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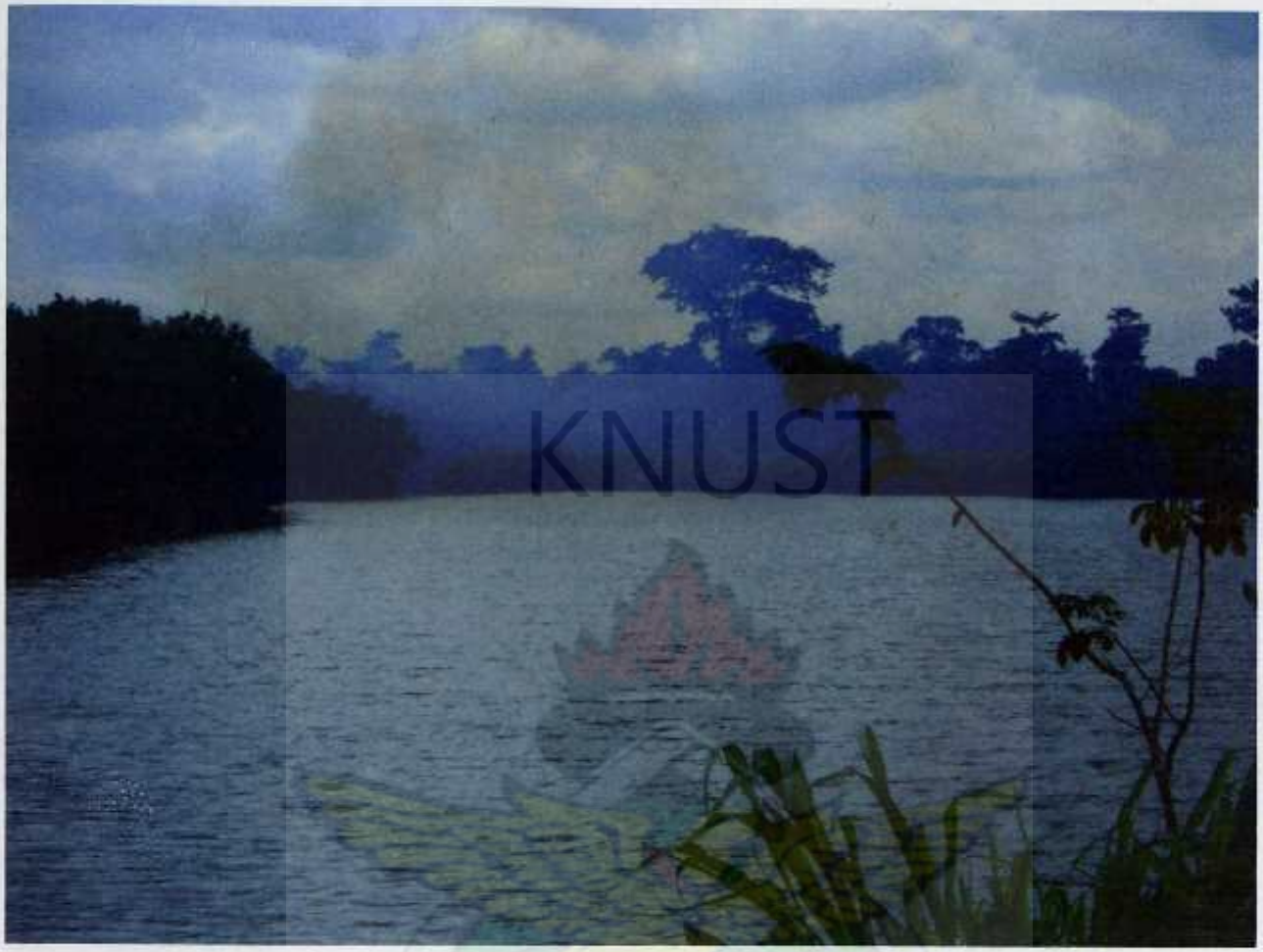

THE IMPACT OF INTEGRATED WATER RESOURCE MANAGEMENT ON THE WATER QUALITY OF THE DENSU RIVER

Jane Naki Tetteh (Miss)

MSc Thesis

May, 2009

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WRESP – KNUST

Faculty of Civil and Geomatic Engineering

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By

Jane Naki Tetteh (Miss)

Supervisors

Dr. Samuel N. Odai

Mr. Richard Buamah

Kumasi

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By

Jane Naki Tetteh (Miss), BSc. (Hons)

A thesis submitted to The Department of Civil Engineering,

Kwame Nkrumah University of Science and Technology, Kumasi

In Partial Fulfillment of the Requirement for the Award of the

Degree of Master of Science in

Water Supply and Environmental sanitation

May, 2009

CERTIFICATION

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

Jane Naki Tetteh _____ 07/05/09 **(Student)**
Signature Date

Certified by:

Dr. S.N Odai _____ May 7 2009
(Principal Supervisor) Signature Date

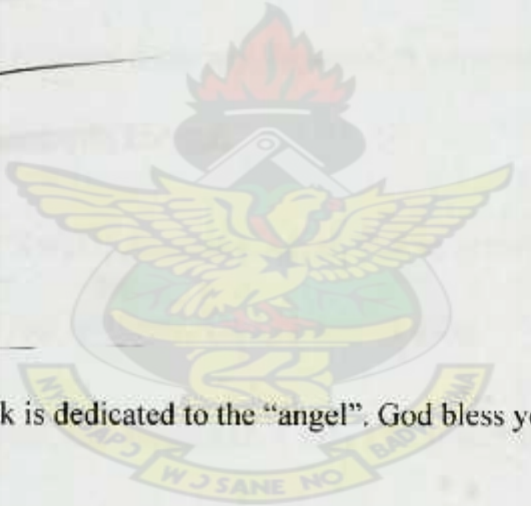
Certified by:

Mr. Richard Buamah _____ May 7, 2009.
(Second Supervisor) Signature Date

Certified by:

Prof.S.I.K. Ampadu _____ 10/05/2009
(Head of Department) Signature Date

Dedication



This work is dedicated to the "angel". God bless you.

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Abstract

In most developing societies, water has not been effectively and efficiently managed over the years because water has been traditionally perceived to be a free commodity. The outcome is pollution that tends to threaten the aquatic environment and the life it supports. The Densu River Basin (DRB) however, is no exception of this case. The problem has mainly been due to uncoordinated activities in the basin. In view of this the Densu River Basin Board was commissioned to implement Integrated Water Resource management (IWRM) to arrest the situation.

The aim of this thesis is to identify IWRM activities currently on- going in the basin and to find their influences on the water quality of the Densu River. To asses this questionnaires were administered and focus group discussions organised for farmers and some members of the community within the basin. Data was collected from Water Resource Commission (WRC), the Densu Basin Board secretariat and Ghana Water Company Limited (GWCL). Samples of water were collected from four monitoring station Potroase (upstream), Mangoase and Nsawam (midstream) and Weija (downstream) and analysed at the environmental quality engineering laboratory of Kwame Nkrumah University of Science and Technology.

The IWRM activities identified being implemented in the Densu river basin includes awareness creation, proper waste management, buffer zone creation, appropriate farming and fishing techniques and water use regulation. Water quality index values calculated were in the range of 15 - 45 and according to the Solway classification the river can be said to have poor water quality. Consumption of alum, chlorine and lime reduced by 6.42%, 10.29% and 89.25 % respectively from 2006 to 2008 at the Koforidua headworks. At Nsawam, alum and chlorine did not show a well defined trend, but lime showed a downward trend over the studied period. This trend in water quality shows that the identified IWRM activities seemed to have had very little impact on the water quality from 2005 to 2008. It was not surprising though, since the IWRM activities identified had immediate cost but long term benefits, hence their full benefits have not yet been derived during the research period.

Continuation of the activities especially the waste management and monitoring program will go a long way to improve the water quality in the Densu river.

