate the impact of industrial effluents in the close proximity.

5.1.4 Total Dissolved Solids (TDS)

Comparing with the EPA guideline values, it was observed that the TDS mean values (371.22 mg/l) in effluents of all the industries was beyond the permissible limits. The effluents with high TDS value may cause salinity problem if discharged into irrigation water. Comparing with EPA guideline values, all samples of lagoon water were also beyond the permissible limit set for discharge into water bodies. The high TDS levels of lagoon water may be ascribed to geomorphologic processes (Batalla and Garcia, 2005) in the Sakumo lagoon during the dry season as a result of changes in weather conditions. High TDS levels may also affect the water balance in cells of aquatic organisms disrupting the survival of such organisms (Spellman and Drinam, 2000). This would prevent sunlight from reaching aquatic plants for photosynthesis by dissolved particles, (UNESCO, 2006).

5.1.5 Dissolved Oxygen (DO)

Mean DO values of the industrial effluents (3.41 mg/l) and the lagoon water (4.36 mg/l) were generally low and comparing with EPA guideline values, they were within the permissible limit and may not adversely affect aquatic life. Low DO levels of effluents can be ascribed to the effluents discharge from food and beverage industries rich in organic compounds (UNEP, 1997).

The low levels of DO in the lagoon may be attributed to the discharge of raw municipal sewage into the stream that drained the Sakumo lagoon (Amatekpor, 1998) coupled with industrial effluents (Biney, 1984). This might be responsible for organic pollution in the lagoon during the dry season, a situation that may be deleterious to aquatic life. Also low DO levels can be associated to pollutant from non-point sources (Hirji *et al.,* 2002) such as agriculture run-off and decomposed vegetation during the rainy season.

5.1.6 Biological oxygen demand (BOD)

It was observed that BOD mean value (1.6 mg/l) of all the industrial effluents and the lagoon water (2.2 mg/l) were within the EPA permissible guideline values. The low values recorded may be due to the discharge of organic waste into the water by residents. Biney (1984) established that waters with BOD less than 3 mg/l are unpolluted and those with BOD values greater than 12 mg/l are polluted. He further added that waters with BOD values between 3 mg/l and 12 mg/l are of poor quality. Using this criterion the

Sakumo Lagoon can be said to be of a poor quality considering the highest mean value of 3.9 mg/l. The mean value of BOD in the lagoon water samples suggested that the industrial effluents might have contributed some organic carbon to the, lagoon which pose potential threat to the lagoon's future.

5.1.7 Turbidity

Generally, mean turbidity values recorded for effluents were within EPA permissible guideline values except PRT value of (439.7 NTU) which is very high. The high value may be due to dyeing materials used in printing because it contains chemicals like caustic soda and hydrogen sulphide. Similarly mean turbidity value (23.12 NTU) of the water quality of the lagoon was within the permissible limits for discharge into water bodies and may not affect aquatic organisms.

5.1.8 Conductivity

The mean conductivity values were within the safe limits except that in the effluents of CCBC which is (1247.7 µS/cm). However the mean conductivity value (6591.6 µS/cm) for all lagoon water samples were found to be beyond the permissible limits compared with the EPA guideline value (1500 µS/cm) established for discharge into water bodies. The natural background level of 0.3µS/cm, may threaten the survival of aquatic organisms, because is an indication of aquatic ecosystem pollution, which may be attributed to high total dissolved solids in the water column of the lagoon (Biney, 1986b).

5.1.9 Nitrate

Comparing with the EPA guideline value (1.0 mg/l), it was observed that mean nitrate values (5.83 mg/l) in effluents of all the three industries and the mean value (3.1 mg/l) of the lagoon water were all above the permissible limits. All the values were higher than the natural background level of 0.25 mg/l reported by (Burton and Liss, 1976).High effluent values may be due to industrial processes such as cooling and effluents rich in nitrate. High nitrate in lagoon water can be due to intensive use of fertilizers and pesticides on vegetables crops such as cabbage, lettuce and okro (Wetzel and Gopal, 1999). Comparing with previous studies the current mean of 3.1 mg/l is higher than the concentration of 0.134 mg/l, 1.44 mg/l and 1.713 mg/l (Koranteng, 1995; Yawson, 2003 and Edor, 2008).Comparatively the high nitrate concentration suggests organic pollution.

5.1.10 Phosphate

Phosphate in effluents was within the safe limits except that in the effluents of CCBC (4.1 mg/l), which was very high. High levels may be due to use of phosphate containing substances for manufacture of soft drinks. Comparatively phosphate mean value (3.2 mg/l) in the lagoon water was double the permissible limit (1.5 mg/l) of EPA. This can be attributed to use of fertilizers and pesticides containing phosphate. Comparing with previous studies of 0.644 mg/l (Koranteng, 1995), 0.00 mg/l (Yawson, 2003) and 3.618 mg/l (Edor, 2008), the current mean value of 3.2 mg/l of the Sakumo lagoon make it highly polluted with phosphate.

5.1.11 Ammonia

The ammonia values in effluents were within safe limits except that in the effluents of CCBC (7.85 mg/l) and KPS (3.3 mg/l). Mean value (3.14 mg/l) for the lagoon water was also higher than the EPA permissible limit (2 mg/l) for discharge into water bodies. This can be due to land activities such as sewage effluent, agriculture run-off as well as the sewage outfall. High ammonia is toxic to invertebrates and fish. This has been shown in both fresh and marine environments (Seager *et al*., 1988; Nison *et al*., 1995). Comparing with previous works the current mean of 3.14 mg/l is higher than 1.39 mg/l (Koranteng, 1995), 1.65 mg/l (Yawson, 2003) and 2.254 mg/l (Edor, 2008).

5.1.12 Livestock rearing

Ten percent (10%) of the respondents are into livestock farming which is on a small scale among residents. Some of the animals reared are cattle, goats, chicken, ostrich and duck. The cattle normally graze along the lagoon and drink water from the streams. When asked about how they dispose off droppings of the animals, most of the respondents pointed to a refuse dump near the lagoon. The faeces and urine of animals contain gases such as carbon dioxide and sulphur which decompose and pollute the water.

