WATER QUALITY AND ORGANOCHLORINE PESTICIDES IN FRESH WATER BODIES IN THE LOWER VOLTA BASIN: A CASE STUDY OF LAKES KASU AND NYAFIE.

A THESIS

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DECLARATION

I hereby declared that this is my original work under the supervision of Dr. D. Carboo, Dr. R. Akuamoah and Mr, W.J. Ntow, and has not been presented for a degree in this or any other university elsewhere.

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DEDICATION

This work is dedicated to my wife and the children for enduring my absence while at school and to the ever-loving memory of my late mother, Madam Grace Afi Gedzah, who did not live to enjoy the fruits of her labour.

ACKNOWLEDGEMENT

I am grateful, first and foremost to the Lord Almighty, for His Divine Love and Protection. My sincere thanks go to my supervisors, Dr, D. Carboo, Dr. R. Akuamoah and Mr. W.J. Ntow, for their patience, tolerance, suggestions and understanding during the duration of the work.

I also wish to thank all lecturers and colleagues of the department for their suggestions and words of encouragement when the going seemed to be tough. My thanks also go to the staff of the Environmental Chemistry Division of the Water Research Institute for their help, healthy criticisms and the use of their equipment. I would also like to show my appreciation to the laboratory and office staff of the department for their help in diverse ways.

Last but not the least, I would like to thank the Headmaster and staff of the Science Resource Centre at Ghanata Secondary School, Dodowa, for the use of their equipment, and my bosom friend, Henry Teku Kreponi, for his kindness and generosity.

ABSTRACT

The study was in two parts. The first part dealt with the determination of water quality parameters such as pH, temperature, DO, BOD, COD, conductivity, turbidity, suspended solids, dissolved solids and total solids. Others are nutrients and ions such as nitrates, nitrites, phosphates, chlorides, calcium, magnesium, sodium and potassium. The rest were under hardness of water such as calcium, magnesium and total hardness. Of all these parameters, only the values for turbidity i.e 80.8 NTU (Super-drain), 68.0 NTU (Kasu) and 25.2 NTU (Nyafie), were far beyond the WHO guideline limit of 5 NTU for drinking water.

The second part dealt with the qualitative and quantitative determination of organochlorine pesticides levels in both water and sediment samlpes from lakes Kasu, Nyafie and the "super drain" The chemicals, lindane, hexachlorobenzene (***HCB***) and 2,4,5-trichlorobenzene (***2,4,5-TCB***), were found to be present using gas chromatography (GC). The water sample mean for HCB in lake Kasu (11.7ng/L) was greater than that found in lake Nyafie (2.3ng/L). No lindane was detected in any of the sediment samples. The water sample mean for *HCB* in lake Nyafie (1.9ng/L) and that for lake Kasu (1.3ng/L) were relatively close. Again, no *HCB* was found in any of the sediment samples. In the case of *2,4,5-TCB*,its water sample mean value for lake Kasu was a high of 1114.1ng/L, while that for lake Nyafie was 822.5ng/L. Of all the pesticides detected, only *2,4,5-TCB* was present in both water and sediment samples of the two lakes. While the sediment mean value for lake Kasu was 125.1ng/L and that for lake Nyafie was 44.2ng/L. On the whole, the lakes can be said to be polluted and as such unsafe for drinking and recreational purposes as a result of the presence of the organochlorine pesticides found in them.

CONTENTS

CHAPTER ONE

INTRODUCTION

The Lower Volta Basin is taken to include all the areas lying below the Akosombo dam. It is made up of parts or all of six districts, namely, Asuogyaman in the northern part, through Manya Krobo, Dangme-West, North Tongu, South Tongu and Dangme-East in the south. The study area, located around Kasunya, containing lakes Kasu, Nyafie and others, is near Asutsuare, in the Dagme-West district in the Greater Accra region. This area in general, lies between Akuse, in the Manya Krobo district, and Battor, in the North Tongu district.

The local Ga-Adangbes and migrant Ewes from the two Tongu districts mainly populate the area. The main occupations of the people are vegetable and rice farming, fishing and animal rearing. The people of the study area do not have access to the Volta river, due to distance, and as such depend solely on the numerous lakes scattered in the area. They use these lakes for drinking, fishing and recreation purposes.

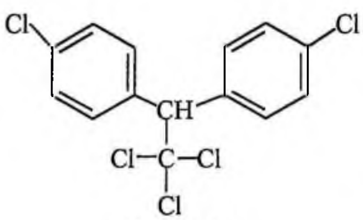
Though, vegetable farming, fishing and animal rearing are mainly at the subsistence level, rice farming in the area since the early 70's, have been commercialised with high level of mechanization, intensive use of fertilizers and pesticides as well as a well laid out irrigation system, by the Irrigation Development Authority (IDA) of The Ministry of Food and Agriculture (MOFA). In order to carry out the rice cultivation, water from the Volta is pumped into large irrigation canals to flood the rice fields. The excess waters from the fields mixed with fertilizers and pesticides applied, are then drained through a single large drain, termed, "Super-drain', into lake Kasu as the final dumping ground. The catchment area of lake Nyafie also receives runoffs from the rice fields of the Korean Semaul Farms Limited (KSF) now known as the Bok Nam Kim Farms, but not through a well defined channel as in the case of lake Kasu.

According to the people staying along the banks of these lakes, the quality of the water has deteriorated, especially along lake Kasu, with regard to aesthetic parameters such as color and taste. In addition, there has been increased siltation and growth of aquatic flora, a possiible indication of the effects of fertilizers and other agrochemicals. Thus for over twenty years (1970-1999), lake Kasu in particular has been used as the dumping ground for fertilizers and pesticides, from rice fields in its catchment area.

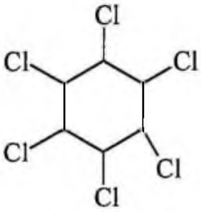
The effects of the rice farming activities in the catchment areas of these lakes coupled with the fact that the Volta river no longer floods these lakes since the construction of the Akosombo dam, resulted in a lot of environmental and socio-economic problems for the people. Some of these problems are;

- lake Kasu in particular, the largest of these lakes, which is the sole source of drinking water for all the villages along its banks, seems no longer wholesome for human consumption due to its "muddy" color which does not become clear even on standing for a long time.
- massive aquatic floral growth, leading to difficulty in fishing as a result of decreased depth and volume of the lakes due to siltation.
- Waning of the fishing industry as a result of the drastic depletion of the desirable fish stocks due to the shallow and muddy nature of the lakes, especially lake Kasu.

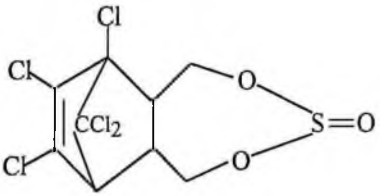
However, since pesticide legislation has been non-existent in this country in the past, all sorts of pesticides were brought into the country without records of what use they were intended. It is also a fact that organochlorine pesticides, such as dichlorodiphenyltrichloroethane (*DDT*) **(I)**, was imported into the country and extensively used in malaria control and prevention, before the worldwide restriction on its use. Other organochlorines such as lindane **(II)** and endosulfan **(III)**, are still been used in cocoa and cotton production, respectively, in the country. The high efficacy and the subsidized cost of both lindane and endosulfan made them attractive to other farmers outside the cocoa and cotton industries. Thus the use of these organochlorines can tend to be diffused, especially in the absence of any effective legislation by the Environmental Protection Agency (EPA), on their movements and uses in the country.



DDT (I)



Lindane (II)



Endosulfan (III)

The problems of fertilizer and pesticide usage in vegetable and rice farming as well as the decrease in the aquatic productivity of the water bodies within the lower Volta basin has been studied by Gordon and Ankrah[1] They identified that, though a lot of pesticides seem to be used especially for rice production in the basin, all of them were carbamates and organophosphates. As no comprehensive work was done to determine the water quality and pesticide levels in these lakes, there is the need for such a study, hence this work.

Aim of the study.

It is therefore the aim of this study is to determine the water quality and organochlorine pesticide burden of the waters and sediments of lakes Kasu and Nyafie as a result of the intensive rice farming in their catchment areas.

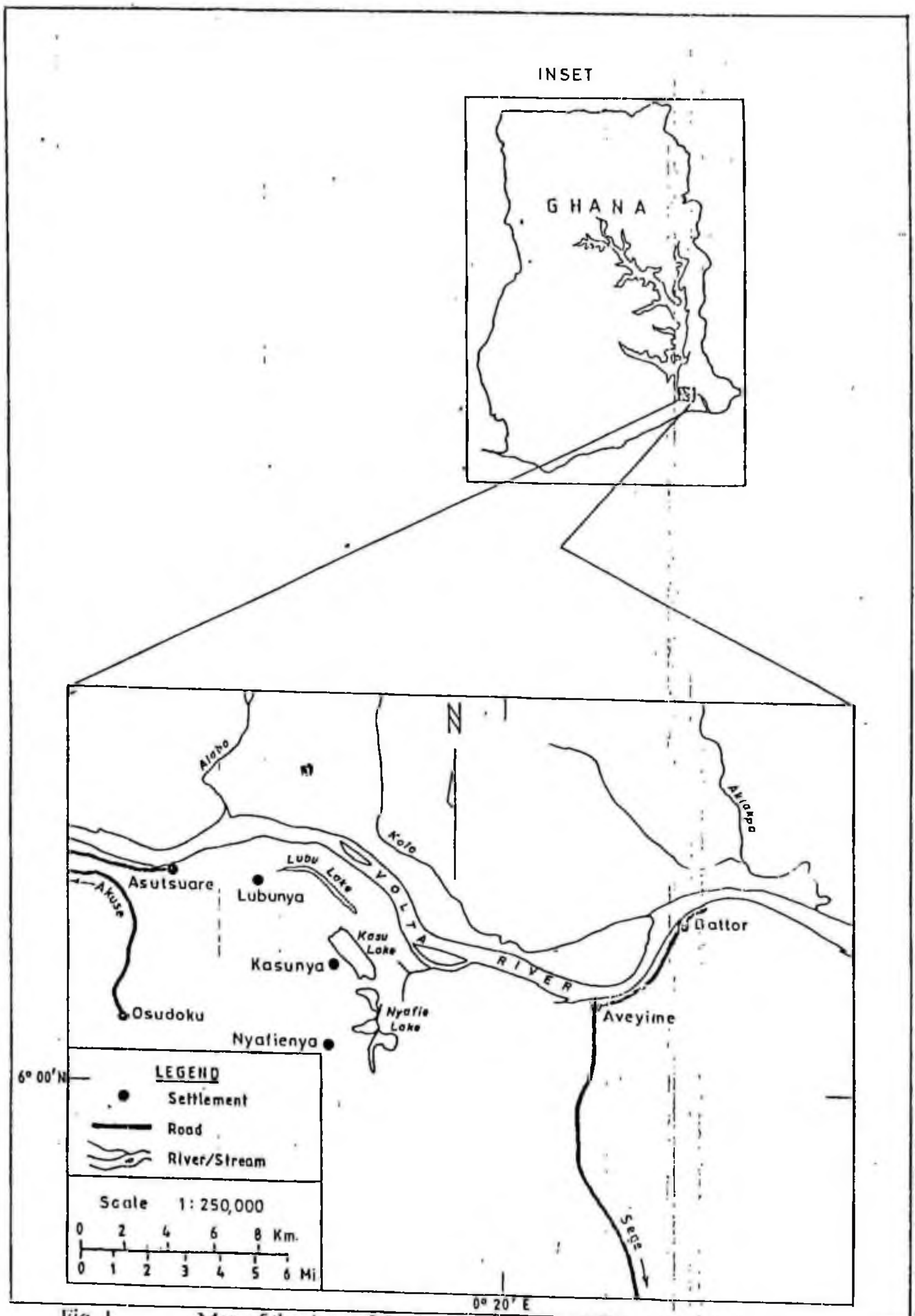


Fig. 1. Map of the Area of Study with the Map of Ghana Inserted.

Fig. 1 Map of the Study Area with the Map of Ghana Inserted.

CHAPTER TWO

LITERATURE REVIEW

2:1 Preamble.

Increased food production using modern methods, from the ever-dwindling agricultural lands, is the prime aim of most farmers and governments, the entire world over. However, the attainment of this food sufficiency goal, seems to carry with it a higher price, which, if not identified and checked, will eventually outweigh the desired benefits. This is because, agricultural wastes and the increasing wrong practices in the application and use of pesticides and fertilizers, threaten the very existence and survival of man and his environment. The dangers of pesticide usage in particular have been highlighted in several textbooks and journals [2]

Man, to help mainly in increasing his agricultural yields, deliberately add fertilizers and pesticides, unlike other chemicals regarded as pollutants, to the environment. While fertilizers are formulated to provide sufficient nutrients to facilitate the rapid growth of desirable plants, pesticides on the other hand, are devised to be lethal to undesirable organisms. The incorrect application of the right type of fertilizer in the correct amount, results in them being washed by runoff water, or leached, into both surface and ground water bodies. This, if not checked, especially in surface waters, results in the massive growth of aquatic flora, eventually, leading to the eutrophication (death) of that water body[3]. The unspecificity, persistence and bioaccumulation of some pesticides, especially the organochlorines, as well as their generally uncontrolled use in this country, pose a considerable threat to the plant and animal population in particular and the environment in general.

The movement of chemicals in the aquatic ecosystem is very fast, and generally difficult to detect initially. Thus lakes can become increasingly polluted and species die out without any obvious signs at least in the early stages. For this reason, environmental monitoring has become recognized as being vitally important in detecting where insidious pollution is occurring, the pollutants involved and the source from which they come [4]. The composition of lakes depend not only on the type of soil surrounding the lake, which influences the amount of salts washed into it, but also, on the age of the lake, the living organism in the lake and the rate of evaporation of the lake water.

In addition to the materials that occur naturally in water bodies increasing amount of many substances are being introduced by mankind. These substances are often harmful to organisms in the water and to humans. Most of these materials are introduced because, natural water bodies are convenient carriers or dumping sites for waste product[13]. Pollution problems rapidly escalate in severity when the rate of pollutant emission exceeds the capacity of the environment to assimilate them. Agricultural wastes are a major source of water pollution. Substances such as fertilizers, pesticides and animal wastes are carried off into water bodies such as rivers, lakes and the oceans by surface runoff [4].

This, as well as the general worldwide agricultural usage of pesticides can be expected to result in residues in foods and drinking water. According to Gordon et al[2], there are pesticides for which approval for their use has been cancelled, but which may contaminate food and water because of their persistence in the environment. To check these occurrences, regulatory systems have been introduced in most developed countries to ensure that pesticide residues do not constitute an unacceptable health risk, if their presence cannot be totally eliminated.

Tolerances are therefore established for individual pesticides in specific commodities. Thus, only an efficient monitoring of food samples from the market and water from its sources can protect the consumer from the potential hazards of pesticide contamination.

The dramatic increase in public awareness and concern about the state of the global and local environments, which has occurred in recent decades, has been accompanied and partly prompted by an ever growing body of evidence on the extent to which pollution has caused severe environmental degradation. The introduction of harmful substances into the environment, have been shown to have many adverse effects on human health, agricultural productivity and natural ecosystems[4]. Thus, the concern for public health is on the ascendancy with regard to the presence of pesticide residues in food, water and aquatic biota, as a result of the intensive and widespread use of pesticides, resulting in the contamination throughout the environment. This concern is due to the fact that, man is at the top of most food chains.

In Ghana, the situation becomes very alarming when it is realized that, there is relatively little or no scientific information on the presence, behaviour and fate of pesticides, especially the organochlorines, in the tropics and on a developing country like Ghana. The gradual awareness in some developing countries like Ghana, of the potential environmental impact of some modern agricultural technologies, therefore, makes the need for environmental protection and resource conservation policies and programs inevitable.

2:1 General Pesticide History.

Ever since the dawn of civilization, man has continually endeavored to improve his living conditions. In his effort to produce adequate supplies of food, the ravages wrought by insect pests, weeds and crop as well as animal diseases have opposed man.

The blasting mentioned in Amos [5] is the same cereal rust disease that is still responsible for enormous crop loss. Also the father of botany, Theophratus (300BC)[6] described many diseases known today, such as scorch, rot, scab and rust. The major pests inhibiting the growth of agricultural crops and animals are insects, fungi and weeds, and the idea of combating them with chemicals (pesticides) is not new.

A pesticide, according to the Food and Agriculture Organization (FAO)[7] is, "any substance or mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies." According to this definition, the term includes substances intended for use as plant growth regulators, defoliants, desiccants or agents for thinning fruit or preventing the premature fall of fruits, and substances applied to crops either before or after harvest, to protect the commodity from deterioration during storage and transportation.

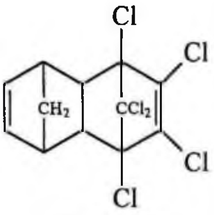
A brief chronological development of chemicals used against pests (pesticides), across the years.[8,9, 6,10,11] is indicated in table 1 below.

Table. 1: Chronological development of some pesticides.

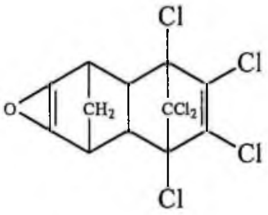
Year	***Name of Chemical***	***Target Organism, kind of disease or Class of Pesticide***	***Discoverer and or Place/country.***
1000BC	Sulphur	insecticide (fungicide)	Homer (Greece)
79AD	Arsenic	insecticide	Pliny
7th century	Nicotine	insecticide	
16th ,,	Arsenic compounds	,,	Chinese
1705	$HgCl_2$	wood preservative	Hamburg
1805	$CuSO_4$	smut pores	Prevost
1814	lime and sulphur mixture	apple scab	Weighton
1818	pyrethrum	insecticide	Persia
1841	lime, sulphur, and tobacco mixture	insecticide	Foreyth
1845	HCH	,,	M. Faraday(USA) first made but not used.
1867	copper arsenate	Colorado beetle	USA
1882	Bordeaux mixture	Wine mildew and potato blight	Mildardet (France)
1886	*HCN*	fumigant	USA
1892	lead arsenate	gypsy moths	
1897	formaldehyde	fumigant	
1900	Paris green	insecticide	USA (1st regulation)
1912	calcium arsenate	,,	W.C Piver (USA)
1913	organo- mercurials	fungicide	
1927	rotenone (fish poison)	insecticide	
1930	alkyl thio-cynate	,,	
1931	salisylamide	,,	
1933	dinitro-o-cresol (sinox)	,,	
1934	dithiocarbamate	fungicide	
1938	chloramil .	,,	
1939	*DDT*	insecticide	Dr Paul Mullre (Swizerland)
1939	schraedan	systemic insecticide	Dr G. Schraeder
1942	*HCH*	insecticide	1st used
1943	*DDT*	1st manufactured and used	Swizerland
1943	*2,4-D* and *MCPA*	herbicide	Templeman and Sexton (ICI)
1946	dinocap and crotonate	fungicide	
1947	sirvin and carbaryl	insecticide	Geiger & Co (Swizerland)
1950	malathion	,,	,,
1951	captan	fungicide	Kittleson (Standard Oil Co)
1958	diquat and paraquat	herbicide	I C I
1961	menazon	aphidicide	

2:2. Chlorinated Hydrocarbons. (Organochlorines).