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List of Abbreviations and Acronyms

AMA	Accra Metropolitan Assembly
ASMA	Akwapim South Municipal Assembly
CBO	Community Based organisation
CWSA	Community Water and Sanitation Agency
DA	District Assembly
DBB	Densu Basin Board
EPA	Environmental Protection Agency
GOFA	Global Organisation for Fundamental Aid
GWCL	Ghana Water Company Limited
GWP	Global Water Partnership
IWRM	Integrated Water Resources Management
KVIP	Kumasi Ventilated Improved Pit
MOFA	Ministry of Food and Agriculture
NJMA	New Juaben Municipal Assembly
WRC	Water Resource Commission

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Fresh water in Ghana as in many developing countries, have not been effectively and efficiently managed over the years because water has been traditionally perceived to be free commodity. The outcome is pollution that tends to threaten the aquatic environment and the life it supports. (WRI, 2003). The Densu River Basin (DRB) is no exception in this case. The Densu River stretches 116 km from its source in the Atiwa Range in the Eastern Region to the Sakumo Lagoon in the Greater Accra Region where it enters the sea. It has three reservoirs along its course of which the Weija Dam, located at the lower course of the river is the largest. The river is a source of raw water for potable water to over one million people within the basin. The general attitude has been the lack of consideration for the downstream consequences of the actions executed upstream. Consequently an extensive pollution of the Densu River Basin with solid and liquid wastes from the settlements (mostly urban) that line up its banks from its source has been observed. Substantial portions of the river bank are unprotected and therefore farmers and estate developers within the communities have encroached on the parcels of land within the catchment of the basin.

Fishermen in the riparian communities use poisonous chemicals and other illegal methods for fishing in the Weija reservoir itself. By virtue of its location at the very last reach of the river before discharging into the sea, the reservoir virtually acts as a sink for all the resultant pollutants ensuing from this heavily urbanized environment.

The Weija reservoir area has been encroached upon to the detriment of the dam structure. Encroachment on the dam area in recent times has taken a different dimension as land developers

and stone quarrying activities involve the use of explosives to blast the rocks which serve as protection for the dam. The explosives apart from breaking the mountains, also weakens the foundational structure of the dam. If the activities within the catchment area of the reservoir are not checked, in an event of a dam collapse, the run-over of the water could spread and submerge areas such as Odorkor and Dansoman which are about 10 kilometres away from the reservoir. The activities of these encroachers have affected the water quality, the level and volume of water in the reservoir since the quarry activities within the banks have contributed to immensely to the deterioration of the water quality.

Integrated Water Resource Management (IWRM) is a process that promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising sustainability of vital ecosystems. (GWP,2000)

In view of these problems, the Water Resources Commission (WRC) (Act 522, 1996) has started implementing Integrated Water Resources Management (IWRM) in Ghana. Two river basins (Densu and White Volta) have been selected as pilots to test capacity building, participation and public awareness strategies, regulations and water resources planning within a decentralized administrative framework with the river basin as the unit for planning. Results and lessons from the pilot activities have now started accruing. For instance, a consultative framework was established for the Densu basin board in 2003. Sustained support is being given to awareness, and promotional activities among local stakeholders have been enhanced for the collection of data and information on the water resources situation.

In addition, water quality guidelines for raw water have been set by Water Resource Commission (2003) to asses the status of raw water and classify them into various potential uses.

1.2 Justification of the study

The Densu River is of specific importance since it includes the Weija Reservoir and other treatment plants which supply water for approximately half of the Accra metropolitan area and parts of Eastern Region. And this study is to document the impact of the IWRM activities on the quality of water.

1.3 Goal of the Study

The main goal of this study is to assess the impact of the IWRM activities on the water quality of the Densu River.

The specific objectives are:

- To identify IWRM Practices in the Densu basin
- To determine the trend of changes in the raw water quality (assuming 2005 as the baseline year)
- To determine the impacts of the changing trend of the raw water quality on the water treatment processes at the various plants situated on the Densu River. (assuming 2006 as the baseline year)

CHAPTER TWO

2.0 Literature Review

2.1 Integrated Water Resources Management

At the United Nations Conference on Water in the Mar del Plata in1977, IWRM was the recommended approach for incorporating the multiple competing uses of water resources. After this conference, it took over a decade for IWRM to be fully recognized and accepted at the political front. Efforts such as the International Conference on Water and Environment (1992), Second World Water Forum in The Hague in 2000, Johannesburg World Summit on Sustainable Development in 2002 and Third World Water Forum in Kyoto, Japan in 2003 collectively led to breakthroughs that thrust IWRM onto the political agenda.

Global Water Partnership defines Integrated Water Resources Management (IWRM) as a process, which promotes the coordinated development and management of water, land and related resources, in order to maximize the economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Integrated Water Resources Management addresses the entire water and land system, as well as the human system. By considering the different functions of water and the different stakeholders, it can be considered as a means to reach a better sharing of water

Capacity building, participatory approaches and public awareness strategies are key to full understanding, acceptance and the implementation of the concept of IWRM. These serve as development tools for guiding and supporting various authorities at different levels involved in the decision-making process.

2.2 Water Resources Management in Ghana

Act 522 (section 37) of the Ghana Water Resources policy defines water resources as "all water flowing from any river, spring, stream or natural lake or part of a swamp or in or beneath a watercourse and all underground water but excluding any stagnant pan or swamp wholly contained within the boundaries of any private land. (Act 522, 1996)

Water resources management can be described as all activities and programmes geared towards the allocation, distribution and conservation of water and its associated bio-physical factors (Owusu et al, 2006).

2.3 Water policy and water law in Ghana

Until recently there was no institution in Ghana that had overall responsibility to manage the country's water resources. Several single purpose state agencies pursued their individual mandates with little co-ordination and without any thought about what other water users required. Little emphasis was put on the management and conservation of water. Secondly, water was provided in a way that did not capture the economic value of producing and conserving it. Thirdly, there was no effective regulation of the water sector. The likely result was that the management of water could not be sustained.

In article 269 of the 1992 Constitution of Ghana the establishment of such a body, the Water Resource Commission (WRC) was called for. In 1996, the Ghanaian Parliament passed the Water Resource Commission Act (Act 522, 1996). This led to the establishment of the Water Resource Commission and the Water Directorate under the Ministry of Water Resources, Works and Housing, and at local river basin level in the form of creation of river basin boards. The WRC acts on behalf of the President, in whom all water rights are vested in trust for the people

of Ghana. Under the act no person or organisation exerts the authority to divert, dam, store, abstract or use water, to develop or maintain any works for the use of water resources, without the WRC's consent (Mensah, 1999). The WRC is to integrate and harmonize the various legal instruments, which are the result of the former, sectoral approach to water resource management in Ghana.

2.4 The Densu Basin environment

The Densu basin environment comprises both natural and human systems. These systems show distinctive pattern of variations upstream, midstream and downstream of the Densu River. Administrative districts within the basin are shown in Table 1.

Table 1: Densu Basin Environment in Relation to Area of District within the Basin

Level	*Districts*	*Catchment Area within Densu Basin (Km^2)*	*Area outside Densu Basin (Km^2)*	*Total area of administrative district (Km^2)*	*Percentage of area within Densu Basin (%)*
Upstream	Akwapim North	146	391	537	27
	New Juaben	209	7	216	97
	Suhum-Kraboa-Coaltar	763	215	978	78
	East Akim	334	1144	1478	23
Midstream	Akwapim South	322	62	384	84
	West Akim	88	753	841	10
Downstream	Ga	556	88	644	86
	Awutu-Efutu-Senya	122	690	812	15

Source: WRC, 2007

2.4.1 Land use pattern and ecological trends

The original ecology of the Densu Basin was moist semi-deciduous forest with thick undergrowth featuring rich flora and fauna. (DRB, 2007). The human activities through time, however, have greatly modified this forest ecology at an accelerating rate. Within the past two decades, the ecological perspective of the Densu Basin has changed dramatically. The thinning

of the forest has intensified, and at the same time the marked shift in land use caused by "urbanization" in the eastern corridor of the basin from Weija area through Nsawam to Koforidua has its ecological impacts. (DRB, 2007)

At present the Densu Basin is characterized by three types of vegetation zones. The north-eastern section of the basin is forested land, but with intensive deforestation because of agricultural activities. In this zone, cocoa farming was predominant until recently when the swollen shoot disease caused land use evolution in the forest area (DRB, 2007). Cocoa farming has been replaced by extensive bush fallow food cropping. The main food crops that are cultivated here include plantain, cassava, yam cocoyam and cereals such as maize. Large estate and present-scale oil palm plantations have also become important in the recent past, which also contributes to deforestation in the Basin (DRB, 2007).

The traditional forest zone in a large part of the Basin is gradually being taken over by the second zone – characterized by scattered trees developing into areas of shrub and grassland. These parts of the Basin are characterized by extensive cultivation of cassava, maize pineapple and vegetables, and host much livestock grazing. The coastal savannah zone in the extreme southern section of the Basin makes up the third vegetation zone.