5.1.13 Farming and land cover change

Farming is the main occupation of the respondents, involving 37% of the residents in Sakumono village, Klagon and Community 3-Tema. Arable crop farming was the dominant occupation in the communities. The arable crop farmers enhance their yield of produce by the use of inorganic fertilizers and pesticides. Fertilizers such as **NPK (15-15-15, 20-10-10), Urea and Ammonia** are used in their farming activities. NPK, according to the respondents, is applied once a week for three months. In the case of pesticides, 15ml is sprayed on the crops each week for three months.

"**Furadan, Karate, DDT, Gameli-20, Run-up, Pawa 2.5EC, Supermaster-20-20-20, Atellic, Confidor, Dursban 4E, Pyrinex 48EC and More harvest**" were some of the pesticides found with the farmers on the farms. The excessive use of pesticides and fertilizers may be the cause of high nutrients in the waters of the lagoon.

5.2 DISCUSSION OF ANOVA RESULTS

Among all the parameters analyzed only pH and turbidity showed statistical significant differences ($p < 0.05$). The other parameters did not differ significantly. The significant variation in pH could be attributed to rapid urbanization resulting in a sharp increase in anthropogenic activities such as intense agricultural activities which use varied agro-chemicals within the catchment of the lagoon. The monthly analysis on ANOVA for pH ($p = 0.005$) varied significantly, this may be due to several factors like temperature, aeration and input from external sources that interfered with the pH of the lagoon water. For the seasonal variation analysis both pH and turbidity ($p = 0.001$) values varied significantly. In terms of pH ($p = 0.001$) variation could be attributed to high evaporation rates within the period and clear marine influence on the lagoon. Turbidity also varied significantly ($p < 0.05$) in the months of June, July and August as compared to the other sampling months. This was probably due to the fact that during these months rainfall pattern was high, consequently resulting in an increase in suspended matter such as clay, silt, finely divided organic matter and inorganic matter soluble as well as plankton and microorganisms. This makes the lagoon water cloudy in appearance and therefore increases turbidity. Increase in turbidity threatens the survival of microorganisms since oxygen for respiration and photosynthesis would be short in supply.

For the monthly analysis turbidity varied significantly ($p = 0.013$), this may be due to the fact that during the rainy season the lagoon water became turbid as a result of leaching and infiltration of agricultural activities around the lagoon. Additionally, variation in turbidity ($p = 0.001$) levels for both seasons could be attributed to anthropogenic activities, urbanization and the discharge of untreated industrial effluent into the lagoon.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

- From the study, physical parameters, temperatures recorded for effluents were relatively above permissible limits set by the EPA, however pH recorded for all the sampling sites during the study were near neutral and within (6-9) the range for most natural water bodies. It was also realized that, conductivity, TSS and TDS were generally higher in both the lagoon water and effluents and exceeded the EPA permissible values and natural background levels, an indication of the pollution of Sakumo ll lagoon in terms of dissolved ions and substances.
- The mean values of chemical parameters BOD and DO were within the EPA recommended guidelines values except the mean concentration of DO which was below the recommended value set by EPA, an indication that the water was under stress. Based on the study, the mean values recorded for nutrients were beyond the permissible limit for surface waters. From the results, the Sakumo II Lagoon can be termed as polluted based on the assertion made by Biney (1982) on pollution in waters in terms of anthropogenic influence.
- In view of the findings made in the ANOVA analysis, the pH and turbidity of the lagoon water were the parameters of the water quality that had been significantly affected by pollution in both wet and dry seasons.
- It was realized from the social survey that residents had little knowledge and education on the use of the lagoon as a wetland and for that matter as a site of

international importance. This has lead to overexploitation of the lagoon resources. The study also revealed that, there were inadequate sanitation facilities around the catchment area of the lagoon forcing some residents to resort to open defeacation.

6.2 RECOMMENDATIONS

6.2.1 RECOMMENDATIONS FOR IMPLEMENTATION

- Based on the study it is recommended that the lagoon should be regularly monitored and assessed by appropriate agencies like the EPA, Tema Metropolitan assembly and the Wildlife department to control indiscriminate release of effluents into the lagoon water.
- Studies should also be carried out to ascertain the level of decline in the aquatic life of the lagoon.
- The Tema Metropolitan Assembly should build new toilet facilities for the residents of the Sakumono village to prevent open defecation within the lagoon area.
- The results of this study would be useful for implementing pollution management strategies in the catchment area of the lagoon.

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APPENDICES

APPENDIX A: Detailed results of Physical and Chemical Parameters of water

Table 6; Monthly mean of temperature (°C)

Months	Bridge	Community 3	Celebrity	Mean
June	29.5	30.4	29.8	**29.9**
July	28.6	29.2	28.4	**28.7**
August	28.2	29.2	27.8	**28.4**
January	28.4	30.6	30.1	**29.7**
February	29.4	30.4	26.5	**28.8**
March	29.4	28.8	29.9	**29.37**
Mean	**28.92**	**29.8**	**28.8**	

Table 7; Monthly mean of pH

Months	Bridge	Community 3	Celebrity	Mean
June	7.1	7.5	7.2	**7.3**
July	7.1	7.3	7.3	**7.2**
August	6.8	7.1	7.4	**7.1**
January	8.0	7.6	8.7	**8.1**
February	7.6	7.9	8.4	**8.0**
March	8.3	7.8	8.4	**8.2**
Mean	**7.5**	**7.5**	**7.9**	

Table 8; Monthly mean of turbidity (NTU)

Months	Bridge	Community 3	Celebrity	Mean
June	14	23	26	**21**
July	11	13	22	**15.3**
August	5.0	7.0	9.0	**7.0**
January	30.5	43.8	25.9	**33.4**
February	22.8	31.3	36.5	**30.2**
March	18.8	47.5	28.8	**31.7**
Mean	**17.02**	**27.6**	**24.7**	

Table 9; Monthly mean of total suspended solids (mg/l)

Months	Bridge	Community 3	Celebrity	Mean
June	17	24	30	**23.67**
July	26	22	51	**33**
August	10	39	44	**31**
January	21	119	223	**121**
February	30	88	32	**50**
March	24	325	73	**140.7**
Mean	**21.33**	**102.8**	**75.5**	