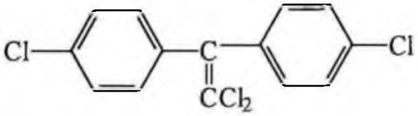
The chlorinated hydrocarbons are chemical compounds of carbon, hydrogen and sometimes oxygen atoms but always with one or more atoms of chlorine. These were the first synthetic chemical pesticides to be developed. Although many compounds were used as pesticides before 1945 (table 1), it was after that year when *DDT* **(I)** came into widespread use that, the era of chemical control of pests really began. By stopping a wartime typhus outbreak in Italy, *DDT* proved its effectiveness and so sparked off a revolution in pesticide manufacturing and usage[8]. Aldrin **(IV)**, dieldrin **(V)**, chlordane and heptachlor are other commonly used chlorinated hydrocarbons.



Aldrin **(IV)**



Dieldrin **(V)**



DDE **(VI)**

Since the discovery of the insecticidal properties of *DDT* in 1942[9], vast quantities of chlorinated hydrocarbons have been sprayed over the surface of the earth in an effort to destroy insects. These efforts initially met with incredible success in ridding large areas of the earth of disease-carrying insects, particularly, those of typhus and malaria[10].

In the course of time, the understanding has begun to dawn on us that this prodigious use of chlorinated hydrocarbons has not been without harmful and in some cases, tragic side effects. Chlorinated hydrocarbons, being usually highly stable compounds, are only slowly destroyed by natural processes in the environment. As a result, many organochlorine insecticides will remain in the environment for many years[11,12]. These highly stable pesticides are called "hard" pesticides.

Chlorinated hydrocarbons are also fat soluble, and thus, tend to accumulate in fatty tissues of most animals. The food - chain that runs from plankta, small fish through larger fish and birds to larger animals including man, tends to magnify the concentrations of organochlorine compounds at each trophic level.

In nature, the principal decomposition product of *DDT* is dichlorodiphenyldichloroethene (*DDE*) **(VI)**. Estimates indicate that, nearly one billion pounds of *DDE* are now spread throughout the world ecosystem[10] One pronounced environmental effect of *DDE* has been in its action on eggshell formation in many birds. *DDE* inhibits the enzyme, *Carbonic anhydrase* that controls the calcium supply for shell formation. As a consequence, the shells are often very fragile and do not survive until hatching time. This effect is expressed in the dramatic decrease in the population of predator birds such as eagles, falcons and hawks[6]. *DDE* **(VI)** also accumulates in fatty tissues of man. Although man appears to have a short-range tolerance to moderate *DDE* levels, the longer-range effects are far from certain.

In 1967, the organochlorines accounted for half the total US production of pesticides[6]. However, the use of these compounds has been steadily decreasing in the US, partly because, insects have developed resistance to them and also as a result of public concern about the large-scale application of these slow-to-disappear chemicals. Though most of them are now either completely banned or greatly restricted in use in the developed countries, it has been estimated that, residues of *DDT* and its metabolites in the environment may have a half-life of 20 years or more[6]. This is because, chlorinated hydrocarbons are not natural chemicals, in that, they are not synthesized by plants or animals. Produced by man in laboratories, these compounds present nature with a difficult disposal problem. Thus organochlorines tend to have persistence problems, resulting in environmental problems of grave concern to man.

Modern agriculture relies heavily on chemical pesticides. There is no doubt that pesticides have contributed much to improve the quality and quantity of agricultural products on a worldwide basis. But attendant with these benefits has been certain risks, some of which we have been slow to recognize. In the two decades immediately following World War II, the usage of *DDT* and related organochlorines as well as cyclodienes insecticides, were extensive and effective. They were also misused and as a result, instances of fish poisoning were documented, local populations of attractive birds were sometimes reduced drastically, and reproductive failures in some species of birds, especially raptors, were suspected, and in a few instances, proven to be associated with the use of the chemicals[13].

According to Kenaga[14], insecticides and herbicides make up the greatest bulk of pesticides as measured by number, volume and value. The period from 1969 to the present, is one of self-imposed constraints on the pesticides we use. Consideration for their impact on the environment as well as the human body itself, have resulted in the suspension or restriction on certain organochlorine pesticides in many countries. The introduction and clearance of new compounds has been made much more difficult by the exertion of stringent safety requirement[9].

The African continent, though not noted for the manufacture of pesticides, nevertheless, is noted as a leading consumer of these chemicals, due to the prevalence of pests as a result of its climatic conditions. Due to the extensive use of organochlorines in Africa, there is the need to monitor and assess the impact of pesticides. This led to the first ever co-ordinated FAO/IAEA meeting, on the effects of pesticide usage on the African environment, in Arusha[15]. This meeting gave birth to the recommendation for the need for scientific data on the use, dissipation and bioaccumulation of these chemicals, which will form the basis of policy formulation on the use of these pesticides. Following on the heels of the Arusha meeting, were others held in Vienna[16] and Upsala[17].

2:3. Pesticide Usage in Ghana.

Pesticide usage in Ghana dated from the colonial period in the early 20th century. It was primarily aimed at combating disease in the emerging cocoa industry at the time. Among the chemicals tried was kerosine[18], which was found to be ineffective, due to its low toxicity.

Others include nicotine sulphate[19], which was also abandoned as a result of its high cost and mammalian toxicity.

The use of synthetic organochlorine pesticides started in the country when *DDT* was introduced into the country in 1948[20], in the form of emulsion spray in the cocoa industry, and for vector (malaria) control. *DDT* was closely followed in 1950[21] by lindane, which was tried and found to be more effective than *DDT*. The pesticide market was after that, invaded by other organochlorines pesticides, following the development of resistance to lindane by some of the cocoa diseases.[21] Trials with organophosphates such as baytex, diazinon, dibron,and sumithion, as well as carbamates like carbaryl, were done after 1963, with varying successes.

Pesticide usage, both in tonnage and variety in the country is on the increase as is the case the world over. These increases are due partly to the commercialization of agriculture from the subsistence level, in cash and food crops, as well as livestock productions. It was also believed to be prompted by the need to increase or maintain the yields from existing farms, especially in the cocoa, cotton and rice industries, as a result of pest resistance[22] and the emergence of new pests[23].

Most of the pesticides used in the country for all the purposes of agriculture and public health control of pests are not produced in the country, but some are locally formulated. Table 2, shows some of the pesticides formulated in Ghana and the industries concerned[24]. The UK was one of the biggest exporters of pesticides to West Africa in 1980[25,26] with Ghana in the second position after Nigeria, as recipient, with 299.5 metric tonnes.

Table: 2: Some pesticides formulated in Ghana.

Pesticides	**Company**	
Raid	Johnson Wax Ltd	Accra.
Shelltox	Shell Gh. Ltd,	Accra
Gammalin 20 (Lindane)	Chemico Ltd,	Tema
Unden	Abwakwa Plant,	Kumasi

In line with the general world ban on organochlorine pesticides as a result of their enviromental persistence, bioaccumulation and biomagnification along the food-chain[27,28,29], Ghana has also followed and restricted the use of pesticides such as dieldrin, aldrin, endrin and *DDT*[30]. Despite this ban, organochlorines such as lindane (gammalin 20) for cocoa and endosulphan (thiodan) for cotton, are the choice of farmers in the production of these crops. The efficacy of these organochlorines in combating pests has made them attractive to vegetable and other food crop farmers, who despite advise and warnings still continue to use them. Another reason for the use of these pesticides by food crop farmers, is the low price for these items, since they are heavily subsidized, as against the others, by the authority[31].

2:4 Hazards of Pesticide usage on Water bodies.

The many ways in which water promotes the economic and general well being of society are known as "beneficial uses" The major ones are water supply, recreation and aquatic life. The relative importance of beneficial uses for any particular stream, lake or estuary, depends on the economy of the area and the desires of the people. Many applications such as public and industrial water supply are restricted within narrow ranges of water quality. Unregulated waste disposal (domestic, industrial, mining, or agriculture), conflicts with use of water as a potable source. Therefore, monitoring and the control of quality is required to ensure that, the best employment of the water is not prevented by the indiscriminate use of water courses for disposition of wastes.

The evaluation of the hazards of pesticides in the environment inevitably requires the matching of residues from pesticides with their biological effects. The public anxiety about environmental pollution has made the side effects of pesticides, now, the principal research activities of biologists, chemists and environmentalists. This is because of the ecological effects these chemicals have on non-target organisms in and around or remote from their area of application. The organochlorine pesticides have given rise to the greatest amount of investigative work[12], resulting in several of them being suspended or banned from general application in most developed countries.

In a study in the US[32], it came out that, the application of agricultural chemicals on row crops is a major source of non-point-source contamination of surface and ground water in the Mid-western. The study then concluded that, pesticides could be transported to streams and lakes by overland flows, through field drainage tiles or by ground water. Once contaminants are transported to a water source, dynamic surface and ground water interactions affect their storage and further distribution in the environment. Smith[33] and Juracek[34] found that pesticides pose a potential threat to water quality and many of these compounds have been detected in surface and ground water in the US in the last several decades. Halgreen[35] and Gillion[36] in related works on surface water assessment, came to the conclusion that, patterns of pesticide detection in surface water, depends on several factors which include usage, persistence, solubility and detection levels.

Pesticide usage as a human activity, has ecological effects on the value and resources of lakes, marshes, rivers and other water sources, as productive zones of the worlds food protein, water supply, recreation and wildlife conservation[37]. Many widely used insecticides such as toxaphene and *DDT* are highly toxic to fish, birds and bees[38]. In the US, it has been observed that spraying *DDT* to control spruce budworms on the Yellowstone river systems, severely reduced the population of important fish food organisms. The effects were observed for a year and were responsible for widespread mortality of brown trouts, mountain white fish and the long-nosed sucker.

Similar observations were made in Zambia[27] and in Botswana[28] when dieldrin was used in the control of tsetse flies. Thus, pesticide applications, though not deliberately intended for the aquatic ecosystem, in most cases, finally end up there by way of runoffs and irrigation canals, resulting in the death of fishes and other aquatic organisms which may be far removed from the area of application and the target organisms.

Some people, especially farmers and people with criminal intentions, sometimes accidentally or deliberately release pesticides into watercourses. An example was reported in a Ghanaian daily newspaper[39], in which some unscrupulous people were said to have deliberately applied chemicals suspected to be *DDT*, to kill fish in the Offin river for sale to the public. This action does not only put the public at a great risk of contamination from eating the fish, but they would also concentrate the chemical from drinking the water and other uses. In addition, many non-target organisms in the aquatic environment as well as birds and other animals dependent on the water, would also be adversely affected.

A similar case of pesticide misuse resulting in the pollution of the aquatic ecosystem occurred in Zambia[40] when a farmer intentionally dumped a drum of toxaphene into a river. The effects were noted 10 km downstream, involving the destruction of all forms of waterlife. The presence of pesticide residues of lindane, *DDT*, *DDE* and endosulphan, in fish oil extracted from the "sangara" *(Niloticus appendiculatus)*, caught in Lake Victoria[41], showed how pesticides from agricultural usage, especially in the catchment areas of water bodies, can find their way into these waters and their resources.

Pesticide contamination of water bodies is of grave concern to the health of man in particular and the environment as a whole. This is because, pesticides, especially, the organochlorines, being fat soluble, tend to bioconcentrate and bioaccumulate in organisms. These processes, viewed with regard to the complicated nature of the aquatic food-chain, becomes alarming as bigger and larger fishes up the chain, cumulating in man himself, tend to biomagnify these concentration.

Characterization of pesticide levels by many people, in various environments is the trend in environmental analysis at the moment. In most of these studies, as in this work, the focus is mainly on organochlorine pesticides, which tend to persist in the environment. In a study by Mansingh[42] and others, to determine insecticide contamination of the Jamaican environment, endosulfan α and β, lindane, *DDE*, endosulfan sulphate, dieldrin and diazinon, were identified. Of these, the first five were organochlorines while the last one is an organophosphate. They were found to be scattered all over the island in soils, surface water, sediments, flora and fauna, thus contaminating most of their rivers and other water bodies. The main sources of these pesticides were detected to be from runoffs from agricultural fields. Amounts found ranged from 0.037μg/kg for dieldrin to 6.4μg/kg for *DDE*. The average amount of lindane was around 1.75μg/kg. In their conclusion, they stated among other things that, the range of residue concentrations in most of their waters, were often well above the tolerance levels of many fish and shrimp species, and over their EPA's recommended levels, and that, many people who utilize raw river and well water are being exposed to risks.

Wong et al[43] and Reutergardh[44] and others, in monitoring environmental pollution in Hong Kong and Thailand respectively, also found varying levels of various organochlorines in their environments, especially in water, sediments and aquatic flora and fauna.

2:5. ANALYTICAL METHODS USED IN PESTICIDE DETERMINATIONS.

Today, most laboratories use one of the multiple detection techniques (paper, thin layer and gas chromatography) for the determination of chlorinated insecticide residues. Each has its advantages and disadvantages, but it is safe to state that GC has some advantages in offering reasonably rapid "semi-qualitative" and quantitative determinations of several compounds which may be present in one sample.[45]

2:5:1. Gas Chromatographic Method.

Gas chromatography, is the most widely used method for pesticide residue analysis due to its simplicity and selectivity. Most pesticides have been analysed using this technique[46,67]. Gas chromatography is an instrumental method invented in 1954 by Martin[48]. This method has been widely used for the analysis of pesticide residues in soils, sediments, flora and fauna tissues and in water.

A gas chromatograph consists essentially of a carrier gas, a column, a detector and a recorder. In gas chromatography, the components to be separated in a given sample are carried through the column by an inert gas such as nitrogen. The mixture is partitioned between the inert carrier gas and a non-volatile solvent distributed on a solid support, which makes up the column. The solvent selectivity retards the sample components according to their distribution coefficient until they form separate bands on the column.

The components leave the column in the gas stream and are recorded as a function of time by the detector. The various components are therefore identified by the use of the retention times and are quantified by the use of the area of chromatographic peaks. The separation of the components is achieved in the column. The success or failure of any separation will therefore depend on the choice of column.

There are two types of columns, namely, capillary columns and packed columns. Capillary columns are open tubes of small diameters with a thin liquid film on the wall. Packed columns consist of an inert solid material supporting a thin film of non-volatile liquid. The solid support, type and amount of liquid phase, method of packing, length and temperature of column, are important factors in obtaining good resolutions. Capillary columns have been found to have higher efficiencies and have been widely used for pesticide residue analysis. Examples of capillary columns in use for pesticide residue analysis are SPB 5, SPB 608 and SE 30. Packed columns that have also been used for pesticide residue analysis include dimethyl silaxane polymers like DC 200 and SE 30[48]

Detectors indicate the presence and measure the amount of components coming from the column. There are various types of detectors. There are non-selective detectors such as the conductivity cell and Flame Ionization Detector (FID). There are however, other detectors, which are selective. Examples of these include Phosphorus detector and Electron Capture Detector (ECD). They have the advantage of selectively detecting only certain types of compounds. The ECD is used extensively for the detection of organochlorines[49] due to its high sensitivity and selectivity for them.

Gas liquid chromatography serves as a means of qualitative analysis. The quantitative determination is based on the measurement of peak areas or peak heights. These are then correlated with the peak areas of or heights of standards of known concentrations. The peak area, which is the most commonly used method, can be measured by one of several techniques as listed below [50,51].

(i). Planimetry.

In this method, the peak area is traced manually with the use of a planimeter. A planimeter is a device for measuring areas, by measuring the perimeter of the peak

(ii). Height and Width at Half-height.

Since normal peaks approximate a triangle, one could approximate the area by multiplying the peak height by the width at half-height. The normal peak base is not taken since large deviations may be observed due to tailing or adsorption.

(iii). Triangulation.

Under this, height is measured from the base line to intersection of two targents. The base is taken as the intersection of the two tangents with the base line. The area is calculated by the triangle formular;

Area. = ½ b x h

Where; b = base of triangle,

h = height of triangle.

(iv) Cutting and Weighing Paper.

Peak areas are determined by cutting out the chromatographic peak and weighing the paper on an analytical balance.

(v) Disc Integrator.

This is a mechanical device in which the integrator pen is linked mechanically to the ball, which rides the rotating disc. When the recorder pen deflects, the ball moves away from the center of the disc and the ball begins to rotate. The rotation of the ball is transmitted mechanically to the integrator pen. Since the disc rotates at a rate proportional to the time base of the recorder chart, the integrator pen traces the line, which represents the area of the recorder pen's travel.

(vi) Electronic Digital Integrator.

In this method, the chromatographic input signal is fed into a voltage to frequency converter which generates an input pulse rate proportional to the peak area. When the slope detector senses a peak, the pulses from the voltage to frequency converter are accumulated and printed out as a measure of the peak area. The quantification is finally done by the correlation of peak area of standards with the concentration of a particular component in the sample. This is done with the help of a calibration curve of concentration and peak areas. Either absolute method or internal standard method may do the calibration.

2:5:2. OTHER ANALYTICAL METHODS FOR PESTICIDES.

Various other analytical methods have been used for pesticide analysis. These include:

2:5:2:1. Colorimetric Method.

Colorimetry with ultra violet (UV) and visible radiation has been used for pesticide residue analysis. A quantitative method for from the analysis for lindane has been described by

Davidow et al[52]. In this method, the pesticide was subjected to alkali hydrolysis yielding 1,2,4-trichlorobenzene, which has maximum absorption at 286nm. Other pesticides such as endosulfan, have also been analysed colorimetrically by heating in alkali medium to liberate SO_2, which combines with p-rosaniline in solution to produce a color absorbing at 570 nm[53] . Colorimetric methods generally have the disadvantage of low selectivity and sensitivity.

2:5:2:2. Bioassay Methods.

These methods are based on the measurement of death, growth or other physiological responses of animals, plants or microorganisms. Lang[54] developed one such method, for the analysis of pesticides such as lindane and *DDT.* Bioassay techniques have however declined in recent times, because of its lack of specificity and difficulties in comparison with some other procedures in obtaining reproducible results.

2:5:2:3. Tracer Methods.

These have been used extensively for pesticide residue analysis. ^{14}C labeled lindane[55] have been used to study the fate and persistence of pesticides. It usually involves dry combustion and measurement of radiation emitted by the labeled substance using a liquid scintillation counter.

2:5:2:4. Distributed Measurement [56].