2.5 Water Quality of Rivers

Good water quality is essential to all living things that live in a river and its watershed. Healthy water contains a balanced amount of nutrients and has normal fluctuations in salinity and temperature. It also has a lot of dissolved oxygen so aquatic animals can breathe;B and little suspended sediment so underwater grasses receive enough sunlight to grow.

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose. Streams can be contaminated

by a range of material from adjacent land. This can include soil particles (sediment), nutrients such as nitrogen and phosphorus, salt, material from crops, chemicals, and microbes. In most areas, eroding soil and associated nutrients are the most important and widespread causes of reduced water quality.

2.6 Water Quality Parameters

Total Dissolved Solids (often abbreviated TDS) is an expression for the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular (colloidal sol) suspended form

The biological life that is present in water including the organism that are responsible for self-purification processes depend on the dissolved oxygen (DO) for survival. Oxygen is not much soluble in water and the DO contents of natural waters vary with temperature, atmospheric pressures, dissolved solids and the photosynthetic activities of algae and plants. (Jain & Singh, 2003)

Variation in DO occurs seasonally or even during the day as a function of temperature and biological activities. Biological respiration including that which relates to decomposition processes reduces DO concentration. Waste that discharge high organic matter and nutrients can lead to decreases in DO concentration, as a result of the increase in microbial activities during degradation of the organic matter.

The level of DO indicates the degree of pollution by organic matter, destruction of organic substance and the lost of self – purification of the water. Concentration below 5mg/l may adversely affect the functioning and survival of biological communities. (Jain & Singh, 2003)

Turbidity in open water may be caused by growth of phytoplankton. Human activities that disturb land, such as construction, can lead to high sediment levels entering water bodies during

rain storms, due to storm water runoff, and create turbid conditions. Urbanized areas contribute large amounts of turbidity to nearby waters, through stormwater pollution from paved surfaces such as roads, bridges and parking lots.

The higher the turbidity level, the higher the risk of that people may develop gastrointestinal diseases. This is especially problematic for immune-compromised people, because contaminants like viruses or bacteria can become attached to the suspended solid. High turbidity levels can block light from reaching lower depths of water bodies, which can inhibit growth of submerged aquatic plants and consequently affect other species dependent on those plants, such as fish and shellfish.

Alkalinity is the concentration of bases dissolved in water and expressed as parts per million (ppm) or milligrams per litre (mg/L) Calcium carbonate ($CaCO_3$). These bases are usually bicarbonates (HCO_3-) and carbonates (CO_3-), and, in rare instances, hydroxide (OH-) ions.These ions, called buffers, are important because they slow the rate at which the pH changes. The magnitude of change is determined by the water's buffering capacity or its ability to absorb acids and/or alkalis (base) and is an often overlooked, though extremely important component of pH balance. Without a buffering system, free carbon dioxide will form large amounts of carbonic acid that may potentially decrease the night time pH level to 4.5. During peak periods of photosynthesis in a heavily planted tank, most of the free carbon dioxide will be consumed by the plants and, as a result, drive the pH levels above 10. A good buffering capacity can prevent excessive build-ups of carbon dioxide and lethal changes in pH.

Hardness is generally defined as the sum of the polyvalent cations present in water expressed as an equivalent quantity of calcium and magnesium. Although no distinctly defined levels exist for

what is constitutes a hard or soft water supply, water with less than 75 mg/l $CaCO_3$ is considered to be soft and above 150 mg/l $CaCO_3$ as hard. (American Water works Association, 1999)

2.7 Water Quality Degradation in Densu River

Water quality in the Densu river basin is degraded and it is caused by agricultural activities and urban waste management.

Farming along the river banks and in the river bed, agrochemicals used to improve soil fertility and also help protect crops are washed directly into the river resulting in contamination. Livestock from the settlements along the river drink directly from and defecate into the river and also cattle farmers living along the Densu in the Ga district are said to dump cow dung into river during the rainy season. Fishermen from Nsawam to Weija along or near the river and the reservoir use explosives and chemicals like DDT in fishing. All these contribute to the degradation of the quality of water in the river.

Inadequate toilet facilities for inhabitants living close to the river cause them to defecate openly along the river banks and into the river which pollute the river. The river is also used as a final disposal site for night soil. Garbage collection points in Nsawam and Koforidua are not cleared promptly and so such pile up in huge heaps and whenever it rains they are washed into the river. Leacheate from the landfill site in Koforidua and Mallam are washed directly in the river because of poor management. Liquid waste fro household, abattoirs and industries (Nsawam and Koforidua) are discharged directly into the river. At Weija Water Works, the Ghana Water Company Limited (GWCL) discharges sludge from the water treatment plant back into the reservoir.

The impact of disposal of various wastes into the Densu River is given by a snapshot of results of water quality analysis on samples taken in the dry seasons between January and February 2001.the analysis showed the follow (Source: WRC, 2001)

- Physical water quality deteriorates from source till it enters the sea. The deterioration is most pronounced at the urban centres. The results showed turbidity above 20FTU.
- Chemically the water in the basin shows a trend towards eutrophication due to nutrients from the wastes discharged into the river.
- The aquatic fauna is made up of those species that can survive under extreme stress conditions.

2.8 Institutional Management Structure for the Densu Basin- The Densu Basin Board.

In implementing IWRM programme, an appropriate management institutional framework was established with the participation of all relevant stakeholders in the Densu basin. Thus, a Densu Basin Board (DBB) was set up and made functional as the coordinating institution for the management of water resources in the basin. The agreed membership of the DBB is made up of a representative each of:

- Five key District Assemblies (out of the eight administrative districts that make up the basin)
- Six ministries and agencies – Ghana Water Company, Environmental Protection Agency, Ministry of Food and Agriculture, Ministry of Health, Forestry Commission, and Eastern Regional Coordinating Council.
- Religious bodies
- Non-governmental organisations
- Regional house of chiefs

- The National Council for Women and Development, and
- Water Resources Commission (WRC).

The process was also facilitated through the establishment of a WRC basin office (Densu Basin Secretariat) according to needs and agreed procedures in the Densu basin.

2.8.1 Awareness Creation and Education

One fundamental solution that was identified to improve the ecological health of the Densu was effective public awareness and education campaign. The Densu Basin Secretariat has organized public awareness activities such as publication and dissemination of IWRM messages and educational materials through the media, and supporting local stakeholders, particularly NGOs and Community Based Organizations. The Secretariat has been involved in the education of seventeen (17) key communities within the Basin. Additionally, seminars and workshops have been organized for all the eight District Assemblies within the Basin. These interactions have gradually led to the established of a strong link between the DBB and the districts towards adapting joint solutions in tackling water resources management issues.

2.8.2 Achievements and Impacts

Many interventions have been initiated over a period of time. Thus, in the beginning of the 1990s consultations were held with representatives of local governments, District Assemblies within the basin and relevant government and research institutions as well as the NGO community to identify actions to be taken to ameliorate the deteriorating situation (Nii Consult 2001). Since then the issue has regularly been discussed publicly, and several surveys and studies presenting proposals for addressing the problems have been put forward. However, in spite of these efforts,

the planned programmes have not been effectively translated into concrete actions on the ground, in part, due to lack of funds and lack of adequate capacity of the various District Assemblies.

The activities initiated by the Water Resources Commission in the Densu Basin were meant to rejuvenate the process towards introducing IWRM with a firm anchorage established among all interested parties and stakeholders in the basin. A Densu Basin Board (DBB) was established to coordinate activities within the basin and manage it on a holistic manner.

Though much has not been done, activities so far undertake in the Densu Basin, favourable and significant ecological and environmental changes have been realised, but which needs to be followed up. Such realised ecological changes include:

- Slight general improvement in the raw water quality especially at the down stream of the Basin. Ghana Water Company has indicated the reduction in the cost of treating water to the population, especially the western parts of Accra (WRC, 2007)
- Some degraded parts of the river catchment that were left fallow are gradually gaining their vegetative cover.
- Linked to the above is significant impact of tree growing that has been undertaken at several parts of the Basin especially at the mid-stream.
- A number of clean-up exercises and the phasing out of outmoded technologies for managing faecal matter/ liquids and solid waste such as Pan Latrines.
- More communities are becoming aware of the consequence of the degradation of the river basin, pollution of water bodies and the attendant diseases, high cost of treatment of the diseases, poverty, and loss of livelihood. In Nsawam, for instance, a youth award scheme on activities for the protection and conservation of water resources has been instituted by an NGO, which is increasing the enthusiasm of youth organizations in the basin. Some District Assemblies and communities are also working hard at instituting better waste management and land use schemes to conserve the basin.