Table 10; Monthly mean of total dissolved solids (mg/l)

Months	Bridge	Community 3	Celebrity	Mean
June	4520	906	773	**2,066.3**
July	840	506	746.5	**2,092.5**
August	18500	728	3080	**7,436**
January	3000	863.5	5920	**3,261.2**
February	6845	747	4670	**4,087.3**
March	6310	925	4945	**4060**
Mean	**6669.2**	**779.3**	**3355.8**	

Table 11; Monthly mean of conductivity (µS/cm)

Months	Bridge	Community 3	Celebrity	Mean
June	9040	1812	1546	**4,132.7**
July	1680	1012	1493	**1,395**
August	37000	1456	6160	**12,859**
January	6000	1727	11840	**6,522.3**
February	13690	1494	9340	**8,174.7**
March	2620	846	9890	**4,452**
Mean	**11672**	**1391.2**	**6711.5**	

Table 12; Monthly mean of DO (mg/l)

Months	Bridge	Community 3	Celebrity	Mean
June	4.2	2.4	3.4	**3.3**
July	5.6	4.2	5.8	**5.2**
August	6.2	4.8	5.6	**5.5**
January	5.6	1.8	2.2	**3.2**
February	3.6	2.3	9.6	**5.2**
March	4.1	2.5	4.6	**3.73**
Mean	**4.9**	**3.0**	**5.2**	

Table 13; Monthly mean of BOD (mg/l)

Months	Bridge	Community 3	Celebrity	Mean
June	1.9	1.2	1.2	**1.4**
July	2.6	1.8	3.8	**2.7**
August	2.8	1.4	2.2	**2.1**
January	2.1	1.2	1.5	**1.6**
February	2.0	1.4	8.4	**3.9**
March	1.6	0.7	1.2	**1.67**
Mean	**2.2**	**1.3**	**3.1**	

Table 14; Monthly mean of nitrate (mg/l)

Months	Bridge	Community 3	Celebrity	Mean
June	1.4	2.7	2.6	**2.23**
July	1.3	2.7	2.8	**2.27**
August	0.7	5.2	9.7	**5.2**
January	2.5	4.3	2.3	**3.03**
February	1.1	3.5	1.7	**2.1**
March	2	6.4	2	**3.47**
Mean	**1.5**	**4.13**	**3.5**	

Table 15; Monthly mean of phosphate (mg/l)

Months	Bridge	Community 3	Celebrity	Mean
June	1.12	1.2	0.31	**0.88**
July	1.7	0.89	1.84	**1.48**
August	3.88	9.76	4.34	**6.01**
January	3.76	4.4	1.36	**3.17**
February	1.52	5.68	1.57	**2.92**
March	4.96	6.44	2.38	**4.59**
Mean	**2.82**	**4.73**	**1.97**	

Table 16; Monthly mean of ammonia (mg/l)

Months	Bridge	Community 3	Celebrity	Mean
June	0.94	0.51	0.33	**0.59**
July	1.56	1.24	1.68	**1.49**
August	8.68	4.1	2.3	**5.03**
January	0.77	0.62	0.44	**0.61**
February	0.21	0.62	0.22	**0.35**
March	6.72	24	1.39	**10.7**
Mean	**3.15**	**5.2**	**1.06**	

APPENDIX B; Detailed results of Physical and Chemical Parameters of Effluents

Table 17; Monthly mean Temperature (°C)

Months	PRT	CCBC	KPS
February	29.4	29.3	29.3
March	28.8	27.9	29.2
April	27.8	29.9	29.8
Mean	**28.67**	**29.03**	**29.43**

Table 18; Monthly mean of pH

Months	PRT	CCBC	KPS
February	6.79	9.99	6.31
March	8.1	7.7	7.8
April	7.1	8.7	6.8
Mean	**7.3**	**8.8**	**6.9**

Table 19; Monthly mean of DO (mg/l)

Months	PRT	CCBC	KPS
February	3.9	5.0	1.4
March	5.8	1.2	1.6
April	6.8	2.2	2.8
Mean	**5.5**	**2.8**	**1.9**

Table 20; Monthly mean of BOD (mg/l)

Months	PRT	CCBC	KPS
February	2	1.5	1.7
March	2.4	0.8	0.4
April	3.4	1.4	0.9
	2.6	**1.2**	**1.0**

Table 21; Monthly mean of Turbidity (NTU)

Months	**PRT**	**CCBC**	**KPS**
February	383	49	14.7
March	460	56	22
April	476	66	20
Mean	**439.67**	**57.00**	**18.9**

Table 22: Monthly mean of TSS (mg/l)

Months	PRT	CCBC	KPS
February	10	111	78
March	177	142	77
April	182	162	70
Mean	**123**	**138.3**	**75**

Table 23; Monthly mean of Conductivity (µS/cm)

Months	PRT	CCBC	PRT
February	628	945	181
March	495	1354	483
April	598	1444	542
Mean	**573.67**	**1247.7**	**402.0**

Table 24; Monthly mean of TDS (mg/l)

Months	PRT	CCBC	PRT
February	320	473	90
March	246	680	240
April	299	722	271
Mean	**288.33**	**625.0**	**200.33**

Table 25; Monthly mean of Nitrate (mg/l)

Months	PRT	CCBC	PRT
February	1.3	16.9	7.7
March	3.4	4.8	6.5
April	2.9	3.7	5.2
Mean	**2.5**	**8.5**	**6.5**

Table 26; Monthly mean of Phosphate (mg/l)

Months	PRT	CCBC	PRT
February	0.26	4.98	2.57
March	0.25	3.14	0.28
April	0.44	4.12	0.32
Mean	**0.32**	**4.1**	**1.1**

Table 27; Monthly mean of Ammonia (mg/l)

Months	PRT	CCBC	PRT
February	0.23	18	8.12
March	0.66	2.24	0.8
April	0.72	3.12	0.84
Mean	**0.54**	**7.8**	**3.3**

APPENDIX C; QUESTIONNAIRE

Confidentiality of respondent views is assured.

Date
……………………………………………………………
Locality
…………………………………………………………….
Questionnaire number
…………………………………………………………….