For the most part, water analysis has involved collecting samples from designated sites and transporting them to the laboratory where determinations are performed. If the number of collection points and the collection frequency are modest, this is appropriate and cost-effective. However, monitoring the water quality of an entire riparian basin, is another matter entirely, especially when a river or lake serves as water source and catchment for multiple uses including farming and drinking water.

One approach for continually acquiring and processing the massive amount of analytical data needed to support comprehensive freshwater monitoring is based on a system design known as "distributed measurement". Here, instead of the usual collect/ transport/ analysis scenario, a distributed measurement system uses an array of on-line sensors, positioned at strategic sites along the river or lake basin or catchment. Analytical data collected by sensors are continually routed over data networks to a central collection point, where they are processed and integrated to provide a constantly updated quality map of the monitored water system.

At present, the fully automated on-line analytical distributed measurement network does not exist. Should such a system come into operation, it will be a great relief to analytical chemists, working on riparian environments.

2:5:2:5. Pulsed-Flame Photometer Detector (PFPD) and a Direct Sample Introduction (DSI) Device[57].

This method, used by Jing and Amirav, was used to analyze pesticide residues in food products. They described it as fast, sensitive and informative. It is based on sampling with a novel direct sample introduction (DSI) device, gas chromatographic analysis and pesticide detection with the pulsed-flame photometric detector (PFPD).

Sampling with the DSI is based on introduction of blended fruit or vegetable in a small glass vial that retains the harmful nonvolatile residue and is disposed of after the analysis. The DSI-GC-PFPD combination provides several new features that were demonstrated and discussed. Though this method was originally developed for pesticide residue analysis in food products, it can be used with or without modification for the analysis of pesticides in water and sediments.

2:5:2:6. Supercritical Fluid Extraction. (SFE)[58].

A supercritical fluid (SF), is defined as "a fluid that is above both its critical pressure and temperature". Supercritical fluids possess unique properties, intermediate between those of a gas and a liquid, that depends on the pressure, temperature and composition of the fluid. In particular, the density (i.e. the solvent power of the fluid), may be adjusted by correctly choosing both the pressure and the temperature. A typical SFE system consists of a high-pressure pump that delivers the fluid of an extraction cell containing the sample and maintained at the correct pressure and temperature. The SFE may be carried out in either a static or dynamic mode. The SFE has become a promising alternative technique in recent years for solid and semi-solid matrices, due to its advantages over classical solvent extraction, especially soxhlet extraction.

2:5:2:7 In situ Corona Reaction[59].

This is an apparently novel technique to aid the detection of a variety of inorganic and organic compounds in environmental and drinking water samples. In an attempt to combine the convenience of an absorption measurement, the background suppression and AC modulation, characteristic of reagent-base flow injection analysis (FIA), with more convenient reagents, Johnson investigated an apparent novel approach that uses UV absorption measurement together with a chemical reaction step induced in situ via highly reactive species generated in a high-voltage point-to-liquid corona discharge. By processing the double signature of absorption spectra measured before and after the contactless electroreagent corona reaction, suppression of the background of non-reacting species is obtained. All these are achieved by modifications to a HP 8452A diode array spectrometer to allow for the in situ corona dosing.

CHAPTER THREE

EXPERIMENTAL

3:1. The study area.

The catchment areas of lakes Kasu and Nyafie, and some of the others at Kasunya, (fig.1), are the sites of some of the large-scale intensive rice farmlands in the southern part of the country. It comprises the rice-farms of the Irrigation Development Authority (IDA) of the Ministry of Food and Agriculture (MOFA), which is centered on lake Kasu, and the Korean Semaul Farms Limited (KSF), situated on lake Nyafie all in the Dagme-west District of the Greater Accra region.

The establishments of these farms were the direct efforts of past and present governments in boosting agricultural production and to provide employment for the rural youths. This gesture is with the hope that, there would be a corresponding improvement in the financial and social lives of the people, thereby encouraging them to stay in the area instead of migrating to the towns and cities for non-existing jobs. Though the extent to which these socio-economic goals have been attained are outside the scope of this study, there are some agricultural technologies employed by the farmers, which are likely to have some effects on the people and the environment in the project areas as a result of these schemes.

Lake Kasu and the others including Nyafie, are large fresh water bodies at Kasunya, near Asutsuare, in the Tettimang traditional area in the Lower Volta basin of the Dangme-West district, within the Greater-Accra region of Ghana. Historically, lake Kasu in particular, which was about 2 km wide and 6 km long, (fig.2), and the others, which are about 15km away on the easten flank of the Volta river, facing north, were the sole source of drinking water for the people staying along their banks. They were also reservoirs for fishes, resulting in a vibrant fishing industry.

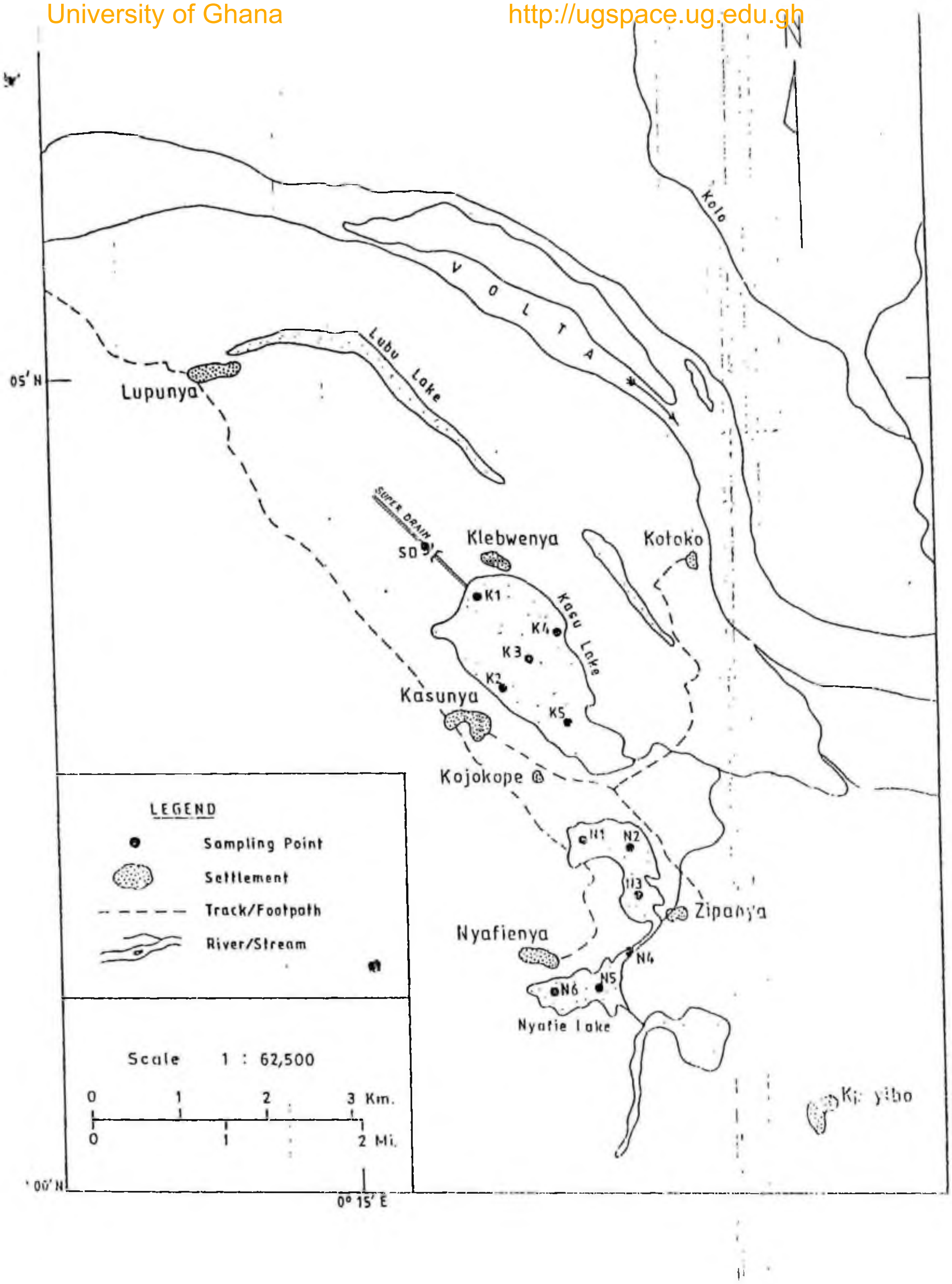


Figure 2. Map of the Study area showing sampling points

This once vibrant fishing industry, according to the people, began to decline after the construction of the Akosombo dam. Their belief is that, the construction of the dam prevented the Volta from flooding these lakes, leading to their fish stocks and waters not to be replenished every year, as was normally the case in the past. The problems of the lakes and the people were compounded, when the government of the first republic acquired a large track of land within the catchment area of lake Kasu, for the establishment of the now defaunt Ghana Sugar Estates Limited (GHASEL), based at Asutsüare.

When GHASEL folded up, its assets were taken over by the IDA for the production of paddy rice. The IDA, in developing its land area for rice production, directed all the drains from the rice fields into lake Kasu, through a single large drain, locally termed “super-drain”. Due to the intensive mechanized nature of the farms, large quantities of fertilizers and pesticides were used to increase yields. To grow the rice after the land had been prepared, it is flooded with water from the Volta. It is this water together with the applied fertilizers and pesticides that were utilized by the crops, as well as a large amount of silt, that is carried by the smaller drains into the super-drain, which takes them to lake Kasu, the final dumping ground.

3:2. Design and Administration of Questionnaire.

Before the chemical analysis of the water and sediments, a survey was conducted in the study area to gain an insight into the types of pesticides that the farmers in the area use.

A questionnaire (appendix A) was designed for this purpose to solicit information on;

- agrochemicals used in the production and storage of crops,
- sources of these chemicals,
- type of crop on which chemical is used,
- disposal of damaged and/or expired chemicals, and
- how these chemicals are stored when not being used.

Fifty (50) farmers, made up of 20 males and 30 females, randomly selected from the catchment areas of the two lakes were administered the questionnaire. The contents of the questionnaire were translated into the local languages of Dangbe and Ewe for those who could neither understand nor read the English language. Their responses were then written down in the appropriate column on the questionaire.

3:3. Selection of Sampling Sites.

Lake water, unlike a river water, is not uniform in the sense that resident time and turnover rate of substances including the water, is very high and very low, respectively. Thus, no single sample can be taken to be representative of the lake. In line with this, several sampling sites, as shown in fig. 2 were chosen in each lake as well as in the "super-drain" that empties into lake Kasu. Since the purpose of the study was to identify and quantify the pesticides present in the waters and sediments of the lakes, as well as water quality parameters, sites were selected such that the overall sample collected in each lake, would be representative of that lake. In all, five (5) sites (K1 to K5) on lake Kasu, six (6) sites (N1 to N6) on lake Nyafie and one site (SD) on the "super-drain" were chosen as shown in fig 2.

3:4. Sampling.

Sampling was done four (4) times in the year, i.e in January, February, June and July. The first period, from January to February was for the dry season while the second period from June to July, was for the rainy season.

At each sampling site, four (4) water samples and a sediment sample were collected at a time. The four (4) water samples were collected for:

- dissolved oxygen (DO)
- biochemical oxygen demand (BOD)

- other water quality parameters, (such as conductivity, turbidity etc,) and
- pesticides

Thus, on each sampling trip, five samples were collected from the "super-drain, 25 samples from lake Kasu and 30 samples from lake Nyafie an overall total of 60 samples per trip. In all, 196 water samples and 48 sediment samples, totaling 220 samples were analyzed.

3:4:3. Type of sample container and conditioning.

For DO, and BOD samples, 250 mL BOD glass bottles with stoppers were used while for pesticide samples for water, 1.5 L borosilicate glass bottles with teflon-lined caps were used. While wide mouth borosilicate bottles with stoppers were used for sediment samples, one-litre polyethylene bottles with covers were used for water samples in the determination of other water quality parameters[60]

The containers for water samples (for water quality), were washed with detergent then rinsed three times with tap water. They were then treated with chromic acid, rinsed three times with tap water, then once with a 1:1 nitric acid and finally, three times with distilled water. Those containers used for both water and sediment samples for pesticide determination were washed with detergent then rinsed three times with tap water and once with 5M HCl solution. This was then followed with double distilled water (3 times), acetone (2 times) and pesticide grade hexane (2 times), after which the bottles were dried (uncapped) in hot air oven at about 360 ^{O}C for one and half hours[61]

3:4:4. Sample Collections.

With the exception of the samples collected in the "super-drain", which was done by wading in the water, all the samples from the two lakes were collected while in a canoe. Below, is a step by step procedure used in taking samples for the determination of the various parameters.

(i) Samples for water quality parameters.

The bottles were uncapped and dipped just below the water surface and filled with water. This water was then poured away on the other side of the canoe, and was repeated two more times. After the third time the water filled bottle without any air bubbles was closed. Samples for DO were fixed before capping, by adding 2 mLof manganous sulphate solution below the surface of the solution, followed by 2 mL of alkaline-azide-iodide solution at the surface of the solution, shaken for sometime and allowed to stand. For BOD and the other water quality parameter samples, nothing was done to them before capping.

(ii) Samples for pesticides.

One litre water samples specifically for pesticide determinations were collected in the same way as was done for BOD and other water quality parameters samples. For the collection of sediment samples, divers were hired to dive and scoop up the sediments using a metal trowel. These were then put into their containers. Each sample as it was collected, was put on ice in an ice chest. After all the samples have been collected, they were then transported to the laboratory in the ice chests.

3:5. Analysis of samples.

The quality of the final result obtained in any analytical work depends on the care and type of sampling and pretreatment procedures followed as well as the type and nature of the equipment used in the final analysis. Most of the methodologies used in the study were based on the established protocol at the chemistry laboratory of the Water Research Institute of the CSIR, Accra, and on GEMS Water Operational Guide[60] as well as APHA's Standard Methods for Examination of Water and Wastewater [61], with relevant modifications when necessary.

3:5:1. Water Samples.

The water samples were tested for water quality parameters as well as for pesticides. The water quality parameters analyzed for are pH, temperature, conductivity, turbidity, DO, dissolved solids (DS), suspended solids (SS) and total solids (TS) and transparency as physical parameters, BOD, chemical oxygen demand (COD) and Cl^- as chemical parameters with NO^{3-}-N, NO^{2-}-N and PO_4^{3-}-P as nutrients and Ca^{2+}, Mg^{2+}, Na^+ and K^+ as major ions. The others are total hardness, Ca hardness and Mg hardness.

3:5:1:1. Analysis of various parameters.

(i) pH and Temperature.

Temperature and pH were determined directly in the field using portable battery operated digital electronic temperature and pH sensometers respectively (Phillip Harris scientific equipment). In measuring the pH, the equipment was calibrated by first dipping the sensor into a standard buffer solution of pH 9 and then rinsed several times with distilled water before dipping it into another standard buffer solution of pH 4 and rinsed again. It was then dipped into the water with the sensor just below the water surface and held still for some few minutes till a constant reading was obtained. It was done two more times. The average of these readings was then taken as the pH for all the samples at that particular site, for that particular sampling operation.

For the temperature measurements, the sensor of the equipment was also dipped just below the surface of the water and held still for some minutes till a constant reading was obtained and was repeated twice. The average of these readings was then recorded as the temperature (^{O}C) of all the samples collected at that particular site for that day.

(ii) Turbidity and Conductivity.

Unlike temperature and pH, turbidity and conductivity were determined in the laboratory. For turbidity, a DRT 100 HF turbidity instrument was used. Turbidity measurement makes use of the presence of particles (dissolved or suspended) in the water that scatter light passing through the solution. The extent, to which the light is scattered, is directly proportional to the amount of particles in the solution. Thus high turbidity values suggest large amount of particles in the solution. Calibration of the instrument for turbidity measurements was done using standard solutions provided in sealed glass bottles by the manufacturers for that purpose. With the calibration done, sample solutions after shaking, were poured into special glass bottles, capped, put into the instrument and the turbidity read in NTU (Nephelometric Turbidity Unit). The solution was then poured out, the bottle rinsed and refilled with another aliquot of the same sample, and the reading taken again. The average of these two readings was then recorded as the turbidity of that sample.

A Jenway 4020 conductivity meter was calibrated using a standard solution of KCl with a known conductivity value, in a special container into which the probe was dipped and the value read on the monitor in μS/cm. After that, the probe was taken out, rinsed several tines with distilled water and dipped into about 50 mL of the sample in a beaker, purposely used for conductivity measurements. The procedure was repeated with another 50 mL solution of the same sample with the mean of the two reading taken as the conductivity for the sample.

(iii) DS, SS and TS.

Gravimetric methods were used for the determination of these parameters. Glass-fiber filter discs (Whatman GF/C grade), and evaporation dishes, specially prepared were used. The preparations were as follows.

The glass-fiber filter discs.

The discs (pore size = 0.45um) were placed on the all-metal filtration unit membrane filter holder with pump attached, and the discs washed with three 200 mL volumes of distilled water. Almost all traces of water were removed by continuing to apply the vacuum, and the washings discarded. They were then heated in an oven to a constant weight and then kept in a desiccator.

The evaporation dishes.

The dishes first were washed and rinsed with distilled water. They were then heated in a muffle furnance for one hour at 550 ± 50 ^{O}C, cooled in a desiccator and left there till required.

DS and SS determinations.

The filtering apparatus was assembled and the glass-fiber filter disc put in place. The sample was shaken vigorously and 100 mL was rapidly transferred to the funnel by means of a 100 mL graduated cylinder. Suction was then applied for about three minutes to remove as much water as possible. The filtrate was carefully transferred into a pre- weighed evaporation dish and evaporated to dryness on a water- bath, for the determination of DS. The evaporated sample was then dried for about an hour at 105±2 ^{O}C in the oven. It was allowed to cool in a desiccator and weighed. The drying and weighing was continued until a constant weight was obtained.

The glass-fiber filter was gently removed and dried in an oven at 104 ^{O}C for one hour, cooled in a desiccator and weighed to determine the SS. The drying, cooling and weighing were repeated to a constant weight.

The TS determination was done through calculation. It involves the addition of the DS and SS values that were determined. See appendix on calculations.

(iv) DO.

DO was analyzed using Winkler's Azide Modification Method. The DO, though fixed in the field was determined in the laboratory the same day. To the fixed DO water samples were added 2 mL of conc H_2SO_4 to digest the precipitates formed. The bottle was gently shaken a few time to hasten the digestion. 100 mL portions of the resulting solution was then titrated with a standard sodium thiosulphate solution, with starch as indicator.