2.8.3 Improvement in water quality

The Water Resources Commission embarked on a systematic water quality monitoring program in 2005 and 2006 in the Densu Basin to determine trends in water quality. Four monitoring sites were included in the program i.e. Potroase, which is at the source of the river, Mangoase and Nsawam at the midstream and Weija at the downstream. A Water Quality Index (WQI) was used for the assessment. This index was developed for the Solway River Purification Board by Bolton *et al.* (1978) and adapted and modified by Ansa- Asare (1998) in 2003 to interpret measurements of ambient water quality parameters (dissolved oxygen, biochemical oxygen demand, ammonia, faecal coliform, pH, nitrate, phosphate, suspended solids, electrical conductivity and temperature). The index is classified into four categories: good, fairly good, poor, and grossly polluted as depicted in Table 2. The index thus indicates the degree to which the natural water quality is affected by human activity.

Table 2: Water quality classifications of surface water (Paintsil & Abrahams, 2008)

Class	Range	Description
I	>80	Good -Unpolluted and/or recovering from pollution II
II	50-80	Fairly good
III	25-50	Poor quality
IV	<25	Grossly polluted

CHAPTER THREE

3.0 STUDY AREA

3.1 Description of study Area

The Densu River Basin is located between latitude 5°30'N and 6° 17'N and longitude 0°10'W and 0°37'W shown in Figure 1. The basin is bounded to the east and north by the Odaw and Volta basins, respectively. The boundary to the northwest is shared by the Birim basin and to the west with the Ayensu and Okrudu basins (DRB, 2007)

The topography of the Basin is diversified. The basin is characterized by steeply dissected landscape with hilly and rolling lands to the north, and flat coastal plains to the south with slopes and erosion surfaces that vary from 30% in the upper sections of the basin to less than 2% at the coast. The Basin is bordered to the east by the Akwapim hills and the Kwahu-Mampong scarps. The highest part of the basin reaches about 750 m above sea level and occurs along the north-western basin boundary.

The Densu River belongs to the Coastal River System group and the basin encompasses an area of about 2,540km^2. The river takes its source from the Atewa Range near Kibi and flows for 116 km into the Weija Reservoir, from where the river gradually changes its course and flows south into the Weija reservoir, one of the two main sources of water supply for the Accra Metropolitan area. When the Weija reservoir is full excess flow discharges into the Densu delta (Sakumo) lagoons and salt pans complex, which constitutes one of Ghana's internationally recognized protected areas (Ramsar sites), before discharging into the Bay of Guinea (Atlantic Ocean) some 10 km, and its main tributaries are the Pompon , Kuia, Adaiso, Dobro and Nsaki Rivers (DRB, 2007).

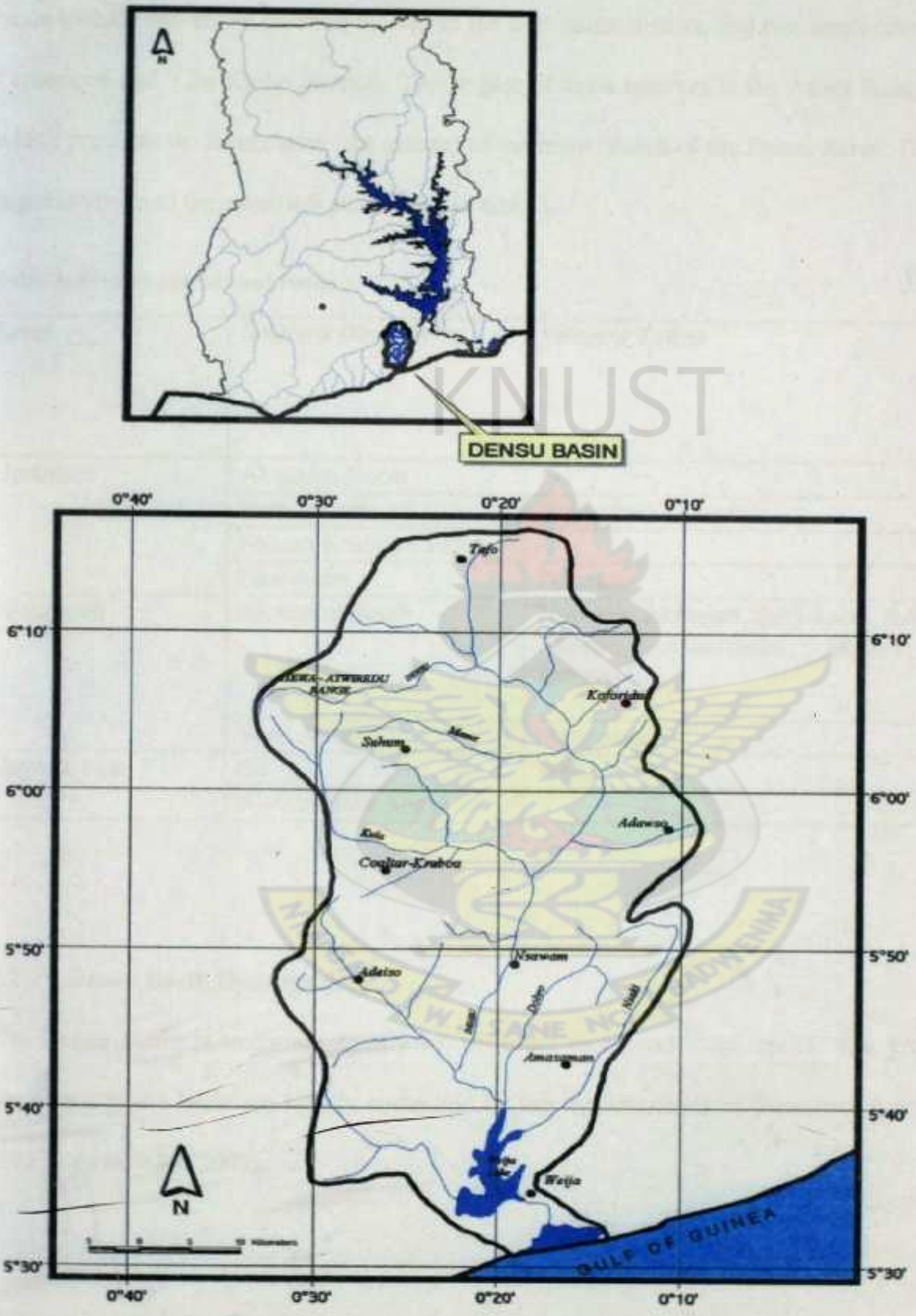


Figure 1: Densu River Basin (Source, 2007)

The vegetation consists of coastal savannah, thicket and grassland in the south, and moist semi-deciduous forest in the north. The mean annual runoff is 500x106 m^3. Protected areas in the basin include two forest reserves located in the East Akim district, and two small reserves in the Fanteakwa and Yilo Krobo districts. The largest of these reserves is the Atiwa Range Reserve, which provides the headwaters (the source) of the main branch of the Densu River. The selected communities and their districts studied are in table 3.

Table 3; Studied districts and towns

Level	*Selected Districts*	*Selected Towns*
Upstream	Akuapim North	
	New Juaben	Koforidua, Akwadum
	Suhum-Kraboa-Coaltar	
	East Akim	Potroase
Midstream	Akwapim South	Nsawam, Akraman, Sekyikrom, Adoadjiri, Ahodjo, Afumkrom, Doboro, Pakro, Amoakrom
	West Akim	Mangoase
Downstream	Ga	Weija
	Awutu-Efutu-Senya	

3.2 Densu Basin Hydrogeology

The Densu Basin is underlain mostly by Birimian rocks and Togo series. The groundwater conditions in the basin are largely controlled by the characteristics of these rock types. (Kesse, 1985 cited in WRC 2007)

CHAPTER FOUR

4.0 Methodology

4.1 Data Used

4.1.1 Primary Data Collection

4.1.1.1 Observations

Communities for the research were identified at the upstream, midstream and downstream portions of the basin. The selection of the communities was based on the proximity of the community in the Basin to the Densu River. Critical observations were made to determine how the attitudes and practices of riparian communities influence the quality of the water body.