Section A (Background Information of Respondent)

1) Sex: Male Female ☐ ☐

2) Age: 15-19 Years 20-29 Years ☐ 30-39 Years ☐ 40-49 Years ☐

50-59 Years ☐60 Years & Above ☐

3) (a) Marital Status Single ☐ Married ☐ Divorced ☐ Widowed ☐

4) Level of Education None☐ Primary☐ JHS/JSS ☐ Secondary/SHS ☐

Tertiary ☐ Others

____

5) Religion: ☐None ☐Christian ☐ Muslim ☐

Traditional

Others………………………………………………..

6) Ethnic Group: Akan ☐ Ga/Adangbe ☐ Ewe ☐ Others

specify…………………….

7) Occupation Primary ____

Secondary ______________________________________

Section B-Fishing

8) Do you fish in Sakumo lagoon? Yes ☐ No ☐

9) If yes, which section do you normally fish? Southern section ☐ Middle section ☐ Northern section ☐

10) What do you use the fish caught for? Home consumption ☐ For sale ☐ Both ☐

11) Do you know of any regulations/laws/taboos that are used to protect fish and other aquatic resources? Yes ☐ No ☐

12) If yes, what are they?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Section C- Livestock

13) Do you own any livestock? Yes ☐ No ☐

14) If yes, what type of livestock do you own?

Cattle ☐ Sheep ☐ Goats ☐ Pigs ☐ Others…………………………………….

15) Do you graze your livestock near the Lagoon? Yes ☐ No ☐

16) Are there any regulations about watering/grazing livestock by the lagoon? Yes ☐

No ☐

17) Are they adhered to? Yes ☐ No ☐

SECTION D. Farming and Land Cover Charge

18) How many areas of land farm on? 1 -2 Acres ☐ 3-4 Acres ☐ 5Acres &Above ☐

19) Do you apply fertilizer to your farm crops? Yes ☐ No ☐

20) Which type of fertilizers do you use? Organic ☐ inorganic ☐

21)

(a)Crop type	(b) Type/s of fertilizer (brand name/active ingredient	(c)Time and frequency of application per cropping cycle	(d) quantity per application	(e) Method of application

22) Do you apply pesticides on your farm crops? Yes ☐ No ☐

23)

a)Crop type	b)Kind/s of pesticide (brand name/active ingredient	c) Frequency of application per cropping cycle	d) Quantity per application	e) Method of application

Section E- Public Health and Sanitation

24) Where do you dispose your refuse? Bush ☐ Zoomlion ☐

25) Are you aware of any refuse being dumped into/near Sakumo lagoon? Yes ☐ No ☐

26) Which of the following do you use as your place of convenience?

KVIP ☐ Pit latrine ☐ Water closet ☐ Free-range ☐

27) What are the common diseases in this area? Malaria ☐ Cholera ☐ Fever ☐

Others…………

28) Where do you normally go for treatment? Clinic ☐ Hospital ☐

Others…………….