(v) BOD

The samples taken for BOD analysis, on reaching the laboratory, were put in an incubator at 20 ^{O}C for 5 days. On the fifth day, the oxygen in the samples were fixed, digested and titrated with the standard sodium thiosulphate, in the same way as was done for the DO samples. For sites, whose DO values were less than 8 mg/L, BOD samples were diluted, with dilution water. In such cases, 100mL of the sample was taken and made up to 600mL, using 500mL of the dilution water and put into the two BOD bottles. The DO of one of the diluted and aerated samples is determined on the first day and the other incubated for 5 days. The BOD determination was done on the 5 day. A blank of the dilution water was also incubated for five days and analyzed.

(v) COD.

Chemical oxygen demand was analyzed using the dichromate method. To 5 mL of the sample in a 100mLconical flask was added 3 mL of standard $K_2Cr_2O_7$, 7 mL of conc. H_2SO_4, 7 mL of silver (I) sulphate and refluxed at 150 ^{O}C for two hours. After the two hours, the flask with its contents were cooled and diluted to 50 mL with de-ionized water. To the 50 ml solution was then added 2 drops of ferroin (an o-phenanthroline ferrous complex) as indicator and the excess dichromate titrated with standard ferrous ammonium sulphate (FAS) solution. The COD was measured as O_2 equivalent, proportional to the dichromate consumed during the refluxing by the organic matter present when Cr^{6+} ions were reduced to Cr^{3+} ions. During the digestion, the reaction taking place according to Baird [68] can be represented as

$$Cr_2O_7^{2-} + 14H^+ + 6e \longrightarrow Cr^{3+} + 7H_2O.$$

The number of moles of O_2 that the sample would have consumed equals 6/4 = 1.5 times the number of moles of dichromate, since the later accepts 6 electrons per ion whereas O_2 accepts only 4:

$$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$$

(vi). Nutrients.

NO_3^--N, NO_2^--N and PO_4^{3-}-P were each determined spectrophotometrically using an LKB Biochron Ultrospec II UV/Visible spectrophotometer. In nitrate-N determination, 10 mL sample solution, I mL of .3M NaOH and 1 mL of a reducing agent (amalgamated Cd/Cu) were heated for 10 minutes at 60°C, cooled and to it was added 1 mL of the coloring agent (sulfanilamide in conc. HCl). For nitrite-N, the same procedure was followed with the exception of the addition of the reducing agent and the heating. In both cases, the absorbance of the resulting solutions was then measured at 540 nm spectrophotometrically, after standardization and calibration, using glass cuvettes.

In the case of phosphate-P, the molybdenum blue method was used. 50 mL each of the samples were measured into conical flasks and to each 50 mL of 2M-ammonium molybdate solution was added. Each mixture was swirled to mix well after which 0.5 mL of the stannous chloride solution was added and mixed, upon which the blue color of the heteropoly phospho-molybdate ion was produced. The absorbance was read at a wavelength of 690 nm. Prior to all these, standard phosphate solutions were passed through the same process to calibrate the machine.

(vii) Chloride (Cl^-) ions.

The Vallard (argentrometric) method was used to determine the concentration of chloride ions. 100 mL of the sample solution was taken and to it was added 1 mL K_2CrO_4 as indicator and titrated against standardized silver nitrate solution to a brownish endpoint.

(viii) Sodium and Potassium

Sodium and potassium were determined using a Gallenkamp flame emission spectrophotometer with liquid petroleum gas as the fuel gas. The equipment was first calibrated with standard solutions of their salts with the appropriate filter selected. The reading in mg/L was direct, thus no calibration graph or calculation was required. After the calibration, the sample solutions were treated the same way and values obtained. After the determination of each sample, the rubber tube, when removed from a solution was each time washed with de-ionized water before being used again. While analyzing the sample solutions, one of the standard solutions used for the calibration was also intermittently analyzed.

(ix) Calcium, Magnesium and Hardness.

Calcium concentration, calcium hardness and total hardness were determined by complexometric titrations using EDTA. Magnesium concentration and magnesium hardness were calculated from the calcium values.

For calcium, 50 mL of the sample solution was transferred into a conical flask then 2 mL of 1M NaOH and a pinch of murexide (ammonium purpurate) powder was added as indicator. The deep red colored solution formed was then titrated with the EDTA to a purple endpoint. Calcium concentration and calcium hardness were then calculated from the titration results.

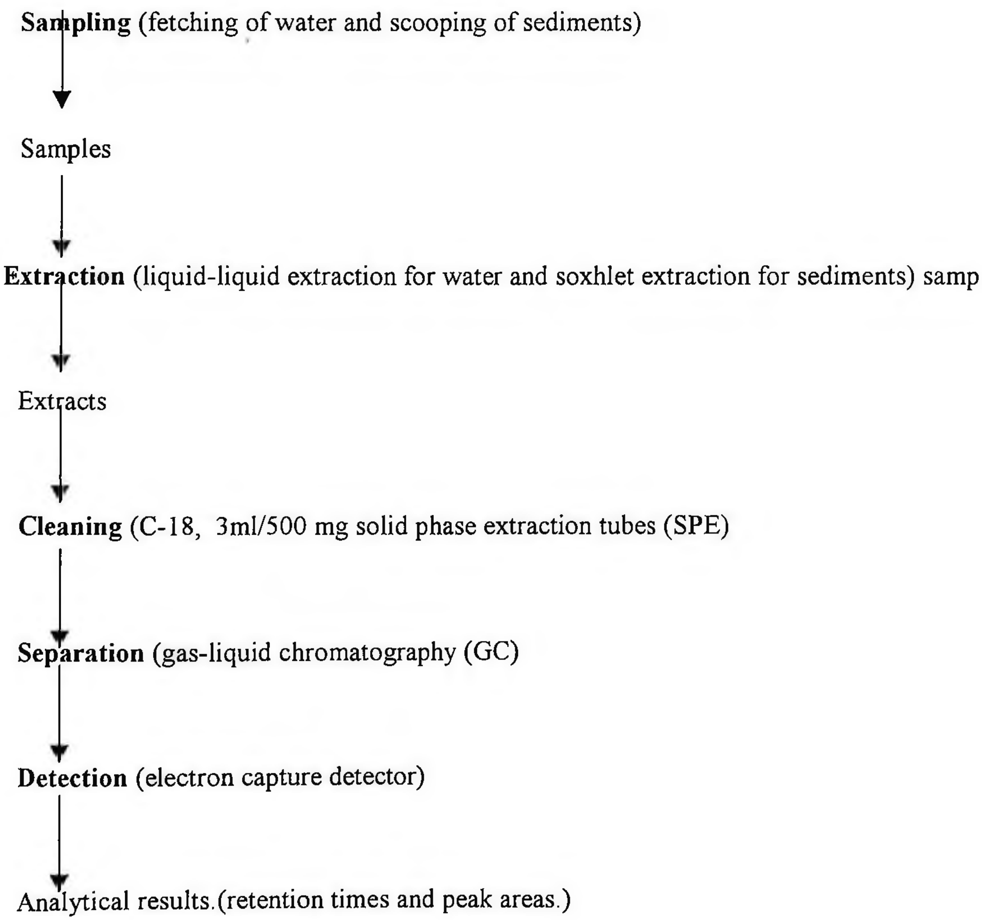
Total hardness was also determined using 50 mL of a sample in a conical flask to which had been added 1 mL of an NH_3 / NH_4Cl buffer (pH of 10) and a pinch of Eriochrome Black T as indicator in this case. The resulting solution (wine colored) was titrated with EDTA solution to a sea-blue color endpoint. Total hardness was then calculated from the titration results.

To obtain and magnesium hardness, the calcium hardness value was then subtracted from the value for total hardness as water hardness is usually assumed to be due to the presence of calcium and magnesium ions. The magnesium concentration was also calculated from its hardness result.

3:5:2:2. Pesticides.

Pesticide residue determinations for the water and sediment samples were carried out using a Hewlett-Packard Series II Model 5890 gas –liquid chromatography (GLC) with a 30m SP5 phase capillary column and a ^{63}Ni electron capture detector (ECD). Fig. 3 shows the scheme used in the analysis of pesticide residues in both water and sediment samples.

Fig. 3. Flow chart of procedures followed in the analysis of pesticides.



(i) Extraction procedure.[60]

The one litre water samples specifically collected for pesticide residue analysis was extracted with dichloromethane (CH_2Cl_2) in 2L separating funnel. 50 mL of the dichloromethane was added to the water sample in its original sample bottle and tightly closed with an aluminum foil line cap. It was then shaken manually for 30 minutes and the contents transferred into a 2L separating funnel. After allowing it to stand for 10 minutes to enable the organic and aqueous phases to separate, the organic layer, was transferred into a 1L-separating funnel. The aqueous layer was returned to the sample bottle while the 2L separating funnel was rinsed twice with dichloromethane: 30 mL at first followed by 20 mL, transferring the solvent to the sample bottle after each rinsing. The shaking, separation and rinsing procedures outlined above was then repeated twice.

After the third separation, the organic layer was again transferred into the 1L separating funnel and the aqueous layer was discarded. The 2L separating funnel was then rinsed as before but this time, the rinsing were added to the contents of the 1L funnel. The 1L-separating funnel was shaken for 2 minutes and allowed to stand for 10 minutes.

About 5cm layer of anhydrous sodium sulphate (Na_2SO_4) put in a 125mL sintered glass funnel was set upon a 500mL round-bottom flask. The flask with the funnel was then connected to a rotary evaporator (as a filtration column) for vacuum filtration. The organic layer in the 1L-separating funnel was then drained onto the filtration column. 50 mL of dichloromethane was added to the aqueous phase remaining in the separating funnel, shaken well for 2 minutes and again allowed to stand for 10 minutes. The organic layer was drained through the Na_2SO_4 filter column and the aqueous layer was discarded. The separating funnel was rinsed twice with 25 mL dichloromethane and the solution passed through the filter column. The Na_2SO_4 column was washed with 50 mL of CH_2Cl_2 and the vacuum applied until the Na_2SO_4 was dry.

Each extract was evaporated under vacuum using the rotary evaporator at 33 ^{O}C (in a water bath) to about 5 mL. This was then transferred with 4 x 2 mL rinsing to a 25 mL graduated weighed samples were then added, one nanogram each of the aforementioned pesticides in 5 mL of double distilled water. They were then covered with aluminum foils and left in the laboratory to air dry. After drying, each weighed sample was then extracted, concentrated, cleaned up and analyzed on the GC

3:7. Pesticide Analysis.

3:7:1. The GLC.

The GC used was a Helweltt-Packard Series II, Model 5890 with a 30 m SP5 phase capillary column and a ^{63}Ni electron capture detector (ECD). Both carrier gas and make-up gas are nitrogen. Table 3 shows the parameters and conditions used in the determinations.

Table 3. Conditions for the GC analysis.

PARAMETER	**CONDITION**
Column internal diameter	0.53 mm
Column length	30 m
Column film thickness	1.5 μm
Detector temperature	250 ^{O}C
Injector operating temperature	200 ^{O}C
Oven (column) temperature	200 ^{O}C
Flow rate of N_2	30 μm per minute
Injection volume	1 μL

1μL of each of the individual and / or combinations of the standard pesticides used, (Aldrin, DDT, DDD, DDE, Lindane, HCB and 2,4,5-TCB) were injected into the GC and the retention times[62,60,61] obtained. In the case of the sample extracts and recovery samples, the same volume of 1μL was taken in each case and subjected to the same treatments as the standards.

and 2 mL of double distilled water. After conditioning the SPE columns as outline for the water sample extracts, the extract was loaded on to it and treated in the same way as for water sample extracts.

3:6. Extraction and Cleanup Recoveries.

Extraction and cleanup recoveries were done to determine the efficiency of the methods used in the extraction, concentration, cleanup and analysis of pesticides. In each case, the amount of pesticide recovered was expressed as a percentage of the amount that was originally added..

3:6:1. Water.

To 1L of pesticide-free distilled water, was added 1 ng of each of the following pesticides, namely, aldrin, dieldrin, lindane, 2,4,5-TCB, HCB, DDT and DDE. The pesticide-seeded water was then taken through the same procedures as the water sample.

3:6:2. Sediment.

For a pesticide free soil sample with a comparable matrix, the following was done.

Some soil samples from the yard of the Water Research Institute (WRI) were taken from a depth of about six inches, ground and soaked in distilled water for about ten hours. The suspension was then agitated and filtered using a 63-μm sieve. The residue was then washed four times with the pesticide-free distilled water then three times with acetone and once with the pesticide grade dichloromethane. The soil sample was then dried in an oven at 500 ^{O}C for 24 hours. 5.0 g was then taken and subjected to the treatment for sediment samples and analyzed on the GC for the presence of pesticides.

When it was confirmed from the GC analysis that no pesticides were present in the soil samples, 5.0 g of it were weighed in beakers that were purposely prepared for this. To the measuring cylinder. It was followed by evaporation to 3 mL, under a gentle stream of N_2 at (water bath), at atmospheric pressure.

(ii) Cleanup.

Pre-prepared Bonded C-18 SPE (3cc/500mg) columns also referred to as bonded elut (Varian, USA), were used for the cleaning of both water and sediment sample extracts. The bonded columns were conditioned prior to loading of the sample extracts, by flushing them with 2 mL of 98% pesticide grade methanol (Sigma Aldrich Chemical Company, USA) followed by 1 mL of double distilled water. 3 mL sample extracts were then loaded onto the conditioned SPE columns and washed with 2 mL of a 30% solution of the pesticide grade methanol, and 1 mL of double distilled water. The column is then air dried by blowing air through it (using a compressor) for about 20 minutes to remove all traces of water and methanol. The dried SPE column was then eluted with 4 mL of pesticide grade hexane (Mallinkcoff Special Chemicals of the USA), in four portions of 1mL each at an eluent flow rate of about 2mL per minute. The eluted volume (4 mL) was then ready for analysis on the GC.

3:5:3. Sediment samples.

Sediment samples were only analyzed for pesticides.

(i) Extraction.

The sediment samples were air dried in the laboratory. They were then ground and sieved through a 63µm screen. 5.0g triplicate samples of the sieved sediments, accurately weighed and transferred into single thickness cellulose extraction thimbles (33mm id x 100mm ed) were soxhlet extracted for about 5 hours, with 150ml of the pesticide grade methanol. The extracts were allowed to cool.

20mL of the extract was evaporated to about 3mL. This was then taken up in 1 mL methanol

The retention times of the standard samples were used to identify the possible pesticides present. Table 4 shows the retention times of the standard pesticides used in the study.

Table 4 Retention times of Standard Pesticides Used in the Study.

Standard Pesticide	Retention Time(Minutes)
Aldrin	12.112
HCB	2.242
Lindane	2.500
2,4,5-TCB	3.017
DDE	7.647
DDD	9.965
DDT	12.717

3:8 Calculation of Pesticide Concentrations.

The quantification of the pesticides identified in the samples were computed from the peak area using the following equation.[60]

$$Csamp = \frac{Psamp}{Pstd} \times \frac{Vstd.\ Inj.}{Vsamp.\ Inj.} \times \frac{Vext}{M} \times Cstd$$

where;

Csamp = concentration of sample

Psamp = peak area of sample

Pstd. = peak area of standard

Vstd.inj. = volume of standard injected

Vsamp inj. = volume of sample injected

Vext. = volume of extract (ml)

M = weight (g) or Volume (L) of sample extraction

Cstd = concentration of standard.

CHAPTER FOUR

RESULTS AND DISCUSSION

4:1. Results of the Survey

The survey was conducted to solicit information on the type of pesticides used by farmers in the study area. Out of the 50 farmers randomly selected for the administration of the questionnaire, 34 responded to it, giving a response level of 64%.

4:1:1. Class of Pesticides.

Pesticide is a generic term used to describe all chemical substances used to either kill or control undesirable organisms. There are four main categories of pesticides in use, namely, organochlorines, carbamates, organophosphates and pyrethroids. Each of these categories has many classes of pesticides with regard to the kind of pest for which the pesticide is being used. Some of these classes are insecticides, fungicides, herbicides, acaridicides, molluscicides e.t.c. Table 5 shows the classes of pesticides used by farmers in the study area.

Table 5. Class of Pesticides Used in the Study Area.

Class of Pesticides Used	**Number of Users**	**Percentage (%)**
Insecticides	32	94
Fungicides	24	70.6
Herbicides	26	76.5
Growth Regulators	22	64.7
None	2	5.9

Generally, it is clear from table 4 that, the majority of our farmers make use of pesticides in the control of pests. This is evident from the table in which 32 out of the 34 respondents constituting about 94% of the polled respondent population, make use of a pesticide in their agricultural activities. This is also shown graphically in fig. 5. Only two farmers (5.9%) do not make use of any pesticide at all.

The table also shows that four main classes of pesticides namely, insecticides, fungicides, herbicides and growth regulator are used by the farmers. It is also clear that insecticides are the most used, about 94% (fig. 5), while the others, herbicides (76.5%), fungicides (70.6%) and growth regulators (64.7%) are used to varying degrees. The most encouraging news from the survey is that, apparently, our farmers do not use organochlorine pesticides, but rather, use only carbamates, organophosphates and pyrethroids.

4:1:2. Type of Chemical Used.

Tables 6,7, 8 and 9 depict the details of each class of pesticides in use by the farmers. From these tables, it is clear that most of the chemicals used belong to the carbamates, organophosphates and pyrethroids. The farmers without any suggestions on the questionnaire gave the names of the pesticides used. In cases where the farmers were not able to give the name of a pesticide offhand, they were asked for the pesticide containers. The large number of the different types of insecticides used attest to the fact that, in the humid climate of the tropics, insects are the major pests to farm crops and animals.. Herbicides are used mostly on the rice farms. The percentages were calculated based on the number of farmers using that class of pesticide. The most encouraging news from the survey is that, apparently, our farmers do not use organochlorine pesticides, but rather, use only carbamates, pyrethroids and organophosphates.