4.1.1.2 Questionnaires Administration

Questionnaires were administered to target groups and some stakeholders (Shown in Plate 1b). The questionnaires were aimed at acquiring both quantitative and qualitative data on activities along the rivers as well as their opinions on watershed management in their community. A sample of the questionnaire can be found at Appendix 2.

4.1.1.3 Focus Group Discussions

Two Focus group discussions were held at Nsawam and Sekyikrom (shown in Plate 1a). This helped in checking responses from the questionnaires administered.

The discussions held within the farming communities were focused on the impact of their livelihood activities on the basin and management of the water resources in their locality and also to ascertain whether some activities are undertaken to help pollution control.

4.1.1.4 Interviews

The field work included structured interviews with all identified stakeholders and collection of water samples upstream, midstream and at the intake of the dam. The stakeholders include the Densu Basin Board (DBD), Ghana Water Company Limited (GWCL), and Water Resource Commission (WRC), Akuapim South Municipal Assembly, Ministry of Agriculture and Agriculture.

4.1.1.5 Sampling

Sample bottles were rinsed with distilled water to ensure that they are free of any contaminants. Water samples were taken from four existing monitoring sites for Water Resource Commission and three other proposed monitoring sites. At each site two 1.5l of samples were taken with one dosed with 5ml of nitric acid for preservation. Before samples were taken at each sampling points, the sample bottles were rinsed with water from that point. This is to ensure that the composition of water in the bottles was only that of water at that point.

The pH and temperature of the samples were measured insitu.

(a) (b)

Plate 1:(a) Focus group discussion at Sekyikrom ;(b) interview with a farmer at Akraman

4.1.1.6 Laboratory and data analysis

The following analysis was carried out on the water samples using the methods given in table 3. The selected parameters based on the physical properties and to water treatment.

Table 4: Methods for the determination of some water quality parameter

WATER QUALITY PARAMETER	METHOD OF DETERMINATION
Metal analysis	-Nitric acid digestion - AAS analysis
Alkalinity	Titration using -HCl -methyl orange indicator
PH	PH-meter
Total hardness	EDTA- titration using Eriochrome black- T as indicator
Chloride	Iron exchange chromatography
Fluorides	Iron exchange chromatography
Nitrate	Iron exchange chromatography
Conductivity	Conductivity meter.
Dissolve oxygen	

4.1.2 Secondary Data

Densu Basin Board annual reports on Densu were acquired and also water quality reports from Water Resource Commission were also obtained. Data on the quantities of chemicals used in treatment of water at the three treatment plants on the Densu River were obtained from Ghana Water Company Limited

CHAPTER FIVE

5.0 RESULTS AND DICUSSIONS

5.1 Integrated Water Resource Management (IWRM) activities in the basin

The Densu Basin Secretariat has undertaken a number of IWRM activities in the river basin. These activities include

1. Awareness creation
2. Waste management
3. Appropriate farming methods
4. Creation of buffer zones
5. Development of woodlots
6. Appropriate fishing activities.
7. Water use and drilling licensing

5.1.1 Awareness creation and education

Radio and television programmes have been organized since 2001 to date to disseminate messages on the need to keep the environment clean, and to manage waste properly within the communities. Additionally, UN habitat established a project named Urban Catchment Management Project of Water for African Cities, Phase II in 2006. This project was purposed to investigate and the encroachment, land degradation and pollution emanating from poor sanitation condition in the Weija catchment. Another objective of the project was to develop appropriate educational material to educate communities and schools on sanitation in the Weija Reservoir Catchment. As part of efforts at implementing the Urban Catchment Management Project policies, seminars were organized for health trainee workers in Koforidua. Development and

distribution of educational materials in the form of stickers and posters have been in progress over the past year (2009). To further the awareness creation strategies, the Densu basin secretariat is currently reviewing the applied measures with the aim of improving performance. The Densu Basin Secretariat collaborates with NGOs and Public Organizations (GOFA, Okyeman Environmental Foundation) to create awareness in schools and communities.

The survey conducted in the communities gave indication that a large percentage(80%) of the populace are at the moment aware of the essence of maintaining a clean environment however the attitudes do not reflect this level of education. Recalcitrant and deviant inhabitants (wee smokers) prefer to defecate along the shores of the river especially under the bridges. This attitude may probably due to inadequate place of conveniences within the settlements.

5.1.2 Waste management and regulation of land use

Densu Basin Secretariat and the Board collaborated with District Assemblies, public and private stakeholder organizations (NGOs, CBOs, EPA, communities etc) to tackle pollution and encroachment issues emanating from farming, fishing, quarrying, poor infrastructure development and poor waste management practices.

5.1.2.1 Waste Management

Solid waste

All the municipalities studied have moved their refuse damps farther away (> 4km) from the banks of the river. Within the municipality, there are townships and villages. Skips have been provided for the township whereas the villages are left to provide their own waste management system.

In the Akwapim South Municipal Assembly (ASMA) skips have been provided in communities such as Nsawam, Adoadjiri, Amoakrom, Sekyikrom and Doboro and its environs and it is hauled to final damping site. The damping site (Shown in Plate 2) situated about 4 km from the river; however is not an engineered site.

The villages have demarcated sites where refuse is damped and burnt and these sites are manned by labourers. Observations made showed that most households damp their waste at the backyard and burn it. As part of the ASMA's agenda to implement IWRM, it has acquired a land at Nyenkyen for an engineered land fill site and liquid waste treatment facility to protect ground water. The Assembly had a target of providing forty 220 litres skips for the communities by 2010. At the moment thirty five skips have been installed but only twenty two are in functioning.

Industrial wastes in the ASMA are managed by the companies themselves and the environmental health and sanitation officer monitors them periodically. Inspection is supposed to be done once every three months, but an inadequate resource limits the number of visits in a year. The solid waste from some of the industries is damped at the assembly's final deposal site. Waste from the only chemical industry existing in Akwapim South Municipality, La Gray chemical limited at Adoadjiri, which could pose a challenge big challenge to the quality of the river is collected by a private waste collection company and disposed off in Accra.

In response to the educational activities embarked upon by the ASMA, one of the many fruit processing companies (Blue Skies industry) in the municipality has establish a compost unit (Shown in Plate 2a).

In New Juaben Municipal Assembly, the refuse in the skips are periodically hauled to a final disposal site near Akwadum, the villages too have select sites and refuse collected is

burnt by a labourer. The industries in the municipality dispose off their waste at the final disposal sites of the Assembly.

The hospitals in Akuapim South Municipal Assembly and New Juaben Municipal Assembly use incinerators to deal with their solid waste generated.

(a) (b)

Plate 2: (a) The Compost site at Nsunia; (b) Final disposal site of ASMA at Ahodjo

Liquid Waste

Formerly some inhabitants used to defecate in the surrounding bushes and others used the pan latrine system. During the raining season, the runoff carries these excreta into the water body. Ever since the ban on pan latrines was passed, the communities in the study area have resorted to the use of household KVIP and water closets. In the Akwapim South Municipal Assembly, cesspit emptier collects the waste and send it to Accra waste treatment plant at Korle Gonno. Liquid waste from industries are channelled onto and effluent chambers and disludge.

Liquid wastes from the New Juaben Municipal Assembly are transported to a waste stabilisation pond near Akwadum.

These practices adopted limit the indiscriminate disposal of untreated waste into the nearby water bodies which hitherto was a common practice.

5.1.2.2 Appropriate farming methods

The use of chemicals (e.g. Pesticides) by farmers poses a problem to the water bodies when they are washed into surrounding streams and rivers. Continuous farming practices make the land infertile and continuous application of fertilizers to increase yield eventually lead to eutrophication and high salinity of the water bodies. The interviews and discussions with farmers revealed that the use of chemical such as urea, NPK, ammonia is on the increase. The Ministry of Food and Agriculture (MOFA) through extension services, advises them on how to use the chemicals (as shown plate 3a) to avoid excesses and contamination of the river.

Most of the farmers in the municipality are vegetable farmers and normally use substantial quantities of various chemical e.g. pesticides, weedicides etc on their farms. Most of these chemicals get washed eventually into the river. To avoid further contamination by these chemicals, the farmers have been introduced to different crop species that are resistant to pest. In some cases farmers have been advised to crop maize ("obaatanpa" maize) that needs relatively lesser quantities of water and chemicals for cultivation. Some farmers have complied, but others still plant vegetable because exporters buy and the market is good.