APPENDIX D: Bar Charts of Lagoon Water and Effluent Mean Values

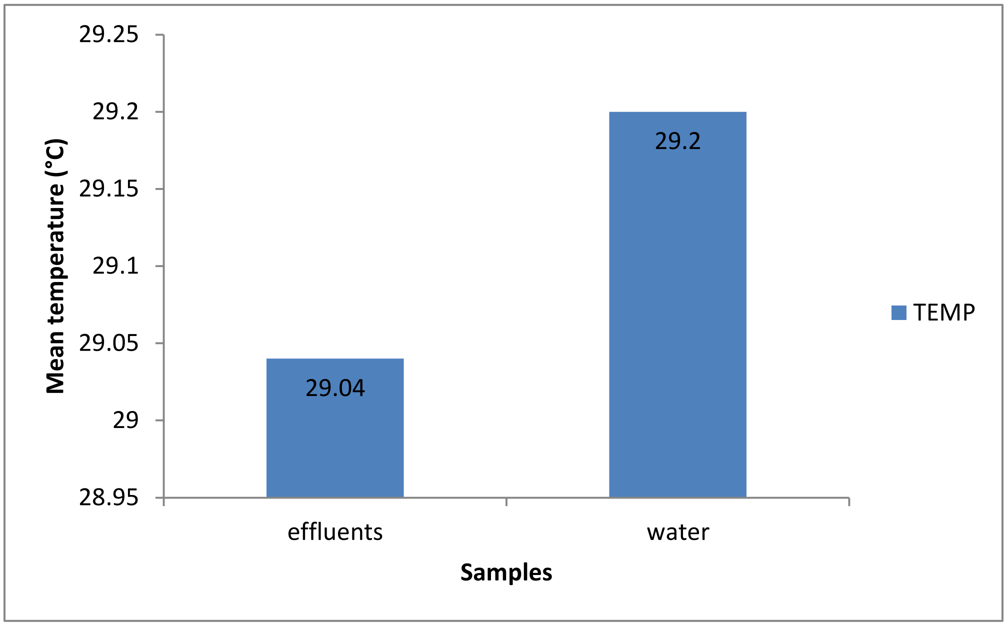

Figure 2; Monthly mean of Temperature of effluents and lagoon water

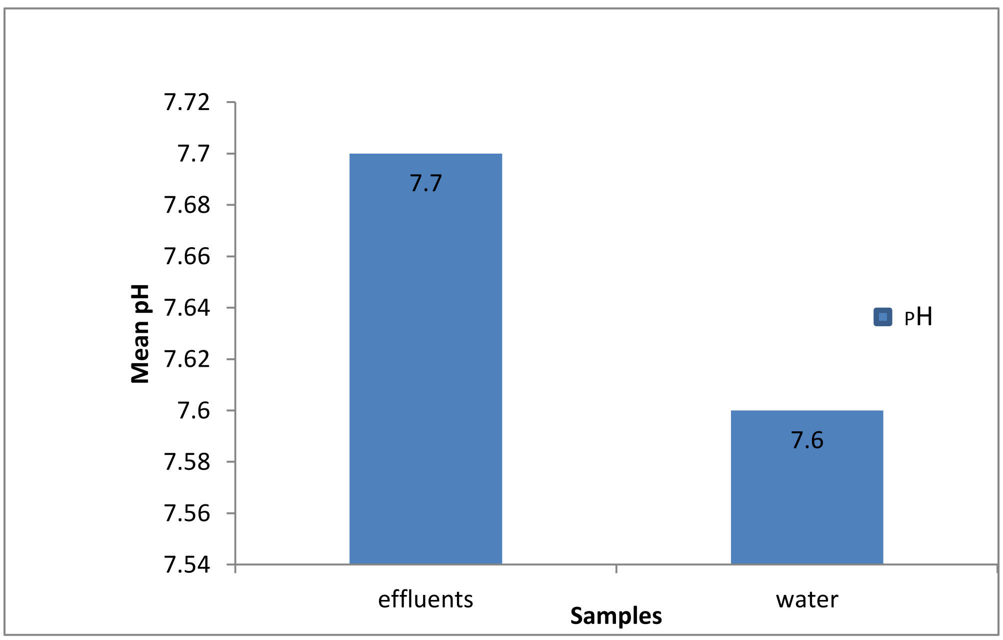

Figure 3; Monthly mean of pH of effluents and lagoon water

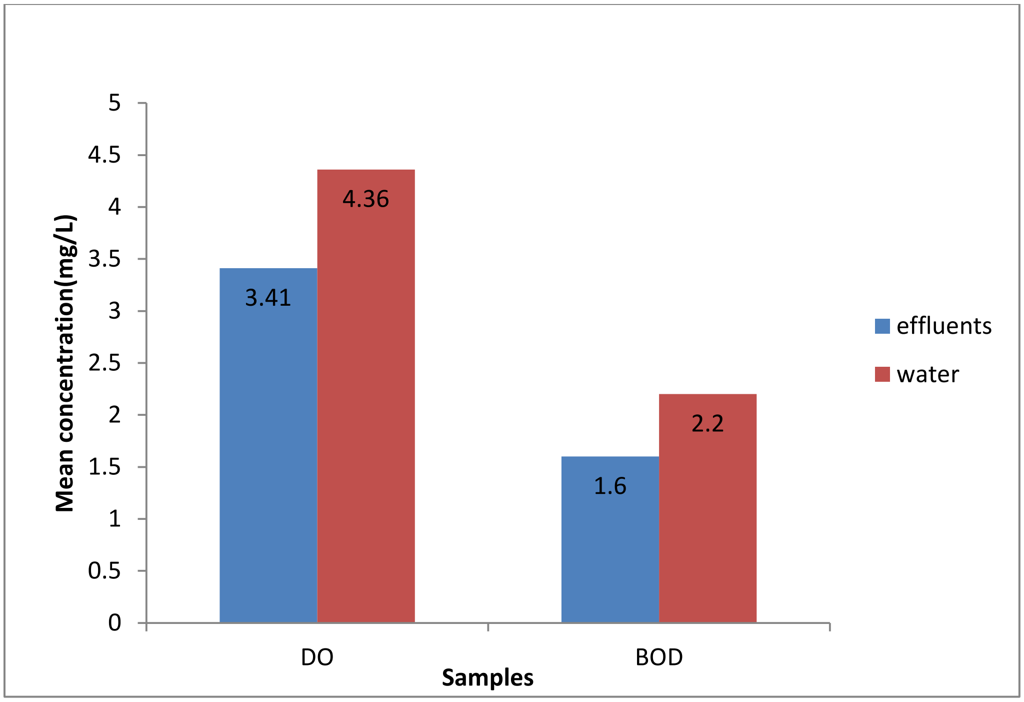

Figure 4; Monthly mean of DO and BOD of effluents and lagoon water

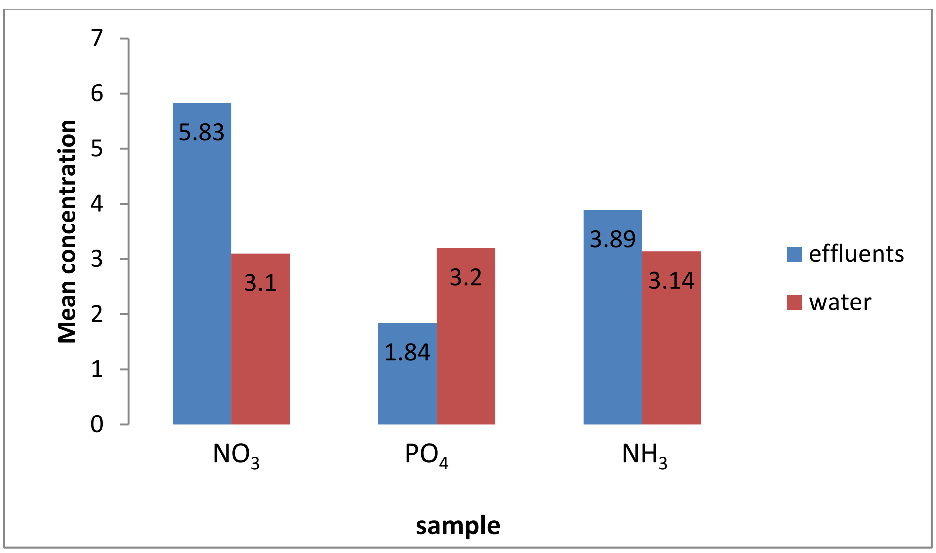

Figure 5; Monthly mean nutrients of effluents and lagoon water

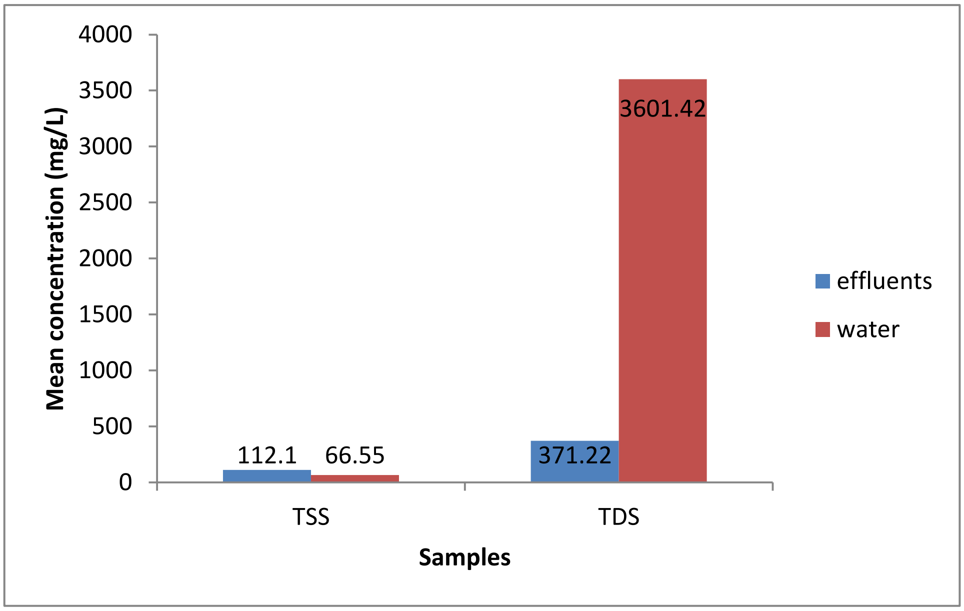

Figure 6; Monthly mean of TSS and TDS of effluents and lagoon water

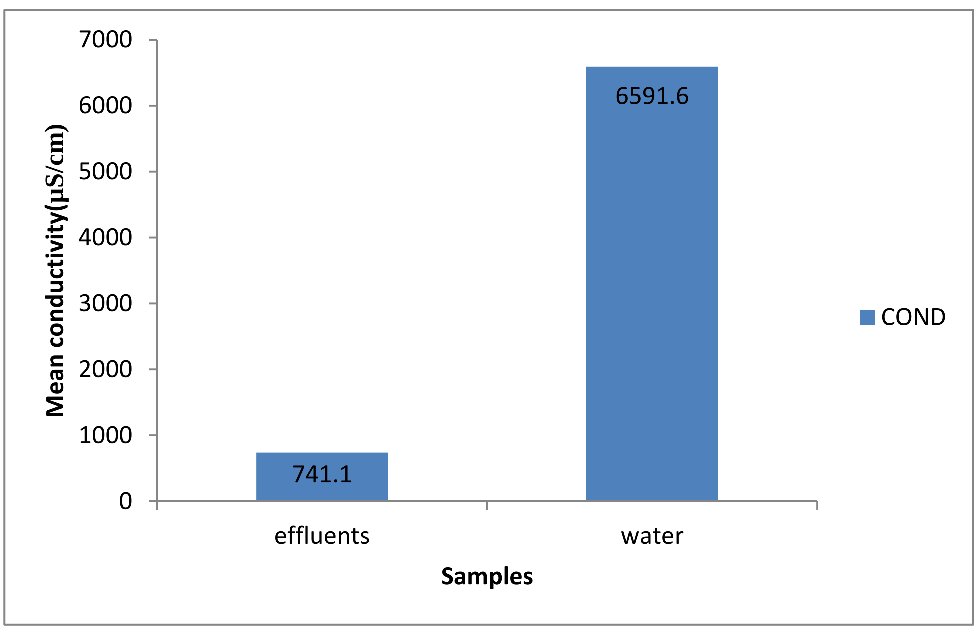