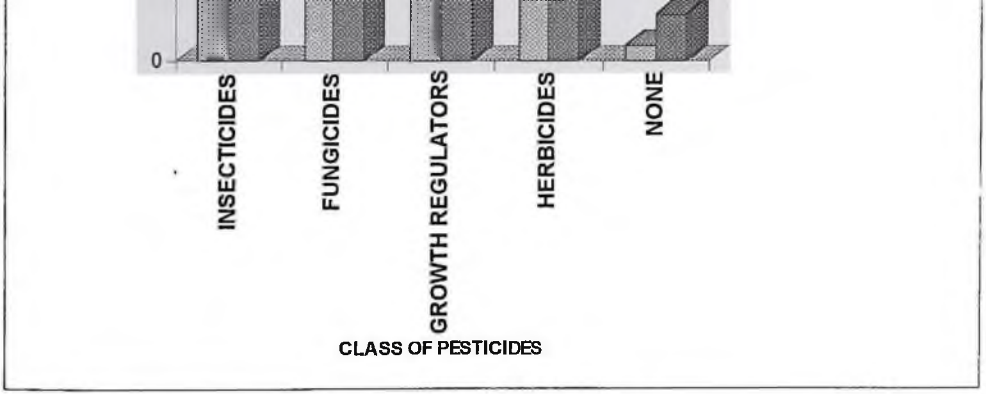


Fig. 4. Class of Pesticide, Number of Users and Percentage

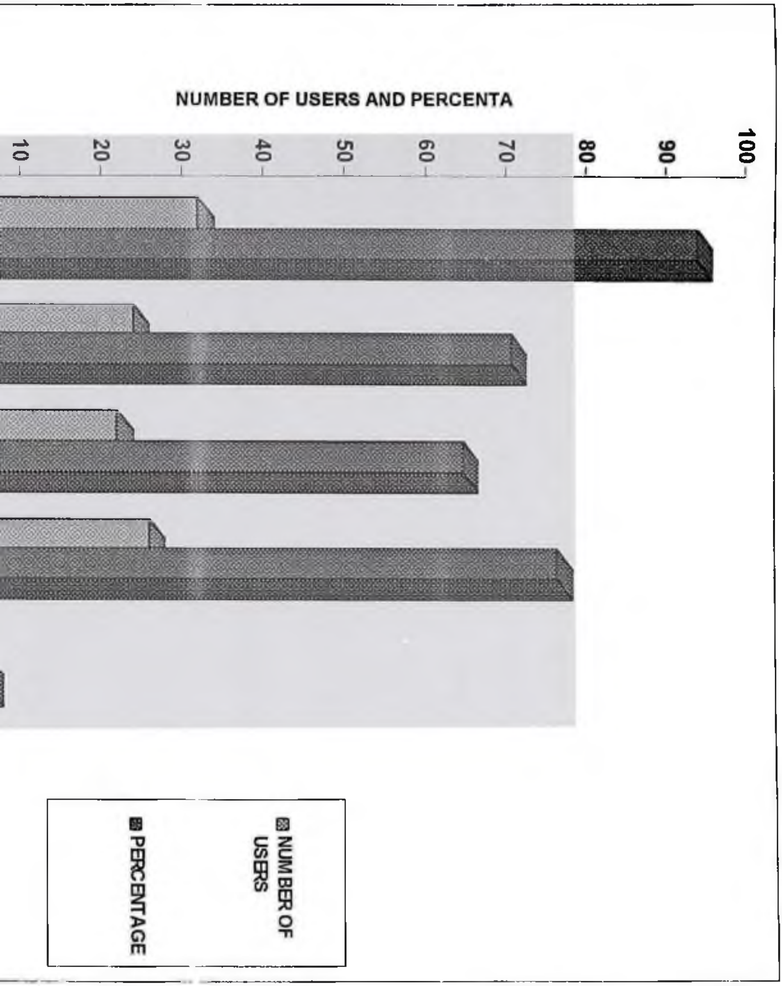

NUMBER OF USERS AND PERCENTA
10
20
30
40
50
60
70
80
90
100
NUMBER OF USERS
PERCENTAGE

Table 6. Insecticides Used by the Farmers.

Name of Insecticide	Number of Users	Percentage (%)	Category
Karate-25EC	24	75	Pyrethroid
Unden	13	40.6	Carbamate
Perfekthion	20	62.5	,,
Fufadan-3G	14	43.6	,,
Cymbush	29	90.6	Pyrethroid
Sumithion-50EC	18	56.33	Organophosphate
Kumakate	6	18.8	Others**
Elocron	13	40.6	Carbamate
Sumicombi-30EC	21	65.6	Others
Actellic	32	100	Organophosphate

** Others refer to those chemicals that can not be identified from the Pesticide Manual [69]

Table 7. Herbicides Used By the Farmers.

Name of Herbicide	Number of Users	Percentage (%)	Category
Furadane	14	53.9	Others
Basta-20SL	15	57.8	Others
Basagram-PL2	11	42.3	Carbamate
Ronta	10	26.0	Others
Dual	12	46.2	Others
Rilof	13	50.0	Organophosphate
Round-up	18	69.2	Organophosphate

Table 8. Fungicides Used by the Farmers.

Name of Fungicide	Number of Users	Percentage (%)	Category
Cocopri	9	37.5	Others
Kocide	12	50.0	Others
Dithane-45	10	41.7	Carbamate
Furadan Topsin-M	8	33.3	Carbamate

Table 9. Growth Regulators Used by the Farmers.

Name of Growth Regulator	Number of Users	Percentage (%)	Category
Biomex	18	81	Others
Sampi	14	63.6	Others
Biozyme-TF	22	100	Others
Dithene	19	86.4	Others

4:1:3. Types of Crops Grown.

The catcment area of the lakes though noted for rice cultivation, recorded only 15 out of the 34 respondents (table 10), i.e 44.1%, as rice growers. This picture is due to the fact that greater number of the farmers have stopped growing rice as a result of a directive from the IDA to them to stop rice cultivation since 1994, for the restructuring of the irrigation canals to extend them to a greater part of the Accra-Plains. It is hoped that when the current restructuring of the irrigation canals is complete, more farmers would go back to rice cultivation.

Table 10. Types of Crops Grown by the Farmers.

Type of Crop Grown	Number of Growers	Percentage (%)
Vegetables**	19	55.9
Rice (only)	3	8.9
Vegetables and Rice	12	35.2

** = Vegetables include all other food crops apart from rice.

4:1:4. Source of Chemicals

Out of the 32 (94%) farmers who claimed to use pesticides, 25 (78.1%), as shown in table 11, responded to purchasing their chemicals from approved sources, i.e from chemical stores and Agricultural Extension Officers. The others (21%) obtained their supply from fellow farmers.

Table 11 Sources of Chemicals Bought by the Farmers.

Source of Chemicals	Number of Buyers	Percentage (%)
Chemical Shops	17	53.1
Extension Officers	8	25.0
Fellow Farmers	7	21.9

It is hoped that, extension officers would intensify their education of the farmers on the benefits and adverse effects of pesticides, and encourage the farmers to obtain the chemicals through them.

4:1:5. Storage of Chemicals.

From table 12, it is clear that, 71.9% of farmers store chemicals at home with only 9 (28.1%) storing theirs on their farms. This is not a healthy development and such they should be advised by the Extension Officers to refrain from doing so. To avoid accidents from these pesticides, farmers should, through extension officers, be educated about the dangers of pesticides poisoning to them and their families if pesticides are stored at home especially within reach of children.

Table 12. Places of Storage of Pesticides by Farmers.

Place of Storage	Number of Farmers	Percentage (%)
At Home	23	71.9
On the Farm	9	28.1

4:1:6. Disposal of chemicals.

Farmers were asked about what they did with expired or damaged pesticides. From table 13, it is clear that all farmers who use pesticides do not dispose of expired or damaged chemicals. Some may even be buying already expired chemicals from the shops, since they do not care whether the chemicals are expired or not. Most of them claimed to reuse the chemical and

Table 13. How Chemicals are disposed off by Farmers.

Type of Disposal Method	Number of Farmers	Percentage (%)
Never disposes of Chemicals	32	100
Disposes of Chemicals	0	0

fertilizer containers for other purposes. There is therefore the need for education of the farmers about the dangers in using expired pesticides just as is with drugs.

4:2. WATER QUALITY: PHYSICAL AND CHEMICAL PARAMETERS

For a fresh water source to be potable, it should satisfy the requirements of the World Health Organization (WHO). For monitoring and surveillance purposes, the WHO has come up with maximum levels of some physical and chemical parameters for fresh water, beyond which the portability of the water becomes questionable. These maximum levels are contained in the "WHO Guidelines Values for Potable Water"[64], part of which is shown in table 14, is what is adopted by the Ghana Water Company.

For a particular water source to be termed potable, and as such to qualify for human consumption, the analysis of its physical and chemical parameters should yield results less than or equal to the WHO guideline values. Exceptions are granted in cases where these guideline values are higher than that of the nation or region, or where background levels do not permit the WHO guideline values to be attained within reasonable costs.

Table 14. WHO Guideline Values for some Physical and Chemical parameters of Potable Water.

PARAMETER	**VALUE**
Total Hardness (TS) as $CaCO_3$	500 mg/L
Chloride	250 ,, ,,
Nitrate	10 , ,,
Phosphate	<0.3mg/L
Turbidity	5 NTU
Conductivity	700 mS cm^{-1}
Dissolved Solids	1000 mg/L
Na+	200 ,, ,,
K+	30 ,, ,,
Ca2+	200 ,, ,,
[illegible]	150 ,, ,,
pH	6.5 - 8.5
DO	8 mg/L
BOD	< 3mg/L
COD	250mg/L

Tables 15, 16, 17 and 18 are the means of the results obtained for the various parameters when the water samples were worked upon.

Table 15. Mean Values of Physical Parameters measured for the Various Locations.

	PARAMETERS				
LOCATION	**pH**	**Temp. (OC)**	**DO (mg/L)**	**BOD (mg/L)**	**COD (mg/L)**
"Super-drain"	7.0 ± 1.2	26.4 ± 0.1	1.2 ± 1.1	76.5 ± 67.8	20.5 ± 14.8
Lake Kasu	7.2 ± 0.2	31.1 ± 1.4	7.0 ± 1.1	73.8 ± 63.3	66.8 ± 55.0
Lake Nyafie	6.9 ± 0.1	31.6 ± 1.2	5.4 ± 2.5	49.7 ± 37.7	19.0 ± 12.6

From tables 15, 16, 17 and 18, it can be seen that on the whole, most of the physical and chemical parameters determined for lakes Kasu and Nyafie, used for drinking fall within the WHO limits with the exception of turbidity and BOD. The higher turbidity values of 68.04 NTU and 25.22 NTU for the two lakes are far above the 5 NTU WHO guideline. The mean BOD values of 73.8mg/L for lake Kasu and 49.7mg/L for lake Nyafie, are also well beyond the WHO value of <3.0 mg/L. Thus the waters of the lakes can be said to be organically polluted with regard to the BOD values as compared to the WHO value. This line of thought is reinforced by the fact that BOD values obtained are higher than COD values. The "super drain" is not of much concern since it is not used as a source of potable water directly though it empties it's contents into lake Kasu.

But this does not mean that the waters of these lakes especially that of lake Kasu are totally wholesome for human consumption. This is because, lake Kasu, on which the majority of the people depend, remains cloudy throughout the year. Especially in the dry season (Nov.-April), the water becomes very brown (high turbidity) as shown graphically in fig 6, that, its aesthetic value is lost especially on someone who is coming into contact with it for the very first time. It is only during the rainy season (May-Oct), when runoffs from the catchment areas fill it that, the color changes towards whitish. Lake Nyafie on the other hand, has a very near to normal clear water colour in the dry season which becomes rather tainted (whitish) during the rainy season leading to the high turbidity values for the lakes.

Table 16. Mean Values measured for Physical parameters at the Various Locations.

	PARAMETERS				
LOCATION	**Conductivity (mS/cm)**	**Turbidity (NTU)**	**SS (mg/L)**	**DS (mg/L)**	**TS (mg/L)**
Super-drain	96.63 ± 30.6	80.75 ± 63.3	101.00 ± 82.6	213.25 ± 39.4	314.25 ± 57.0
Lake Kasu	159.22 ± 38.6	68.04 ± 28.7	118.79 ± 29.8	315.36 ± 117.9	434.15 ± 141.0
Lake Nyafie	118.00 ± 58.0	25.22 ± 15.7	99.11 ± 96.4	157.35 ± 68.7	256.66 ± 91.3

Table 17. Mean values of some Chemical parameters (Nutrients and Ions) measured at the Various Locations.

	PARAMETERS. (mg/L)							
LOCATION	**NO_3^-**	**NO_2^-**	**PO_4^{3-}**	**Cl^-**	**Ca^{2+}**	**Mg^{2+}**	**K^+**	**Na^+**
Super-drain	0.187 ± 0.12	0.083 ± 0.04	0.203 ± 0.12	1.45 ± 1.0	6.43 ± 2.4	1.75 ± 1.1	8.86 ± 2.0	3.20 ± 1.5
Lake Kasu	0.178 ± 0.11	0.058 ± 0.02	0.087 ± 0.04	11.11 ± 3.9	8.62 ± 5.0	3.71 ± 0.4	17.40 ± 4.1	6.61 ± 1
Lake Nyafie	0.180 ± 0.11	0.039 ± 0.01	0.192 ± 0.02	7.50 ± 4.3	5.37 ± 2.8	3.65 ± 0.7	12.46 ± 6.6	4.79 ± 2.1

Table 18 Mean Values of Hardness of Water measured at the Various Locations.

	PARAMETERS. (mg/L)		
LOCATION	**Ca hardness**	**Mg hardness**	**Total hardness**
Super-drain	16.10 ± 6.0	7.18 ± 4.5	23.28 ± 5.8
Lake Kasu	20.19 ± 13.4	15.23 ± 1.7	35.42 ± 12.1
Lake Nyafie	13.41 ± 6.9	15.01 ± 2.8	28.43 ± 8.8

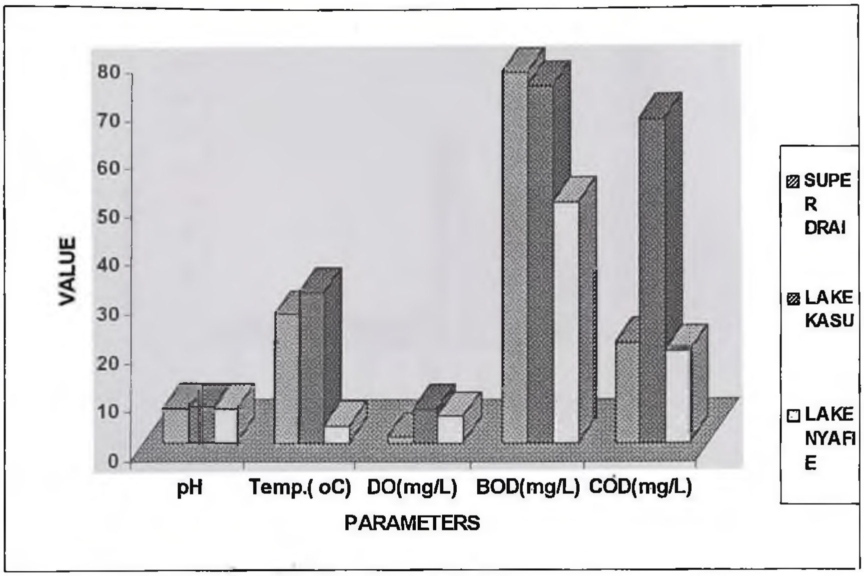


Fig. 5. Mean Values of Physical and Chemical Parameters for all the Locations

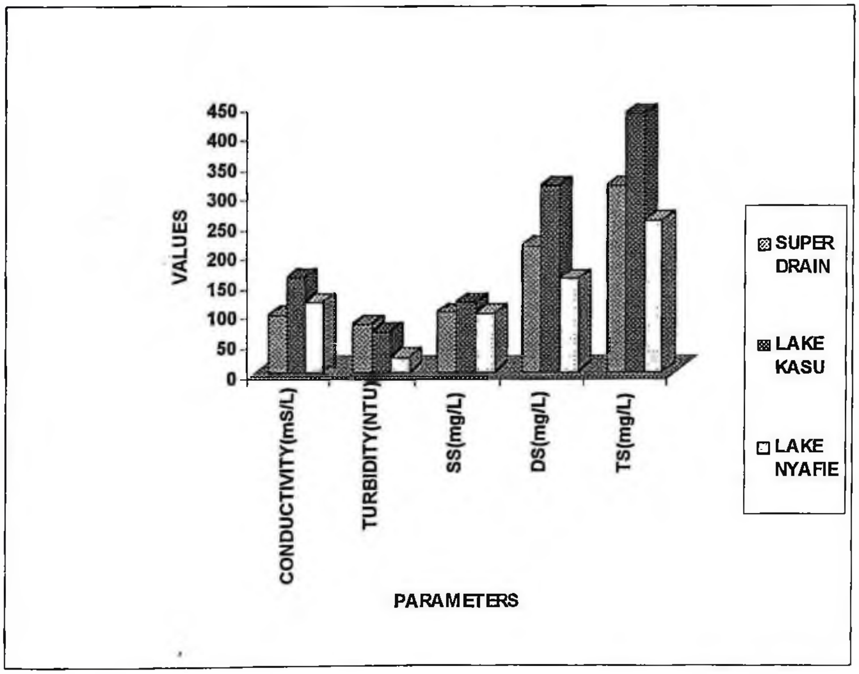


Fig. 6 Mean Values for Physical Parameters at all the Locations

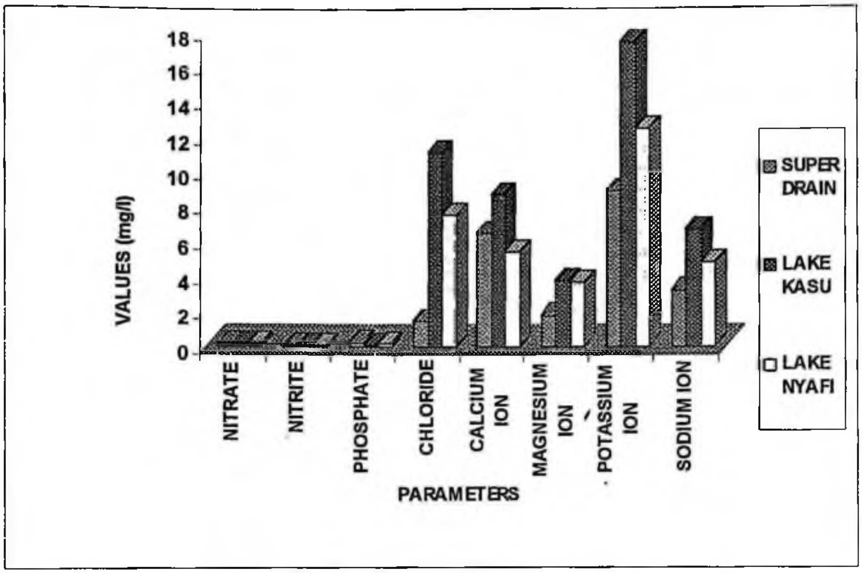


Fig. 7. Mean Values of Nutrients and Ions at all the Locations.