The farmers are also advised to use organic manure instead of inorganic fertilizer. When asked why they prefer this to organic manure, the answers were that it takes a quite some time for the manure to mix with the soil and the crops cultivated are short term ones.

Some farmers have accepted the use of manure for cultivation but only for planting onions

MOFA also encourages zero tillage in farming that is the use of weedicides and planting through the weeds. So that after harvesting the land still has it vegetation covers to hold the soil together. They are advised not to spray any time they see insects because some are pollinators and some insects are not harmful to the crops. If farmers are in doubt, they have to confirm from the extension officers before they spray the crops since the use of a particular insecticides depends on a number of factors. Farmers in Weija practice the zero tillage than those at Nsawam and its environs.

(a) (b)

Plate 3: (a) Fertilizer applied to a crop; (b) discussions with MOFA

5.1.2.3 Creation of buffer zone

One important measure to safeguard the quality of a river basin is the creation of a buffer zone. According to Water Resource Commission creation of buffer zone with legal backing is at policy formulation stage. Observation shows that many farmers, especially those engaged in vegetable production operate less than 5 metres away from the river

bank (as shown in plate 4a) which is supposed to form part of the buffer zone. Legally, farming close to river channels is not an offence. However, the WRC advise various collaborators especially MOFA to educate farmers to preserve since the vegetation on the banks serves as a protective covering. Some interviewed farmers confirmed that they have been advised to leaving a buffer of about fifty yards (≈45m), but due to unavailability of land they are not able to comply.

Plate 4: A farm close to the river at Sekyikrom

Commercial farms around Weija eg. Gannat farms have planted mango tress to demarcate the zone from their farms and the river.

MOFA plays advisory role and there are no deterring measures put in place against defaulting farmers.

5.1.2.4 Woodlots creation

Districts Assemblies in collaboration with NGOs, CBOs, women groups and churches are involved in trees planting (woodlots) exercises to reclaim the degraded lands around the river (as shown in plate 5). Some of the communities championing this activity include Densuano, Apapam, Nsawam and Weija. At Nsawam four kilometre stretch of woodlot

with a width of about fifteen meters have been planted. Currently, the planting of more trees is suspended due to unavailability of funds.

Plate 5: Woodlots at Nsawam

5.1.3 Fishing activities

One of the major employments within the riparian communities is commercial fish farming. Laws (Act 625, 2002) have been promulgated to prescribe the kind of fishing nets to be used on the river basins. A ban on the use of chemicals and explosives for fishing has been implemented to prevent contamination of the water body. Densu basin secretariat in collaboration with the law enforcement Agency (The Police Force) has made some arrest of culprits in the past. However, more monitoring activities are required to curtail these obnoxious acts. To supplement the efforts of the law enforcement agencies, several communities have established "watchdogs" bodies comprising mainly the unit committee of the towns.

5.1.4 Implementation of the Urban Catchment Management Project

The Urban Catchment Management Project of water for Africa cites project, phase II programme was a project sponsored by the United Nations Habitat (Nairobi) in September 2006 to December 2008. The mandate was to deal with the encroachment, land degradation and pollution emanating from poor sanitation condition in the Weija catchment. Activities carried out for the implementation were as follows:

- The setting up of a Weija Reservoir Catchment Development Committee
- Development of land Use and Land Cover Maps for 2006 and 2008 were developed Findings of the study were disseminated in the Ga West and South Municipal Assemblies as well as the mass media
- Acquisition of 4 garbage containers and 5 household latrines were provided in four communities of the Ga West Municipal Assembly (i.e. Ashalaja, Manhean, Kwameanum and Danchira)
- awareness creation was intensified as indicated above and partly sustained through the mounting of a billboard and two smaller signboards by the Weija Lake.
- Organisation of training programmes for the various stakeholders enlisted by the Project document including the Densu Basin Officer. The Waste Management Department was also strengthened through training on the relevant legislation on environmental health and sanitation.

The implementation of the Urban Catchment Management Project stimulated a fencing project of the Weija Reservoir Catchment that is currently in progress. All these activities are geared towards improving the ecological health of the Weija Reservoir Catchment as well as water quality and quantity of the Weija Dam.

5.1.5 Water use permits and Drilling Licensing

The water users in the study area require permit before abstracting. The WRC is the agency authorised under section 13 and 16 of Act 522 of the Ghanaian constitution to regulate and control the use of water resources, through granting of water rights and water use permits. Abstraction of water by mechanical means requires no permit if the abstraction level does not exceed five litres per second or the abstraction is for subsistence agriculture not exceeding one hectare. Most farmers along the river abstract water to irrigate their farms by mechanical means have been cultivating less than one hectare, so they were not paying any fee for the abstraction. The industries, borehole drillers and individuals have permits. To regulate the activities of well drillers, periodic meetings are held by the DBB.

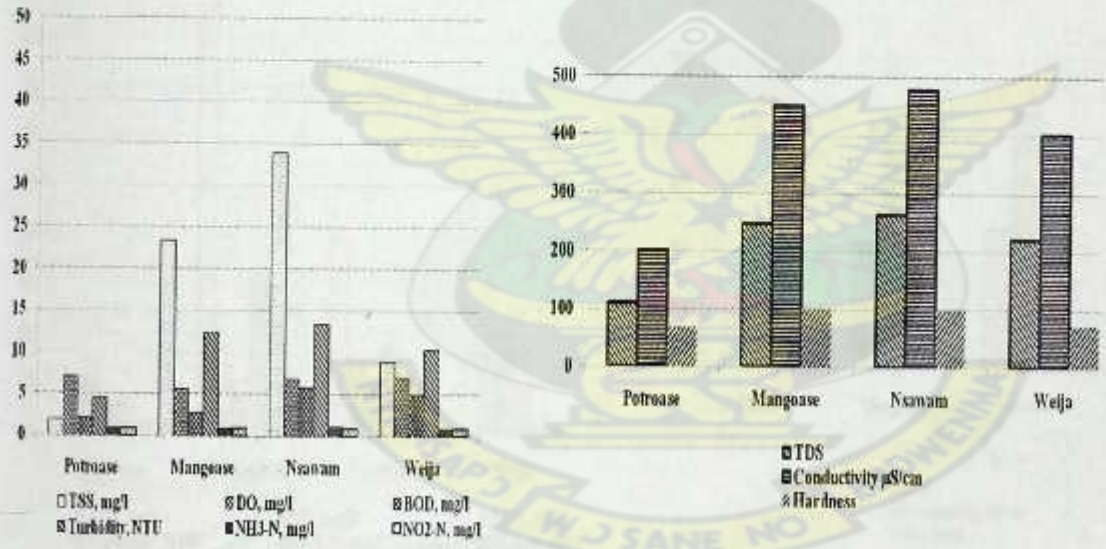
Most of the IWRM activities mentioned are geared towards attitudinal change, which takes time to impact on the behavioural pattern of people and subsequently impact upon the water quality of the river. In view of this the IWRM activities being executed need to be sustained and monitored regularly to achieve the required impacts.

5.2 Trend in water quality

To relate the impact of the IWRM to the changing trends of water quality, data on the water quality of the river basin were acquired at WRC for 2005- 2007covering both wet and dry seasons and studied. In addition water samples were taken in the wet season of 2008 from the four communities and analysed at the lab to determine and investigate the changing trends in the water quality. Given below are the observed water quality trends for the dry and wet seasons.