Figure 7; Monthly mean of Conductivity of effluents and lagoon water

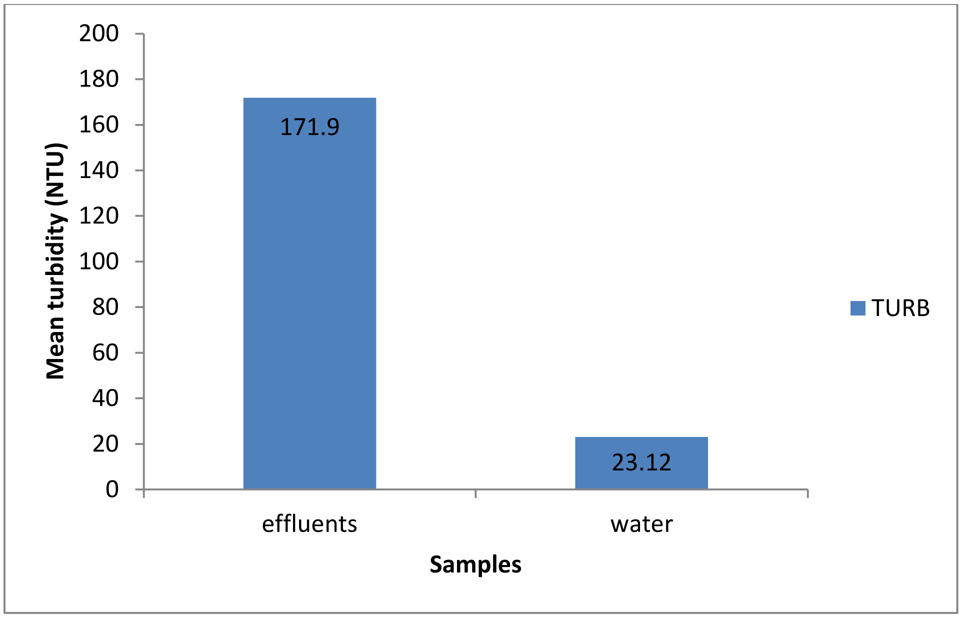

Figure 8; Monthly mean of Turbidity of effluents and lagoon water

APPENDIX E; Social survey results

Table 2; **Respondents in the study area**

Age Group	Frequency	Percentage (%)
15-19 years	17	17.0
20-29 years	29	29.0
30-39 years	29	29.0
40-49 years	14	14.0
50-59 years	4	4.0
60& Above	7	7.0
Total	100	100.0

Table 3; Level of education

	Frequency	Percent
None	10	10.0
Primary	32	32.0
JHS	39	39.0
SHS	14	14.0
Tertiary	3	3.0
No Response	2	2.0
Total	100	100.0

Table 4; Occupation

	Frequency	Percent
Traders	16	16.0
Crop Farming	37	37.0
Fishing	32	32.0
Unemployed	15	15.0
Total	100	100.0