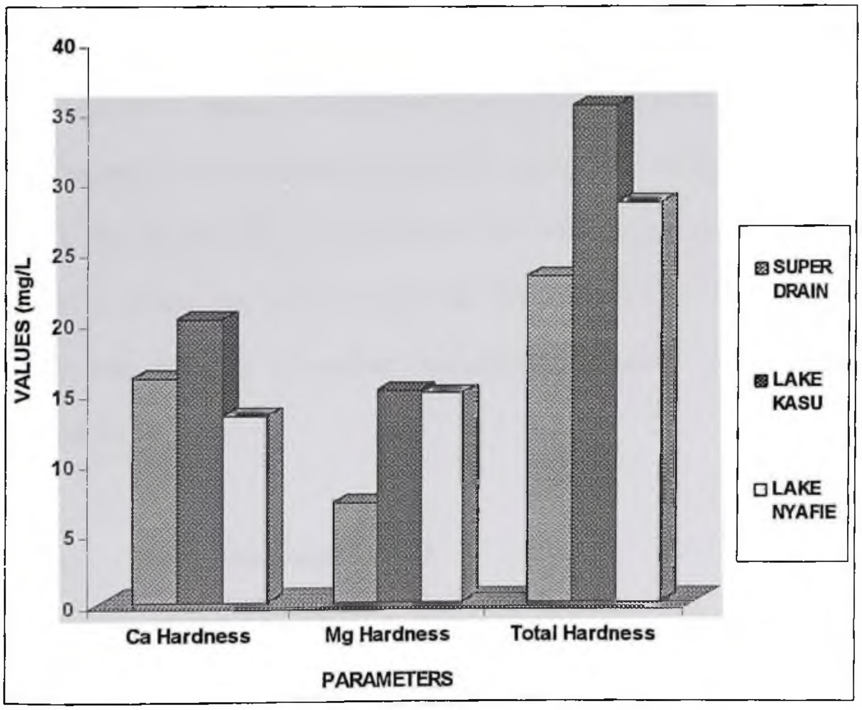


Fig. 8. Mean Values of Water Hardness at all the Locations.

4:2:2. SEASONAL VARIATIONS.

The results show some seasonal variations in the values for most physical and chemical parameters at all the sampling locations as shown in tables 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, and 30.

4:2:2:1. pH

The pH is an important parameter in water quality measurement, as it influences many biological and chemical processes within a water body and all processes associated with water treatment and supply. The pH of water determines which substances would dissolve in or precipitate out of it. The life of the organisms in the water, such as fishes, and those that depend on it, such as man, birds and animals, is affected by the pH of the water.

From tables 19, 23 and 27, it is generally clear that, the pH in the rainy season is higher than that for the dry season at all locations. This can be attributed to the large volume of water that came to dilute the relatively acidic conditions for the dry season (figs. 9, 10 and 11). Though rain water is expected to be acidic, it can only be acidic if it is collected as it falls, but ones it touches the ground and begins to flow, it turns to dissolve salts especially of sodium, potassium and calcium carbonates, thereby increasing its pH.

4:2:2:2. Dissolved Oxygen. (DO)

Water, which is in contact with O_2 or with an O_2-containing mixture of gases, contain some dissolved O_2. When water is saturated by O_2, the concentration of O_2 is called the equilibrium concentration. Its value depends on the partial pressure of O_2 in the gaseous phase, the temperature of the water, and the concentration of salts in the water. The normal equilibrium concentration of O_2 in drinking water, ranges from 4.5 to above 8 mg/L in most cases[61]. The real concentration of O_2 may differ from the equilibrium concentration because of physical, chemical and biochemical conditions or activities such as sudden changes in temperature or barometric pressure, chemical oxidation of substances contained in the water, or contacted by it, biochemical oxidation by assimilative activity of green organisms etc. The DO concentration is important for the evaluation of surface water quality and wastewater treatment control. From table 15, the mean DO values for the locations ranged from a low of 1.2 mg/L for the "super-drain", through 5.4 mg/L for lake Nyafie to a high of 7.0 mg/L for lake Kasu. Thus the values for lakes Kasu and Nyafie all fall within the acceptable range for drinking water. Seasonally, the DO values of the lakes decreased (7.59 to 6.45 mg/L for Kasu and 8.63 to 3.25 mg/L for Nyafie) from the dry to the rainy season as expected, with the exception of the "super-drain", in which the DO value increase during the dry to the rainy season as shown in tables 19, 23 and 27, and in figs. 9,10 and 11. The decrease in the DO values from the dry to the rainy season was as a result of increased levels of biodegradable materials carried into the lakes by the flood waters which required the DO in the water to oxidised them. The exception of the value of the "super-drain" and the relatively small decreases in the values for the lakes, were due to the turbulence created by the swift flood waters, thereby leading to increase dissolution of O_2 in the waters.

Table 19. Mean seasonal Values of Physical and chemical parameters for "Super-drain".

SEASON	**PARAMETERS**				
DRY SEASON	**pH**	**Temp.(0C)**	**DO**	**BOD**	**COD**
January	5.9	26.50	0.71	11.43	3.10
February	6.10	26.40	0.48	12.36	10.84
Mean	**6.00**	**26.45**	**0.59**	**11.80**	**6.97**
	±0.1	**±0.1**	**±0.1**	**±0.5**	**±3.9**
RAINY SEASON					
June	8.4	26.30	0.10	170.00	41.50
July	7.6	26.30	3.30	112.00	26.43
Mean	**8.0**	**26.30**	**1.70**	**141.00**	**33.97**
	±0.4	**±0.0**	**±1.8**	**±34.0**	**±7.5**

Table 20. Mean Seasonal Values of Physical parameters in the "Super-drain"

SEASON	**PARAMETERS**				
DRY SEASON	**Conductivity (mS/cm)**	**Turbidity (NTU)**	**SS (mg/L)**	**DS (mg/L)**	**TS (mg/L)**
January	102.60	19.00	40.00	265.00	305.00
February	153.90	16.00	32.00	238.00	270.00
Mean	**123.25**	**17.50**	**36.00**	**251.50**	**287.50**
	±25.7	**±1.0**	**±4.0**	**±13.5**	**±17.5**
RAINY SEASON					
June	84.20	140.00	94.00	178.00	272.00
July	45.80	148.00	238.00	172.00	410.00
Mean	**65.00**	**144.00**	**166.00**	**175.00**	**341.00**
	±19.2	**±4.0**	**±72.0**	**±3.0**	**±69.0**

4:2:2:2. BOD.

The biological oxygen demand (BOD) is an approximate measure of the amount of biologically degradable organic matter present in a water sample. It is determined by the amount of oxygen required for the aerobic microorganisms present in the sample to oxidise the organic matter to a stable inorganic form. As such, it is a very important pointer to pollution and health status of the lakes.

Generally, as BOD levels increase, DO levels drop. This was clearly shown in the results of lakes Kasu and Nyafie in tables 19, 23 and 27 and in figs. 9,10 and 11. Considering the activities within the areas of these lakes, it can be said that the BOD values were not as high as expected.

The increased values for the biological oxygen demand at all the locations for the rainy season as compared to that for the dry season as shown in tables 19, 23 and 27, and graphically depicted in figs. 9, 10 and 11, is as a result of the flooding of these locations. This then leads to the rotting of plants as well as human and animal wastes, carried by the surface runoff water. Thus all these are expected to increase available biodegradable matter, consequently increasing BOD at the expense of DO, as noticed earlier. Thus taking the average BOD values for the lakes and the "super-drain", it can be said that these waters are polluted, if BOD value is the sole indicator of pollution since its values for all the locations is greater than the WHO value of 3 mg/L for drinking water.

Table 21 Mean Values for Nutrients and Ions in the "Super-drain".

SEASON	**PARAMETERS (mg/L)**							
DRY SEASON	**NO_3^-**	**NO_2^-**	**PO_4^{3-}**	**Cl^-**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**	**K^+**
January	0.038	nd	nd	2.30	7.09	0.72	2.56	10.6
February	0.048	nd	nd	2.60	7.58	0.58	9.82	2.05
Mean	**0.043**	**nd**	**nd**	**2.45**	**7.34**	**0.65**	**6.16**	**6.33**
	±0.01			**±0.2**	**±0.3**	**±0.1**	**±3.6**	**±3.8**
RAINY SEASON								
June	0.306	0.083	0.146	0.50	8.66	2.76	9.40	5.80
July	0.358	0.082	0.200	0.40	2.40	2.92	5.50	2.40
Mean	**0.332**	**0.083**	**0.173**	**0.45**	**5.53**	**2.84**	**6.85**	**4.10**
	±0.03	**±0.0**	**±0.03**	**±0.1**	**±3.1**	**±0.1**	**±1.5**	**±1.7**

Table 22 Seasonal Means of Hardness of Water for the "Super-drain"

SEASON	**PARAMETERS (mg/L)**		
DRY SEASON	**Ca hardness**	**Mg hardness**	**Total hardness**
January	17.73	2.97	20.70
February	19.00	2.40	21.40
Mean (dry)	**18.37±0.6**	**2.69±0.3**	**21.05±0.4**
June	21.65	11.35	33.00
July	6.00	12.00	18.00
Mean (rainy)	**13.50±7.8**	**11.63±0.4**	**25.50±7.5**

4:2:2:3. Turbidity.

The above parameter increased from the dry season to the rainy season (figs. 12,13, and 14) at all the locations. Turbidity has a low of 10.67 NTU in the dry season for lake Nyafie and a high of 148 NTU in the rainy season for the Super-drain (tables 20, 24, and 28). This is as expected, because during the rainy season, the runoff waters into these lake from the catchment areas bring with them lots of silt and other particulate matter. But this does not mean that the reading for the other locations are within the WHO limit. As a matter of fact, of all the physico-chemical parameters, it is only the turbidity which is above the WHO guideline value of 10 NTU. Thus in terms of the physico-chemical parameters, the water from the lakes can be made potable by the addition of alum or by way of filtration, to reduce the turbidity to within acceptable levels, thus increasing its aesthetic values.

Table 23 Seasonal Means of Physical and Chemical parameters for Lake Kasu

SEASON	**PARAMETERS**				
DRY SEASON	**pH**	**Temp. (0C)**	**DO (mg/L)**	**BOD(mg/L)**	**COD(mg/L)**
January	7.04	32.84	5.48	15.30	16.73
February	7.05	31.85	9.70	16.48	17.80
Mean	**7.05**	**32.35**	**7.59**	**15.89**	**17.27**
	±0.0	**±0.5**	**±1.6**	**±0.6**	**±0.5**
RAINY SEASON					
June	7.47	30.47	6.70	166.67	150.18
July	7.03	29.07	6.20	97.80	82.56
Mean	**7.25**	**29.77**	**6.45**	**132.24**	**116.37**
	±0.2	**±0.8**	**±0.3**	**±34.4**	**±33.8**

Table 24. Physical parameters measured for Lake Kasu with Mean Seasonal Values

SEASON	**PARAMETERS**				
DRY SEASON	**Conductivity (mS)**	**Turbidity (NTU)**	**SS (mg/L)**	**DS (mg/L)**	**TS (mg/L)**
January	159.98	47.80	170.00	453.60	625.60
February	215.00	34.00	107.50	376.50	484.00
Mean	**187.49**	**40.90**	**138.75**	**415.50**	**554.80**
	±27.5	**±6.9**	**±31.3**	**±38.6**	**±70.8**
RAINY SEASON					
June	156.07	106.67	97.67	296.00	393.67
July	105.63	83.67	100.00	135.33	235.33
Mean	**130.85**	**95.17**	**98.84**	**215.67**	**314.50**
	±25.2	**±11.5**	**±1.2**	**±80.3**	**±79.2**

Table 25. Nutrients and Ions measured for Lake Kasu with Mean Seasonal Values.

SEASON	**PARAMETERS. (mg/L)**							
DRY SEASON	NO_3^-	NO_2^-	PO_4^{3-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
January	0.065	nd	nd	13.96	5.29	3.03	20.52	7.08
February	0.075	nd	nd	15.35	5.97	4.05	21.95	7.52
Mean	**0.07**	**nd**	**nd**	**14.66**	**5.63**	**3.54**	**21.24**	**7.30**
	±0.01			**±0.7**	**±0.4**	**±0.5**	**±0.7**	**±0.2**
RAINY SEASON								
June	0.310	0.042	0.052	9.67	17.29	3.65	15.47	6.92
July	0.262	0.073	0.122	5.47	5.93	4.09	11.67	4.93
Mean	**0.286**	**0.058**	**0.087**	**7.57**	**11.61**	**3.87**	**13.57**	**5.93**
	±0.02	**±0.02**	**±0.04**	**±2.1**	**±5.7**	**±0.2**	**±1.9**	**±1.0**

Table 26. Hardness of Water with Mean Seasonal Values for Lake Kasu.

SEASON	**PARAMETERS. (mg/L)**		
DRY SEASON	**Ca hardness**	**Mg hardness**	**Total hardness**
January	13.23	12.47	25.70
February	9.47	16.58	31.05
Mean	**11.35±1.9**	**14.53±2.1**	**28.38±2.7**
RAINY SEASON			
June	43.22	15.04	58.27
July	14.82	16.84	32.33
Mean	**29.02±13.7**	**15.94±0.9**	**50.30±13.0**

5:2:2:4. SS, DS and TS.

These are solid residues contained in the water samples. The term “residues” applies to the substances remaining after evaporation of a water sample and its subsequent drying in an oven at a given temperature, which is usually, 105 °C. The term “solid” is widely used for the majority of compounds that are present in natural waters and remain in solid state after evaporation (some organic compounds will remain in the liquid state after the water has evaporated). Suspended solids (SS) and dissolved solids (DS), correspond to filterable and non-filterable residue respectively. Total solids (TS), is the sum of the SS and the DS.

As evident from figs. 12, 13 and 14, these parameters did not follow any particular pattern across the seasons. While some, such as SS and TS increased from the dry season to the rainy season, DS on the other hand, decreased as one moves from the dry season to the rainy season for all the locations as shown in tables 20, 24 and 28.

These trends are in line with the conditions in the area. Naturally, it is expected that, the floodwaters would carry a lot of soil and organic matter with it as it moves towards these water sources, thus increasing SS and TS. The decrease in the value of the DS on the other hand, could be due to; (a) the dilution of the water sources and (b) the inability of most of the nutrients, both, organic or inorganic, to dissolve sufficiently at the time of sampling. Thereby increasing the amount of SS. These values, though appearing to be high, are far below the WHO guideline limit of 1000mg/L for TS in drinking water.

Table 27. Physical and Chemical parameters for Lake Nyafie with Mean Seasonal Values.

MONTH	**PARAMETERS**				
	pH	**Temp. (0C)**	**DO (mg/L)**	**BOD (mg/L)**	**COD (mg/L)**
January* **		-	-	-	-
February	6.80	33.37	8.63	5.80	3.61
Mean	**6.80**	**33.37**	**8.63**	**5.80**	**3.61**
June	7.00	30.67	2.60	96.67	33.59
July	6.97	30.67	4.90	47.50	19.83
Mean	**6.99 ± 0.0**	**30.67 ± 30.0**	**3.25 ± 0.7**	**72.09 ± 24.6**	**26.71 ± 6.9**

*** = No sampling was done in January due to damage to the canoe.

Table 28 Seasonal Values for Physical Parameters for Lake Nyafie.

SEASON	**PARAMETERS**				
DRY SEASON	**Conductivity (mS)**	**Turbidity (NTU)**	**SS (mg/L)**	**DS (mg/L)**	**TS (mg/L)**
January***	-	-	-		
February	187.93	10.67	48.67	253.33	302.00
Mean	**187.93**	**10.67**	**48.67**	**253.33**	**302.00**
RAINY SEASON					
June	10.17	18.00	14.67	124.00	138.67
July	45.90	47.00	234.00	95.33	329.33
Mean	**83.04** **± 37.0**	**32.50** **±14.5**	**124.34** **±109.7**	**114.67** **±14.3**	**230.00** **±95.8**

*** No sampling was done due to damage to the canoe.

Table 29 Results of Nutrients and Ions with Mean Seasonal Values for Lake Nyafie.

SEASON	**PARAMETERS (mg/L)**							
DRY SEASON	NO_3^-	NO_2^-	$PO_4 3^-$	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
January***	-	-	-	-	-	-		-
February	0.002	Nd	nd	9.63	4.52	2.74	20.60	7.46
Mean	**0.002**	**00**	**00**	**9.63**	**4.52**	**2.74**	**20.60**	**7.46**
RAINY SEASON								
June	0.224	Nd	0.135	11.30	9.08	4.50	12.37	4.57
July	0.283	0.067	0.248	1.57	2.51	3.81	4.40	2.33
Mean	**0.254** **±0.03**	**0.033** **±0.03**	**0.192** **±0.06**	**6.44** **±5.4**	**5.79** **±3.3**	**4.20** **±0.4**	**8.88** **±4.0**	**3.45** **±1.1**

*** No sampling was done due to damage to the canoe.

Table 30. Results of Hardness of Water for Lake Nyafie.

SEASON	PARAMETERS (mg/L)		
DRY SEASON	**Ca hardness**	**Mg hardness**	**Total hardness**
January***	-	-	-
February	11.29	11.27	22.56
Mean	**11.29**	**11.27**	**22.56**
RAINY SEASON		-	
June	22.70	18.09	40.79
July	6.25	15.68	21.93
Mean	**14.48 ± 8.3**	**16.89 ± 1.3**	**31.36 ±± 9.4**

*** No sampling was done due to damage to the canoe.

4:2:2:6 Conductivity.

Conductivity or specific conductance, is a measure of the ability of water to conduct an electric current. It is sensitive to variations in dissolved solids, mostly mineral salts. The degree to which these salts dissociate into ions, the amount of electrical charge on each ion, ion mobility and the temperature of the solution, all have an influence on conductivity. Thus, the general decrease in conductivity as observed between the dry and rainy seasons for all the locations (figs. 12, 13 and 14), is consistent with decrease in the concentration of ions such as Cl^-, Na^+, K^+ and Ca^{2+} This can be due to the large volume of runoffs in the rainy season, thus, diluting the ion concentrations.

5:2:2:7 Nitrate and Nitrite.

The nitrate ion (NO_3^{-}), is the common form of combined nitrogen found in natural waters. It may be biochemically reduced to nitrite (NO_2^{-}) by denitrification process, usually under anaerobic conditions. The nitrite ion is rapidly oxidised to nitrate by dissolved atmospheric oxygen. Natural sources of nitrate in surface waters include igneous rocks, land drainage and plant and animal debris. Natural levels, which do not normally exceed 0.1mg/L, may be enhanced by the use of inorganic fertilisers. Nitrate which is an essential nutrient for aquatic plants, experience seasonal fluctuations as a result of aquatic plant growth and decay.