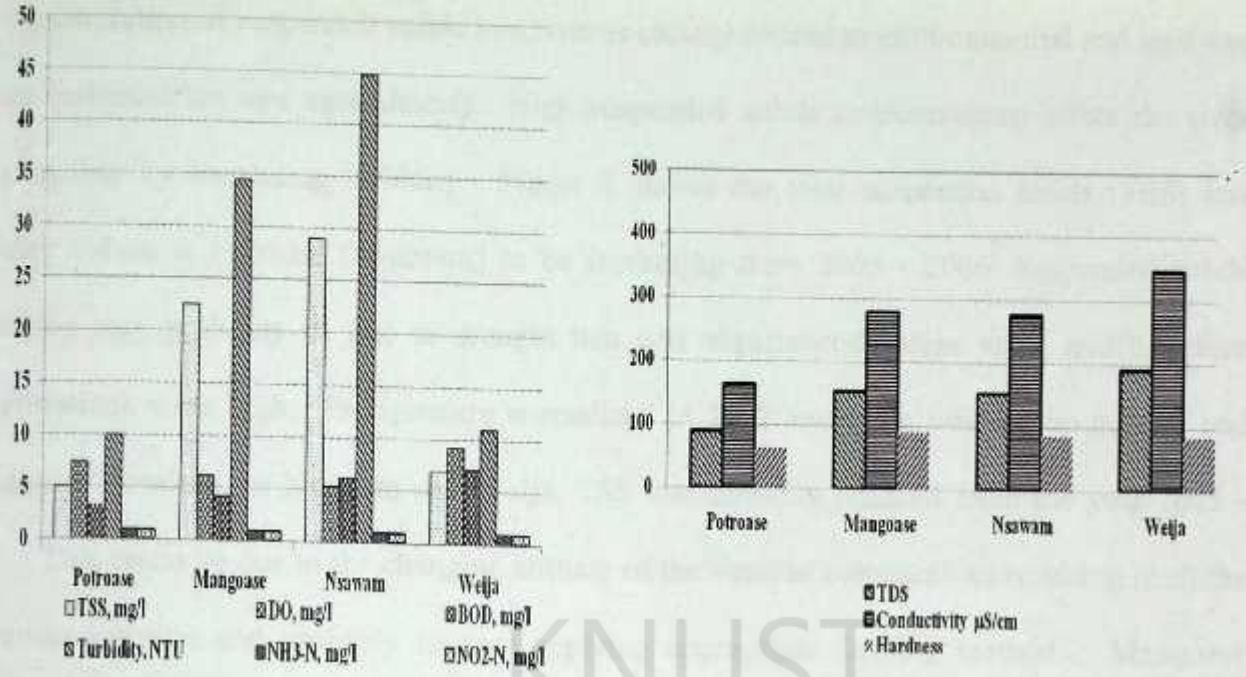
5.2.1 Dry Season

Figure 3 provides information for the dry seasons on selected parameters- total suspended solids (TSS), dissolved oxygen (DO), Biochemical oxygen demand (BOD), turbidity, ammonia, nitrite, total dissolved solids (TDS), conductivity and hardness. This data covers the period 2005-2007 for Potroase (upstream), Mangoase & Nsawam (midstream) and Weija communities.



(a)

Figure 2: Variations in the selected water quality parameters at the four monitoring sites for dry season of (a) 2005.



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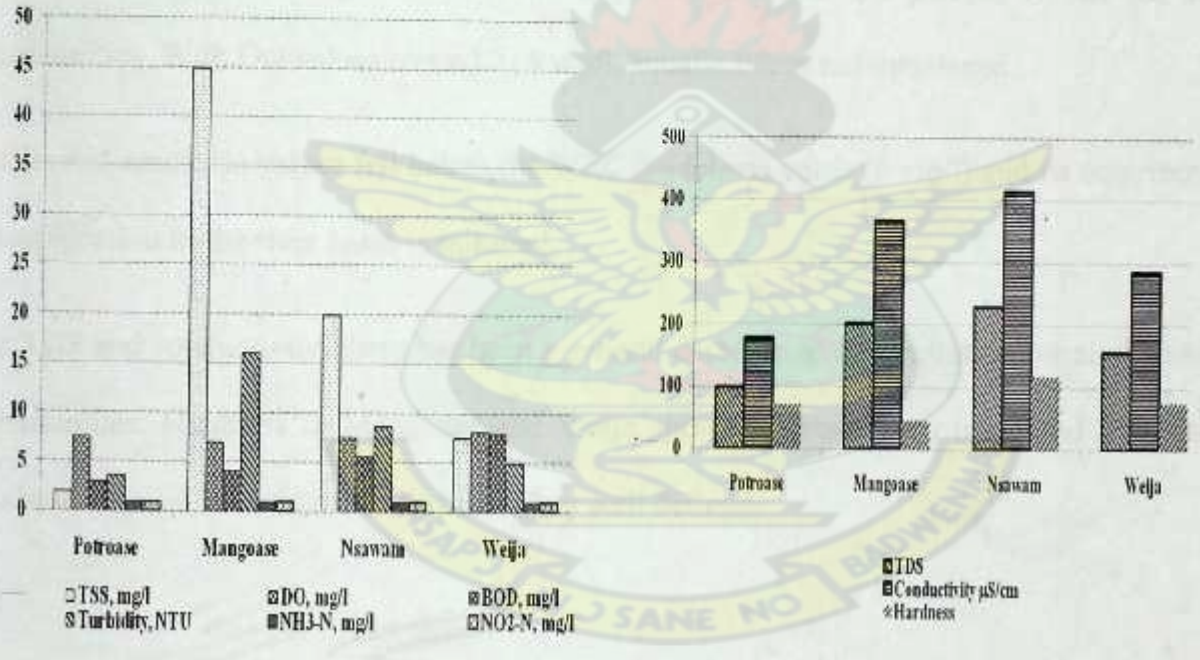


(c)

Figure 3 Variations in the selected water quality parameters at the four monitoring sites for dry season of (b) 2006; (c) 2007

The concentration of suspended solids in a river is closely related to environmental and land-use factors (urbanisation and agricultural). High suspended solids concentrations affect the river water quality by increasing turbidity. Figure 3 shows the total suspended solids (TSS) and turbidity values at Potroase (upstream) to be increasing from 2005 - 2006. Suspended solids increasing may probably be due to drought that was experienced nation wide, and therefore concentrations were high. Precipitation normalised in 2007 and there was a drop in TSS and turbidity at Potroase. In Nsawam and Weija, TSS and turbidity reduced from the year 2005 - 2007. This could be due to the changing attitude of the riparian communities resulting from the awareness creation and probably farmers applying appropriate farming methods. Mangoase showed an increment in 2007 which was not expected.

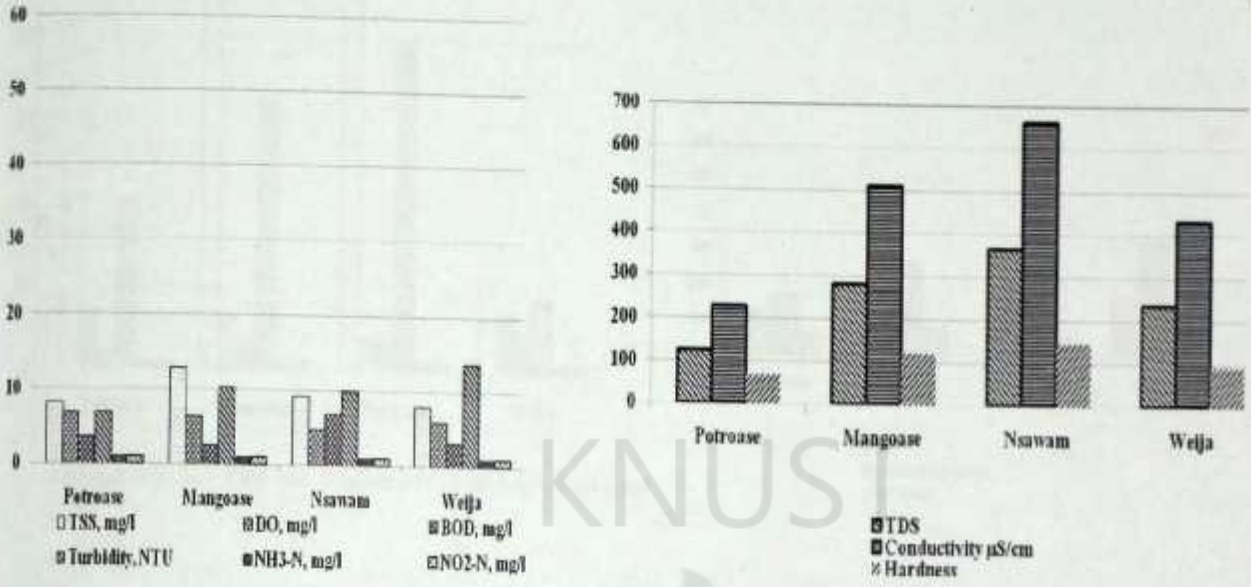
Dissolved oxygen and BOD were about fairly constant over the periods for all the studied communities. With DO values around 7- 8 mg/l, aquatic life is not threatened.

Nitrite and ammonia values fell below the WRC guidelines value (6 mg/l) and its contribution to eutrophication in the river basin is minimal.