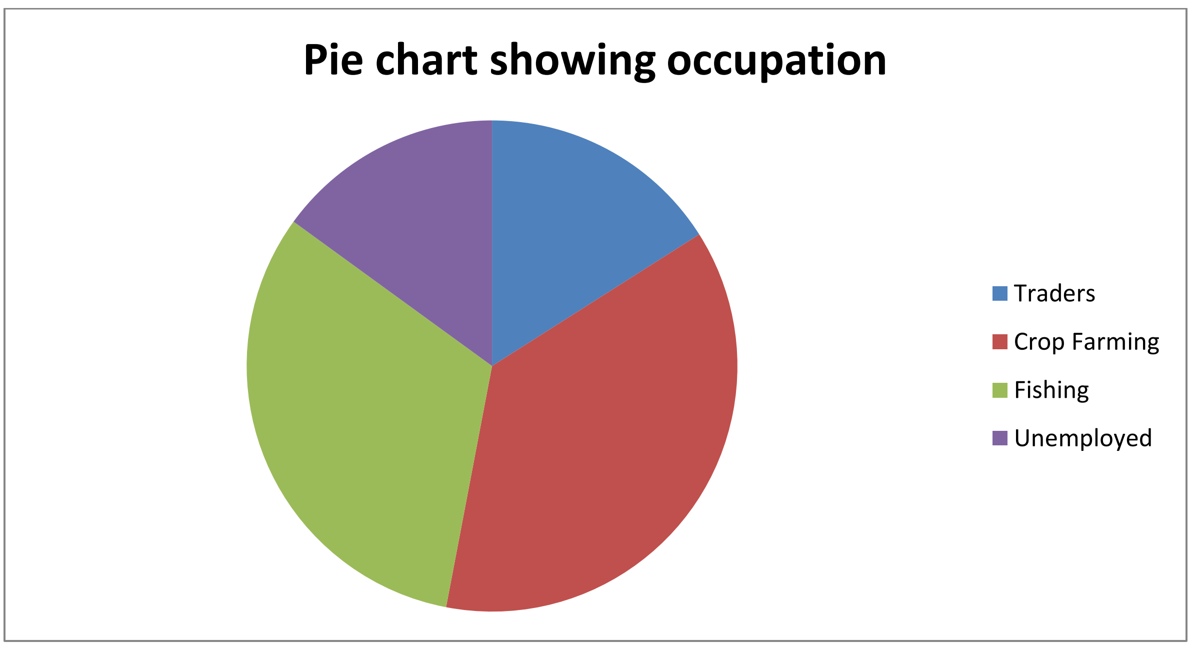

Table 5; Place of convenience

Facility	Frequency	Percentage
KVIP	19	19.0
Pit Latrine	8	8.0
Water Closet	15	15.0
Free-range	55	55.0
No response	3	3.0
Total	100	100.0

APPENDIX F; EFFLUENT MEANS

STATISTIX 7.0 5/13/2012, 4:02:47 PM

DESCRIPTIVE STATISTICS FOR MONTHS = 1

VARIABLE	MEAN	SE MEAN	MINIMUM	MAXIMUM
BOD	1.7333	0.1453	1.5000	2.0000
COND	584.67	221.61	181.00	945.00
DO	3.4333	1.0651	1.4000	5.0000
NH3	8.7833	5.1405	0.2300	18.000
NO2	4.1333	1.8836	1.3000	7.7000
PH	7.6967	1.1550	6.3100	9.9900
PO4	1.0267	0.7717	0.2500	2.5700
TDS	218.67	67.787	90.000	320.00
TEMP	29.333	0.0333	29.300	29.400
TSS	66.333	29.734	10.000	111.00
TURB	148.90	117.47	14.700	383.00

DESCRIPTIVE STATISTICS FOR MONTHS = 2

VARIABLE	MEAN	SE MEAN	MINIMUM	MAXIMUM
BOD	1.2000	0.6110	0.4000	2.4000
COND	777.33	288.35	483.00	1354.0
DO	2.8667	1.4712	1.2000	5.8000
NH3	1.2333	0.5050	0.6600	2.2400
NO2	4.9000	0.8963	3.4000	6.5000
PH	7.8667	0.1202	7.7000	8.1000
PO4	1.2233	0.9584	0.2500	3.1400
TDS	388.67	145.68	240.00	680.00
TEMP	28.633	0.3844	27.900	29.200
TSS	132.00	29.297	77.000	177.00
TURB	179.33	140.68	22.000	460.00

DESCRIPTIVE STATISTICS FOR MONTHS = 3

VARIABLE	MEAN	SE MEAN	MINIMUM	MAXIMUM
BOD	1.9000	0.7638	0.9000	3.4000
COND	861.33	291.78	542.00	1444.0
DO	3.9333	1.4438	2.2000	6.8000
NH3	1.5600	0.7808	0.7200	3.1200
NO2	3.9333	0.6741	2.9000	5.2000
PH	7.5333	0.5897	6.8000	8.7000
PO4	1.6267	1.2471	0.3200	4.1200
TDS	430.67	145.89	271.00	722.00
TEMP	29.167	0.6839	27.800	29.900
TSS	138.00	34.487	70.000	182.00
TURB	187.33	144.94	20.000	476.00

APPENDIX G; WATER SAMPLE MEANS

STATISTIX 7.0 NEW DATA 3, 5/15/2012, 3:36:39 PM

DESCRIPTIVE STATISTICS FOR SAMPLES = 1

VARIABLE	MEAN	SE MEAN	MINIMUM	MAXIMUM
BOD	2.6000	0.4163	2.0000	3.4000
COND	573.67	40.275	495.00	628.00
DO	5.5000	0.8505	3.9000	6.8000
NH3	0.5367	0.1543	0.2300	0.7200
NO2	2.5333	0.6333	1.3000	3.4000
PH	7.3300	0.3953	6.7900	8.1000
PO4	0.3167	0.0617	0.2500	0.4400
TDS	288.33	22.018	246.00	320.00
TEMP	28.667	0.4667	27.800	29.400
TSS	123.00	56.518	10.000	182.00
TURB	439.67	28.707	383.00	476.00