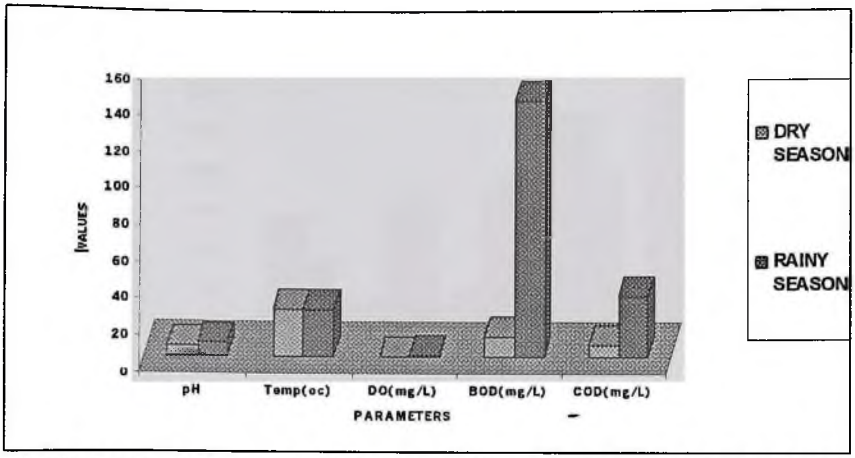


Fig. 9 Seasonal Changes in Physical and Chemical Parameters in the "Super-drain"

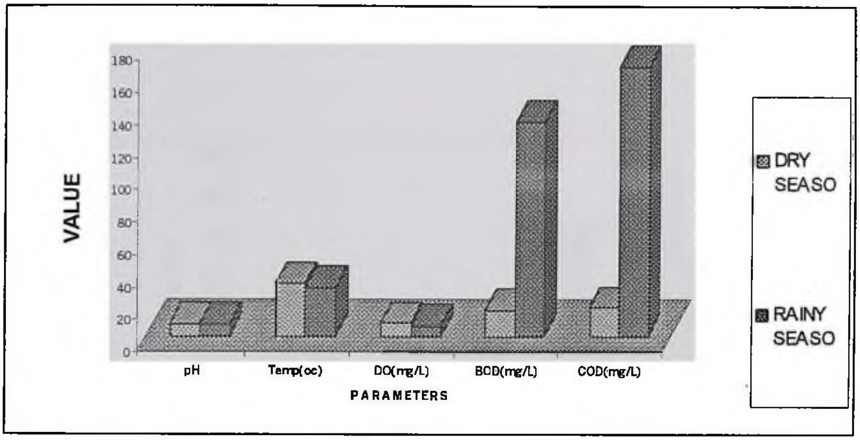


Fig. 10 Seasonal Changes in Physical and Chemical Parameters for Lake Kasu.

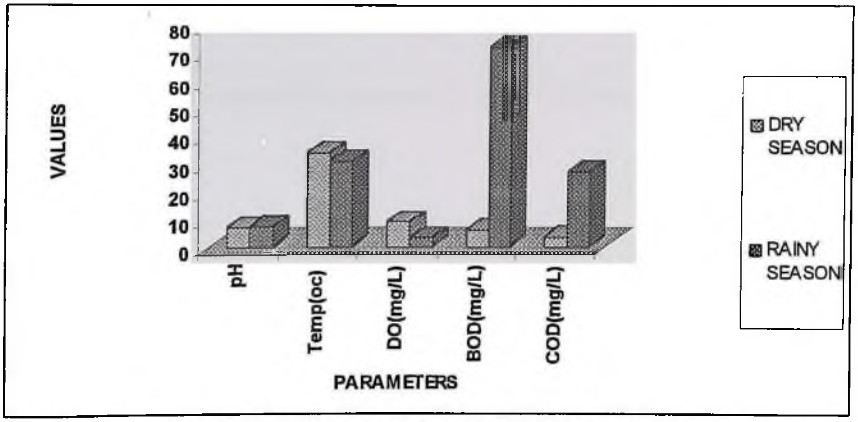


Fig. 11 Seasonal Changes in Physical and Chemical Parameters in Lake Nyafie.

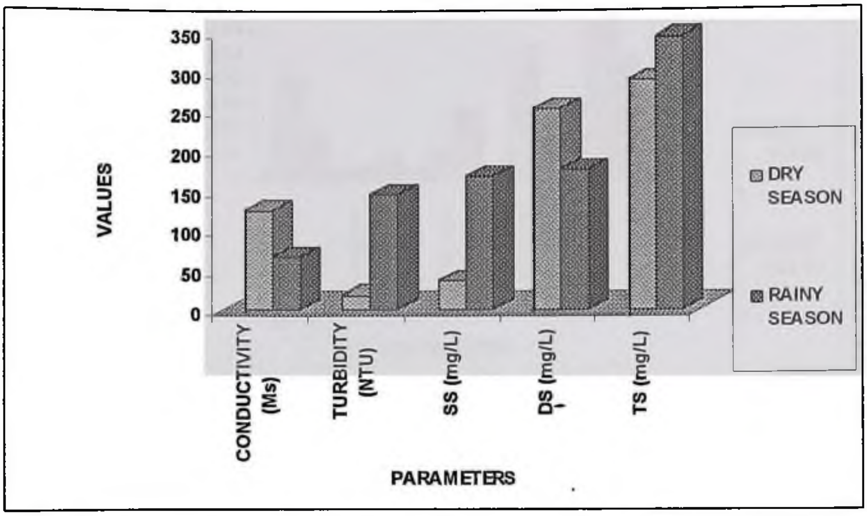


Fig. 12 Seasonal Changes in Physical Parameters in the "Super-drain"

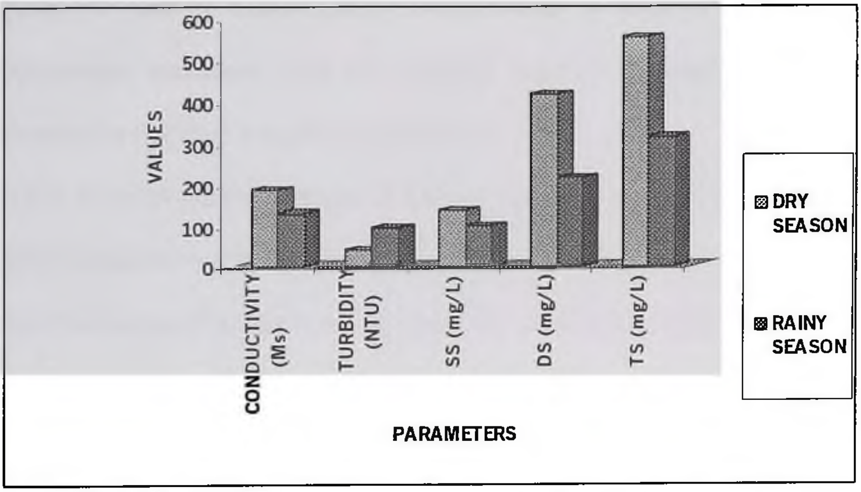


Fig. 13 Seasonal Changes in Physical Parameters in Lake Kasu.

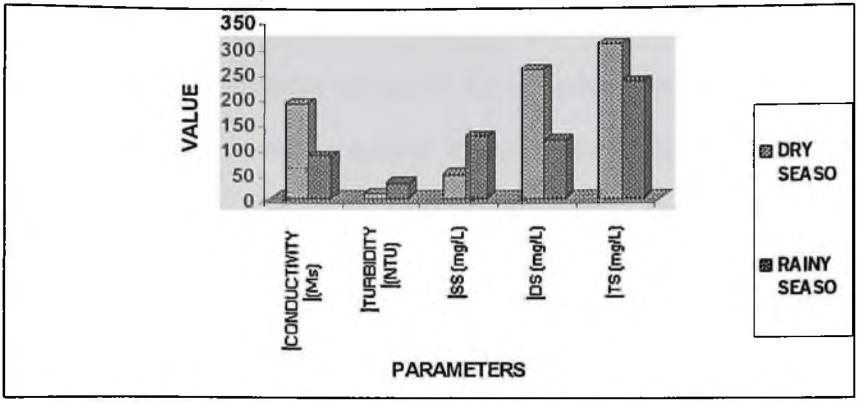


Fig. 14 Seasonal Changes in Physical Parameters in Lake Nyafie.

When influenced by man's activities, surface waters normally contain nitrate concentrations up to 5mg/L but often. Less than 1mg/L. Levels in excess of 5mg/L usually indicate pollution by human and or animal waste, or fertilizer runoffs. As the WHO recommended maximum limit for drinking water is 10 mg/L, waters with higher concentration represent a significant health risk.

In lakes, levels of nitrate in excess of 0.2mg/L tend to stimulate algal growth and indicate possible eutrophic conditions. Determination of nitrate and nitrite in surface waters gives a general indication of the nutrient status and level of organic pollution. Consequently, these species are included in most basic water quality survey and multipurpose or background monitoring programs to monitor the impact of organic or relevant industrial and agricultural inputs. Nitrate levels are also measured in drinking water sources due to the potential treats it posses to human health. For nitrate and nitrite, there is a general increase in concentration from the dry to the rainy season for all the locations (tables 7, 11, and 15.). Actually, no nitrite was determined in the dry season. It's presence and the increase in the amount of nitrate during the raining season, can be attributed to their being washed from the catchment areas by surface runoff, either from fertiliser applications on the farms or from the wastes of human and farm animals which are abundant. The area is one of the major cattle raring areas on the Accra plains.

4:2:2:8. Phosphate.

Phosphate (PO_4^{3-}) is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate species. It is generally the limiting nutrient for algal growth and, therefore, controls the primary productivity of a water body. Artificial increases in concentrations due to man's activities are the principal causes of eutrophication.

Natural sources of phosphates are mainly the weathering of phosphorus bearing rocks and the decomposition of organic matter. Domestic wastewater, particularly those containing detergents and fertilizer run-off, contribute to elevated levels in surface waters. Phosphorus associated with organic and mineral constituents of sediments in water bodies can also be mobilised by bacteria and released to the water column.

Phosphorus is rarely found in high concentrations in freshwater as plants actively take it up. As a result, there can be considerable seasonal fluctuations in concentrations in surface water. In most natural surface waters, phosphorus ranges from 0.005 to 0.020 mg/L. As phosphorus is an essential component of the biological cycle in water bodies, it is often included in basic water quality surveys or background monitoring programs. High concentrations of phosphorus can indicate the presence of pollution and are largely responsible for eutrophic conditions. The management of a lake or reservoir, particularly for drinking water supply, requires knowledge of the levels of phosphorus in order to control the rate of algal growth.

From tables 21, 25, and 29, there is a general increase in the concentration of phosphate from the dry to the rainy season. Just as was the case of nitrite, no phosphate was determined at any of the locations in the dry season. The reason for its presence in the rainy season could be due to inflows from runoffs from the surrounding farmlands.

4:2:2:9. Sodium.

All natural waters contain some sodium since its salts are highly water-soluble and it is one of the most abundant elements on earth. It is found in the ionic form (Na^+), and in plant and animal matter, since it is an essential element for living organisms. Sodium is commonly measured where the water is to be used for drinking or agricultural purposes, particularly irrigation.

In figs. 15, 16 and 17, there is a gradual decrease in the concentration of sodium from the dry to the rainy season. This decrease can only be attributed to dilution from the large volume of water from the runoffs into these water bodies, though, there is the possibility that some sodium may be contained in the runoffs as well.

4:2:2:10. Chlorine.

Most chlorine occurs as chloride (Cl^-) ions in solution. The presence of chlorine in natural waters can be attributed to dissolution of salt deposits, sewage discharges, irrigation drainage and contamination from refuse leachates, among others. High concentrations of chloride can make waters unpalatable and, unfit for drinking or livestock watering. As chloride is associated with sewage, it is often incorporated into assessments as an indication of possible fecal contamination or as a measure of the extent of dispersion of sewage discharge in water bodies, if the possibility of seawater intrusion or bedrock contributions can be ruled out.

From both tables 21, 25 and 29, as well as figs. 15, 16 and 17, the chloride concentration tend to decrease from the dry season to the rainy season at all the locations. This can again be attributed to the dilution effect of the floodwaters. The mean range of 1.45 mg/L to 11.11mg/L for the "super-drain and lake Kasu respectively, is far below the recommended WHO limit of 250 mg/L. Thus, looking at the values for chlorine, and if chloride ion concentration can be used as a measure of fecal contamination, then these water bodies can be said to be free from fecal pollution.

4:2:2:11. Calcium.

Calcium is present in all waters as Ca^{2+} and is readily dissolved from rocks rich in calcium minerals, particularly as carbonates and sulphates, especially limestone and gypsum, making it abundant in both ground and surface waters. The salts of calcium together with those of magnesium are responsible for the hardness of water.

Calcium like the other ions showed a gradual decrease towards the rainy season, which was clearly shown in figs. 15, 16 and 17, as well as tables 21, 25 and 29. The reason is the usual one of dilution.

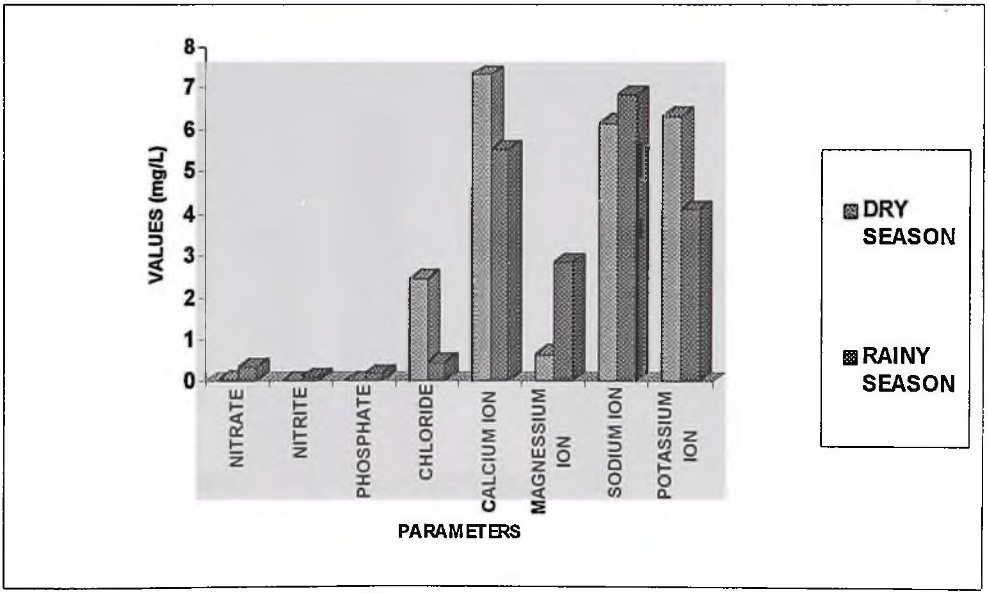


Fig. 15. Seasonal Changes of Nutrients and Ions in the Super-drain.

4:2:2:12. Potassium.

Potassium as K^+, is found in low concentrations in natural waters since rocks that contain potassium are relatively resistant to weathering. However, potassium salts are widely used in industry and in fertilizer for agricultural lands. Potassium is usually found in the ionic form and the salts are highly soluble. It is readily incorporated into mineral structures and accumulated by aquatic biota, as it is an essential nutritional element. Concentrations in natural waters are usually less than 10 mg/L. Though the concentrations of potassium in these water are higher than the 10mg/L, they are however below the WHO guideline value of 30mg/L for potable water. Potassium, like sodium, exhibits the same trend of behavior, from the dry season to the rainy season. This is as shown in tables 21, 25 and 29 as well as in figs. .15, 16 and 17

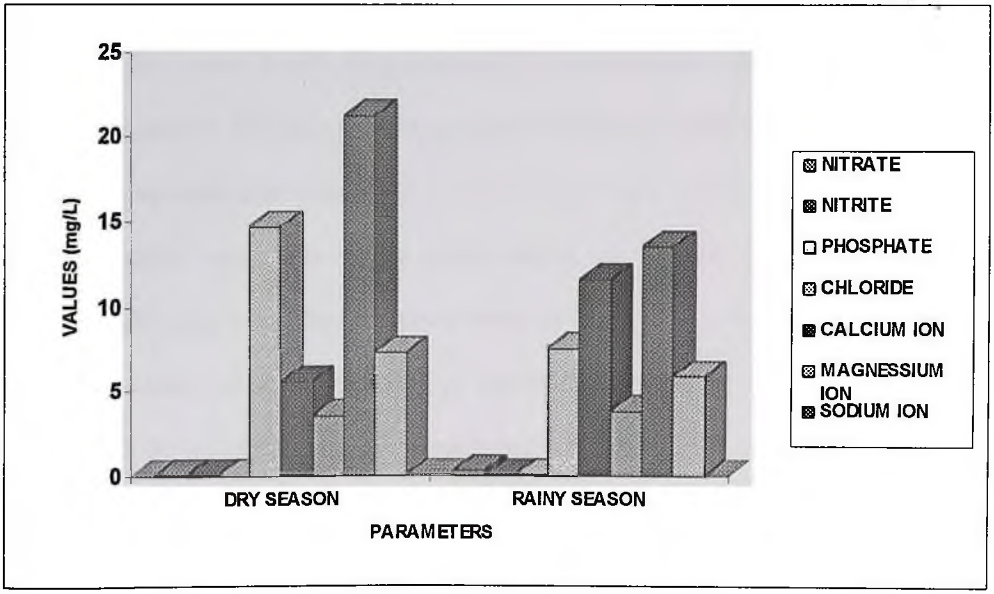


Fig. 16. Seasonal Changes of Nutrients and Ions in Lake Kasu.

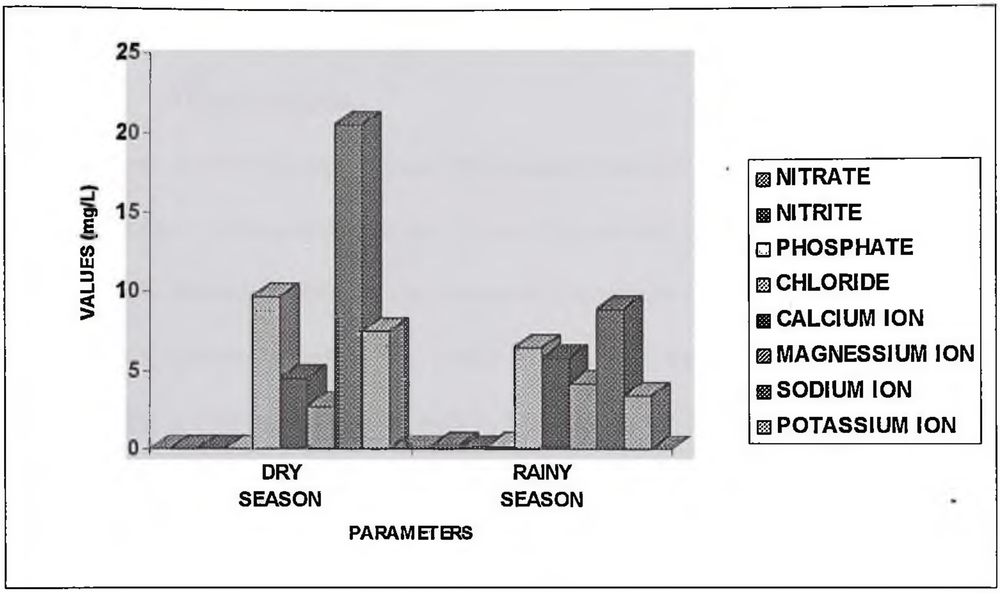


Fig. 17. Seasonal Changes of Nutrients and Ions in Lake Nyafie.