DESCRIPTIVE STATISTICS FOR SAMPLES = 2

VARIABLE	MEAN	SE MEAN	MINIMUM	MAXIMUM
BOD	1.2333	0.2186	0.8000	1.5000
COND	1247.7	153.55	945.00	1444.0
DO	2.8000	1.1372	1.2000	5.0000
NH3	7.7867	5.1130	2.2400	18.000
NO2	8.4667	4.2286	3.7000	16.900
PH	8.7967	0.6628	7.7000	9.9900
PO4	4.0800	0.5315	3.1400	4.9800
TDS	625.00	76.961	473.00	722.00
TEMP	29.033	0.5925	27.900	29.900
TSS	138.33	14.836	111.00	162.00
TURB	57.000	4.9329	49.000	66.000

DESCRIPTIVE STATISTICS FOR SAMPLES = 3

VARIABLE	**MEAN**	**SE MEAN**	**MINIMUM**	**MAXIMUM**
BOD	1.0000	0.3786	0.4000	1.7000
COND	402.00	111.80	181.00	542.00
DO	1.9333	0.4372	1.4000	2.8000
NH3	3.2533	2.4334	0.8000	8.1200
NO2	6.4667	0.7219	5.2000	7.7000
PH	6.9100	0.4852	6.1300	7.8000
PO4	1.0567	0.7568	0.2800	2.5700
TDS	200.33	55.888	90.000	271.00
TEMP	29.433	0.1856	29.200	29.800
TSS	75.000	2.5166	70.000	78.000
TURB	18.900	2.1779	14.700	22.000

APPENDIX H; EFFLUENT SAMPLE MEANS

STATISTIX 7.0 5/12/2012, 1:58:26 AM

DESCRIPTIVE STATISTICS FOR MONTHS = 1

VARIABLE	MEAN	SE MEAN	MINIMUM	MAXIMUM
BOD	1.4333	0.2333	1.2000	1.9000
DO	3.3333	0.5207	2.4000	4.2000
COND	4132.7	2454.9	1546.0	9040.0
NH3	0.5933	0.1810	0.3300	0.9400
PH	7.2667	0.1202	7.1000	7.5000
NO2	2.2333	0.4177	1.4000	2.7000
PO4	0.8767	0.2843	0.3100	1.2000
TDS	2066.3	1227.4	773.00	4520.0
TEMP	29.900	0.2646	29.500	30.400
TSS	23.667	3.7565	17.000	30.000
TURB	21.000	3.6056	14.000	26.000

DESCRIPTIVE STATISTICS FOR MONTHS = 2

VARIABLE	MEAN	SE MEAN	MINIMUM	MAXIMUM
BOD	2.7333	0.5812	1.8000	3.8000
DO	5.2000	0.5033	4.2000	5.8000
COND	1395.0	198.96	1012.0	1680.0
NH3	1.4933	0.1313	1.2400	1.6800
PH	7.2333	0.0667	7.1000	7.3000
NO2	2.2667	0.4842	1.3000	2.8000
PO4	1.4767	0.2961	0.8900	1.8400
TDS	697.50	99.482	506.00	840.00
TEMP	28.733	0.2404	28.400	29.200
TSS	33.000	9.0738	22.000	51.000
TURB	15.333	3.3830	11.000	22.000

DESCRIPTIVE STATISTICS FOR MONTHS = 3

VARIABLE	**MEAN**	**SE MEAN**	**MINIMUM**	**MAXIMUM**
BOD	2.1333	0.4055	1.4000	2.8000
DO	5.5333	0.4055	4.8000	6.2000
COND	14872	11147	1456.0	37000
NH3	5.0267	1.8991	2.3000	8.6800
PH	7.1000	0.1732	6.8000	7.4000
NO2	5.2000	2.5981	0.7000	9.7000
PO4	5.9933	1.8880	3.8800	9.7600
TDS	7436.0	5573.5	728.00	18500
TEMP	28.400	0.4163	27.800	29.200
TSS	31.000	10.599	10.000	44.000
TURB	7.0000	1.1547	5.0000	9.0000

DESCRIPTIVE STATISTICS FOR MONTHS = 4

VARIABLE	**MEAN**	**SE MEAN**	**MINIMUM**	**MAXIMUM**
BOD	1.6000	0.2646	1.2000	2.1000
DO	3.2000	1.2055	1.8000	5.6000
COND	6522.3	2931.0	1727.0	11840
NH3	0.6100	0.0954	0.4400	0.7700
PH	8.1000	0.3215	7.6000	8.7000
NO2	3.0333	0.6360	2.3000	4.3000
PO4	3.1733	0.9253	1.3600	4.4000
TDS	3261.2	1465.5	863.50	5920.0
TEMP	29.700	0.6658	28.400	30.600
TSS	121.00	58.321	21.000	223.00
TURB	33.400	5.3669	25.900	43.800

DESCRIPTIVE STATISTICS FOR MONTHS = 5

VARIABLE	MEAN	SE MEAN	MINIMUM	MAXIMUM
BOD	3.9333	2.2400	1.4000	8.4000
DO	5.1667	2.2482	2.3000	9.6000
COND	8174.7	3568.6	1494.0	13690
NH3	0.3500	0.1350	0.2100	0.6200
PH	7.9667	0.2333	7.6000	8.4000
NO2	2.1000	0.7211	1.1000	3.5000
PO4	2.9233	1.3784	1.5200	5.6800
TDS	4087.3	1784.3	747.00	6845.0
TEMP	28.767	1.1695	26.500	30.400
TSS	50.000	19.009	30.000	88.000
TURB	30.200	3.9929	22.800	36.500

DESCRIPTIVE STATISTICS FOR MONTHS = 6

VARIABLE	MEAN	SE MEAN	MINIMUM	MAXIMUM
BOD	1.1667	0.2603	0.7000	1.6000
DO	3.7333	0.6333	2.5000	4.6000
COND	4452.0	2766.8	846.00	9890.0
NH3	10.703	6.8241	1.3900	24.000
PH	8.1667	0.1856	7.8000	8.4000
NO2	3.4667	1.4667	2.0000	6.4000
PO4	4.5933	1.1863	2.3800	6.4400
TDS	4060.0	1616.3	925.00	6310.0
TEMP	29.367	0.3180	28.800	29.900
TSS	140.67	93.246	24.000	325.00
TURB	31.700	8.4109	18.800	47.500