4:2:2:12. Magnesium.

Magnesium is mainly found in waters as Mg^{2+}, and along with calcium, is a contributor to water hardness. Magnesium arises principally from the weathering of rock containing ferro-magnesium minerals and from some carbonate rocks. Magnesium occurs in many organometallic compounds and in organic matter, as it forms an essential elemental component for flora and fauna. Natural levels of magnesium in freshwaters may range from 1 to about 100 mg/L, depending on the rock type within the catchment area.

Among all the ions determined, magnesium was the only one that tends to increase from the dry season to the rainy season by figs. 15,16 and 17 as well as tables 21, 25 and 29. The reason for this trend is not very apparent, except that one can be tempted into saying that, there may be some magnesium bearing rocks within the environs of these waters. Thus with the onset of the rains, such a rock being weathered, would be washed by run-offs into the water bodies.

4:2:2:13. Water Hardness.

Water hardness is the traditional measure of the capacity of water to react to soap, hard water requiring a considerable amount of soap to produce lather. The hardness of natural waters, depends mainly on the presence of dissolved calcium and magnesium salts. The total content of these salts is known as general hardness. Generally, hardness may vary over a wide range, with calcium hardness being usually prevalent (about 70%), though in some cases, magnesium hardness can reach 50 to 60%. Seasonal variations in river water hardness often occurs, reaching the highest values during low flow conditions (dry season), and the lowest values during floods (rainy season). Lake water hardness is less variable between seasons and may tend to increase during floods.

This trend is closely followed by the determined hardness at all the locations, as shown in figs 19, and 20, as well as tables 22, 26 and 30. This trend may be due the fact that, while in the case of river water, the ions are washed to sea or a reservoir during the rainy season (floods), in lakes on the other hand, all things are deposited and thus tend to increase in concentration.

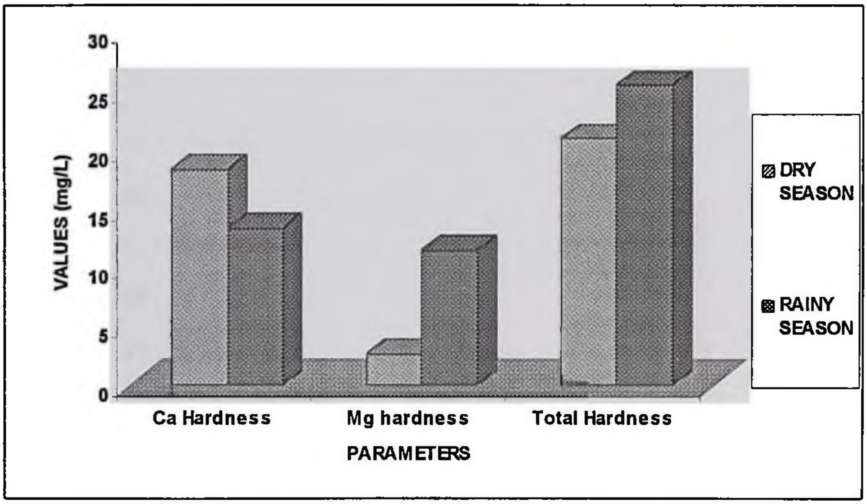


Fig. 18. Seasonal Changes in Water Hardness in the “Super-drain”.

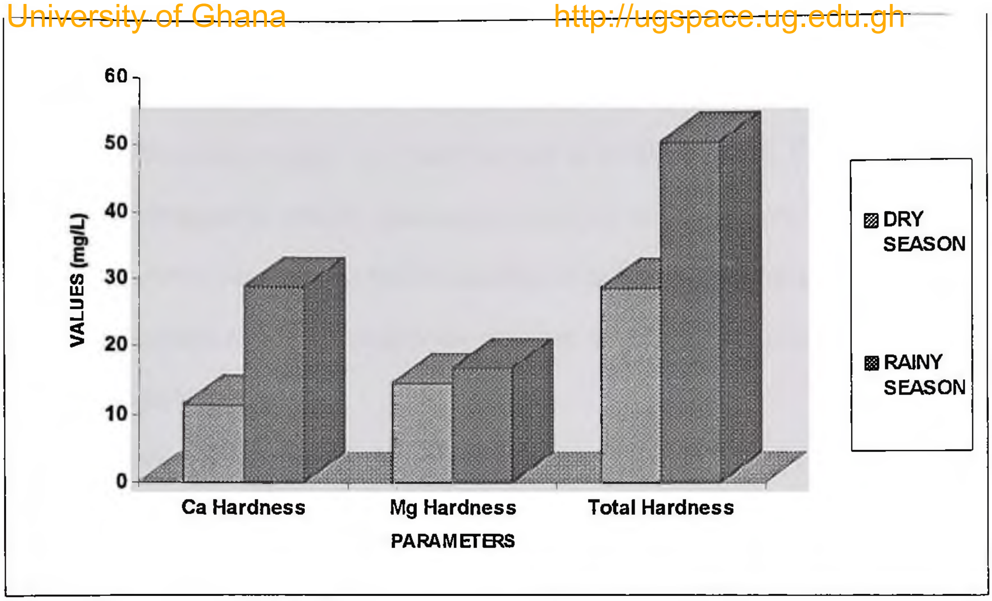


Fig. 19. Seasonal Changes in Water Hardness in Lake Kasu.

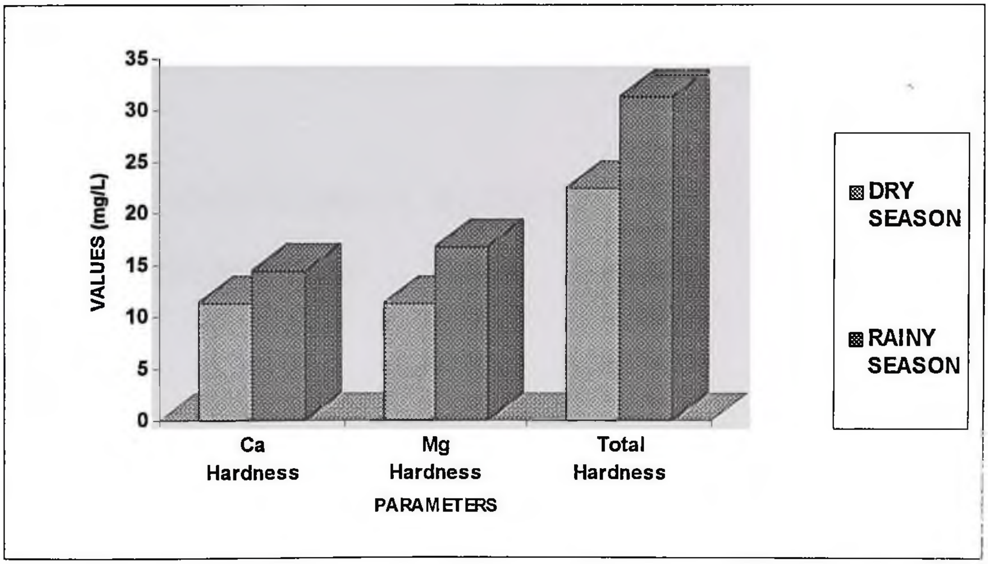


Fig. 20. Seasonal Changes in Water Hardness in Lake Nyafie.

4:2:3. VARIATIONS BETWEEN LOCATIONS.

Generally, looking at the mean values for physical and chemical parameters for the three locations shown in figs. 5,6,7 and 8 as well as in tables 15, 16, 17 and 18, some subtle variations can be noticed. Ignoring the values for the Super-drain on the grounds of its small volume and the fact that its contents all drain into lake Kasu, it can be said that, there are noticeable variations in the values of most of the variables between lake Kasu and lake Nyafie.

On the whole, values for lake Kasu are higher than those for lake Nyafie, with the exception of nitrate and phosphate. The higher values for these nutrients in Nyafie over that for Kasu could be attributed to the fact that, while serious rice growing is practiced in the catchment area of lake Nyafie all year round by KSF and therefore nitrate and phosphate based fertilizers are applied, the catchment area of lake Kasu has seen less farming activities especially in the past five to six years. Despite its low values for these nutrients, lake Kasu seems to be in a more deplorable state as far as water quality as well as species of fishes, especially, commercial types are concerned

4:3. ORGANOCHLORINE PESTICIDES IN WATER AND SEDIMENTS.

4:3:1. General

Clean and pollutant free water is essential for good health for man and all other organisms. The fact that, water is a very good medium for the storage and transport of other substances, especially, pollutants within the environment, makes the analysis for such chemicals a pre-requisite to maintaining a good water quality record.

Pesticides, unlike inorganic pollutants in the environment, which may come from human activity sources or from the geological make-up of the area through which the water flows, are what can be termed, point source pollutants. Thus, their presence in the environment can only be attributed to human activity, since they are not natural products.

Organochlorine pesticides were the ones of concern in this study because, of all pesticides, they are the most notorious as pollutants. This does not mean that they are the most toxic of pesticides, far from that, as there are some carbamates and organophosphates, which are many times more toxic than most organochlorines. The importance of organochlorines as pollutants is linked to some of the properties that make them very good pesticides, apart from toxicity. These properties are, (1) their persistence in the environment and (2) their high solubility in fatty tissues as against a very low solubility in aqueous mediums. The persistence makes their presence and effects to be felt for a long time after they have been used[12]. A typical example in this case is DDT, which because of its "miraculous power", was extensively used throughout the tropics i.e. in Africa, Latin America and Southeast Asia especially in India for combating mosquito-borne malaria[66]. The solubility of the organochlorines in fatty tissues makes them to be concentrated, bioaccumulated and biomagnified in living organisms along the food chain. This effect is mostly profound in predatory animals especially birds such as hawks, kites, sea eagles and other fish eating birds, resulting in most cases in reproductive failures and outright death[13].

4:3:2 Recovery Rate.

Recovery rate determination is an important integral part of most analytical works that involve extraction, concentration and cleanup. It is done to test the reliability of the processes involved in the work and the sensitivity of the equipment used. Generally, it is agreed that a recovery rate of 75% and above makes the methodology and equipment reliable, thus making the values so determined by that method and equipment also to be relied upon.

Table 31. Results from Recovery Experiment for Methods and Equipment Used in the Analysis of Pesticides.

	RECOVERY RATE (%)	
Pesticide	**Water**	**Sediment**
Aldrin	89	93
Dieldrin	84	87
Lindane	87	89
2,4,5-TCB	82	86
HCB	86	87
DDT	87	88
DDE	86	89

Since the recovery rates in this study were all above the 75% reliability level, the methods, procedures and equipment used in the study can also be said to be reliable and the results obtained can be relied upon.

4:3:3. Samples Analysis.

Analysis was carried out on all water and sediment samples for aldrin, dieldrin, DDT, DDE, DDD, HCB and 2,4,5-TCB. Out of these, only HCB, lindane and 2,4,5-TCB could be identified. Those that could not be identified were labeled "bdl"

Table 32. Pesticide levels in Sediment and Water of "Super-drain"

	WATER (ng/L)				SEDIMENT (ng/g)			
PESTICIDE	**Jan.**	**Feb.**	**June**	**July**	**Jan.**	**Feb.**	**June**	**July**
Lindane	15.86	7.00	bdl	bdl	bdl	bdl	bdl	bdl
HCB	Bdl	13.00	bdl	bdl	bdl	bdl	bdl	bdl
2,4,5--TCB	Bdl	bdl	bdl	bdl	1104.7	422.7	bdl	bdl

bdl = below detection level

Generally, it can be stated that, pesticide levels in these lakes, Kasu and Nyafie, are restricted to only a few chemicals species (3). These are lindane, HCB and 2,4,5-TCB. On the whole, it can be said that there is the presence of lindane, HCB and 2,4,5-TCB in the waters of lake Kasu and lake Nyafie, while the waters of the Super-drain shows the presence of only lindane and HCB. All sediments from the various locations indicate some amounts of 2,4,5-TCB. Tables 32, 33, and 34 show the levels of the pesticides in the sediment and water in the study areas.

Table 33 Pesticide levels in Sediment and Water of Lake Kasu.

	WATER (ng/L)				SEDIMENT (ng/g)			
Pesticide	**Jan.**	**Feb.**	**June**	**July**	**Jan.**	**Feb.**	**June**	**July**
Lindane	14.93	5.42	26.36	bdl	Bdl	bdl	bdl	bdl
HCB	bdl	1.18	4.08	bdl	Bdl	bdl	bdl	bdl
2,4,5-TCB	bdl	bdl	4214.91	241.62	290.39	34.94	56.07	118.80

Table 34 Pesticide Levels for Sediment and Water from Lake Nyafie.

PESTICIDE	WATER (ng/L)				SEDIMENT (ng/g)			
	Jan.**	Feb.	June	July	Jan.**	Feb.	June	July
Lindane	-	6.96	bdl	bdl	-	bdl	bdl	bdl
HCB	-	5.03	0.62	bdl	-	bdl	bdl	bdl
2,4,5-TCB	-	bdl	2316.1	151.26	-	46.85	26.93	59.01

** = There was no sampling due to damage to the canoe.

bdl = below detection level.

Table 35 Mean values for Pesticides Levels for Water and Sediment at Various Locations.

	Locations Water (ng/L)			Locations Sediment (ng/g)		
PESTICIDE	Super-drain	Lake Kasu	Lake Nyafie	Super-drain	Lake Kasu	Lake Nyafie
Lindane	5.72	11.68	2.32	00	00	00
HCB	3.25	1.31	1.88	00	00	00
2,4,5-TCB	00	1114.13	822.45	381.87	125.05	44.20

4:3:3:1 Lindane

The absence of lindane, a pesticide in the sediments of all the locations while present in their waters, can only be attributed to a relatively high solubility and rapid dissipation of lindane within the aquatic system. The initial high levels of lindane in the Super-drain for January and February as compared to those of lake Kasu, can be attributed to the fact that the Super-drain is the feeder for lake Kasu. The high lindane level of 26.36ng/L in lake Kasu in June as compared with it's total absence in the

Super-drain in the same month, can only be due to the run-off action which might have carried practically everything from the drain into lake Kasu at the start of the rains.

The apparent absence of lindane in lake Nyafie in June and July, and also in lake Kasu in only July, can be accounted for on the grounds of its very low concentration making it tofall below detection level, as a result of the large volume of the flood waters in these months (tables 32, 33 and 34).

4:3:3:2 HCB

The presence of HCB, a herbicide, in the waters of the Super-drain and the lakes, did not show up as a surprise. This is because, the areas of these lakes, where rice and the vegetables are grown, were usually overgrown with weeds. Thus, for the farmers to break even in their farming ventures, they no doubt turned to the use of herbicides as compared to mechanical weeding which is relatively more costly. The low amounts of HCB detected may not mean that it is not used very much, but may be as a result of it being readily converted into other forms, or easily dissipated.

4:3:3:3 2,4,5-TCB.

The presence of this chemical in the waters of both lakes starting from June and its high concentrations (tables 32, 33 and 34) indicates that it is the herbicides in current usage in the catchment areas of these lakes. The very high amounts of this herbicide present in the waters of lake Kasu (1114.13 ng/L) and lake Nyafie (822.45 ng/L), is of grave concern with regard to human and other organisms' life either in the water or dependent on the waters of these lakes.

The presence of the chemical in the sediments of all the location, indicates its wide distribution in the environment, and as such, needs critical monitoring and or surveillance system to check its presence in future.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION.

A world without water is difficult to imagine. But images from the moon and Mars show clearly what conditions might be like without it. Water is vital for drinking, sanitation, agriculture, industry and other countless purposes. Life on earth begun in water, now fresh water brings life to thirsty cities and parched crops, and provides the habitat for a multitude of living things. However, water can also mean death and destruction. Polluted water brings diseases and death to those who drink it and kills the birds, fish and other forms of life that need it to survive.

The history of pollution in the developed world provides a model for the likely scenario in other areas. For example, the eutrophication caused by abundance of phosphates and nitrates in discharges, which first affected lakes in Europe and North America in the 1950's, has extended to all continents[65]. The elevated levels of nitrates in surface and ground waters, associated with intensive farming practices and high rate of fertilizer and pesticide application, have also become widespread.

The significance of changes in the structure and quality of aquatic systems, is often not closely related to the specific effects of separate stresses on individual components, but rather to the total or joint impact of man-induced changes. Interactions between pollutants and their impacts after use, appear to be the rule rather than the exception, and the total effects of a large number of "minor" pollutants or their impacts, each in small concentration or intensity, may be as great as the effect of one "major" pollutant or impact acting alone. Thus, the total burden imposed by man's activities may be impossible to evaluate except by observation and analysis of the overall effect on aquatic ecosystems[67]. Thus, clear, clean and pathogen-free water is a valuable resource in any country. Though renewable in the long-term sense, water and the ecosystems, which depend upon it may be essentially non-renewable in the short-term, if managed carelessly. Water must therefore, no longer be considered a "free resource".

1. With regard to the physico-chemical parameters studied, it can be concluded that the waters of the lakes, except for turbidity and BOD, are not dangerous for human consumption since values for the other parameters were within the WHO accepted limits.
2. The fact that the presence of some organochlorine pesticides have been detected and particular ones such as lindane, HCB and 2,4,5-TCB, were identified in the waters and sediments of these lakes, which are the sole source of drinking water for communities along their banks, should be taken seriously.
3. The answers from the questionnaire as to the types of pesticides used were not truthfully given. This is because, the presence of some organochlorines in the water and sediments of the lakes, shows that they are being used in the area. Though, quantitatively their presence as individual substances seem to be below permissible levels, viewed collectively, their combined effects should be of grave concern to environmentalists and health-workers.
4. Since the inhabitants along the banks of these lakes depend largely on the fishes from their waters, there is the urgent need to analyse for these pesticides in the fishes, especially the bottom-feeder species that are now the only ones mostly available in lake Kasu.
5. Health authorities in conjunction with the Dangme-West District Assembly and some NGOs must be made aware of the presence of these pesticides in the water of the lakes, for them to provide alternative sources of drinking water for the people.

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APPENDIX

Sample of the Questionnaire used in the Survey.

1. What types of crops do you grow?
2. Do you use Chemicals on your farm and on the crops?
3. Which class of Chemicals do you use? (Insecticides, herbicides, fungicides or growth regulators)
4. Which specific insecticides do you use?
5. Which specific herbicides do you use?
6. Which specific fungicides do you use?
7. Which specific growth regulators do you use?
8. Where do you get your supply?
9. How do you store chemicals when not using them?
10. How do you dispose of damaged and/or expired chemicals?