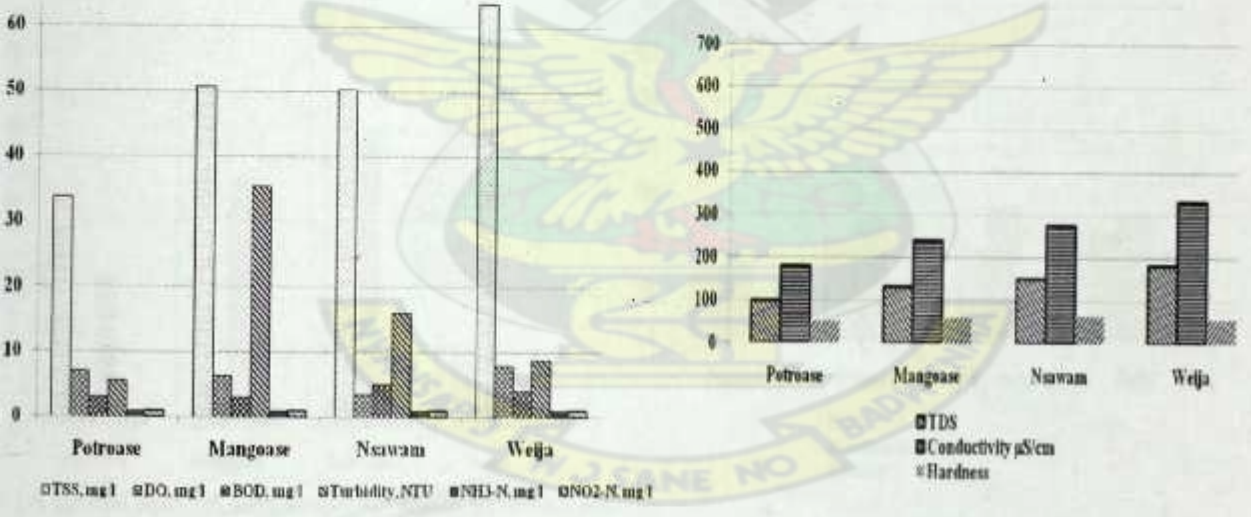
For TDS and conductivity, there has been a general decrease in concentration for all the sampled communities. Hardness in Mangoase and Weija showed a downward trend and Potroase and Nsawam showed an erratic trend which is not well defined.

5.2.2 Wet Season

Figure 3 and 4 gives information for the wet seasons of 2005 - 2008 .

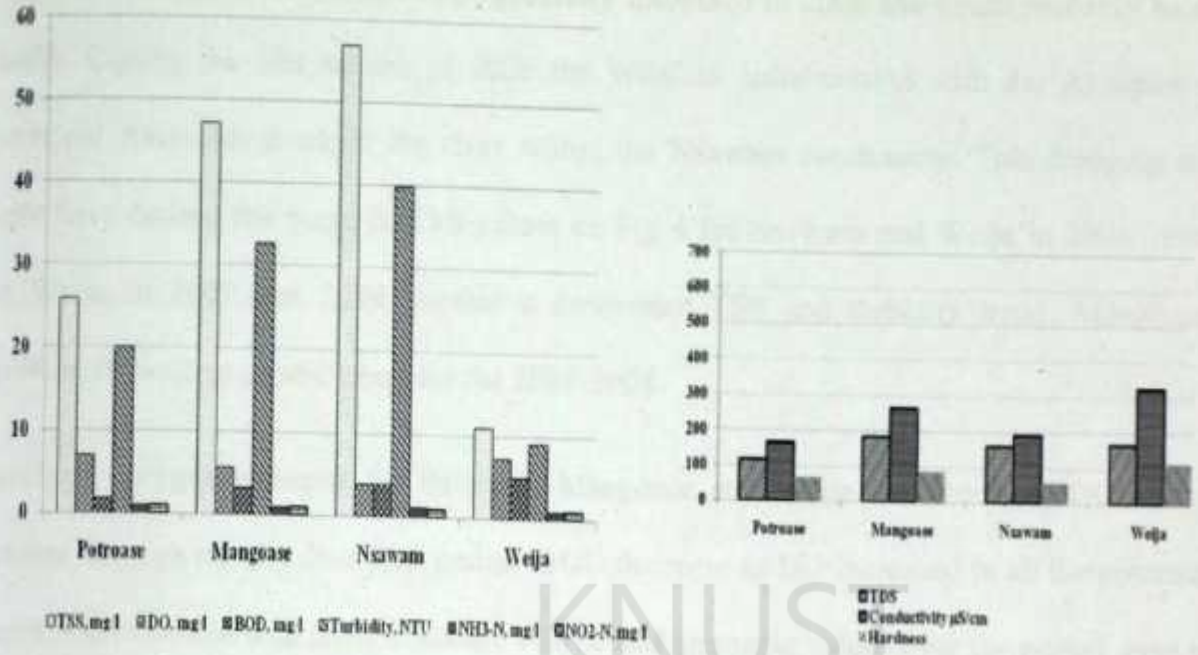


(a)

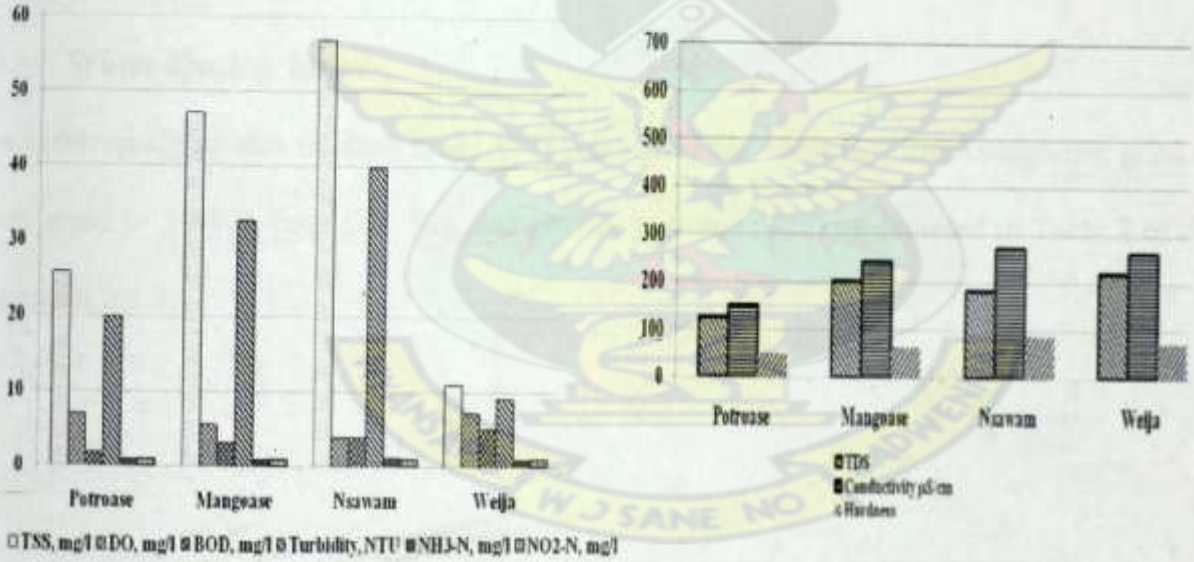


(b)

Figure 4: Variations in the selected water quality parameters at the four monitoring sites for wet season (a) 2005: (b) 2006.



(c)



(d)

Figure 5: Variations in the selected water quality parameters at the four monitoring sites for wet season c) 2007: (d) 2008

In the wet season, TSS and turbidity, generally increased in 2006 and could probably be due to runoffs. During the wet season of 2006 the WRC in collaboration with the Akuapim South Municipal Assembly dredged the river within the Nsawam community. This dredging activity might have caused the surge in TSS values on Fig 4 for Nsawam and Weija in 2006. Potroase and Weija in 2007 and 2008 showed a downward TSS and turbidity trend. Mangoase and Nsawam showed an erratic trend for the 2007-2008.

Dissolved Oxygen increase for Potroase, Mangoase and Weija. At Nsawam, DO was fairly constant through out the four year period. BOD decrease as DO increased in all the communities except Nsawam that was fairly constant. Nitrite and ammonia values over the period were below the guidelines value. For TDS and conductivity, there has been a general decrease in concentration for all the sampled communities. Hardness in all the communities studied showed an erratic trend which is not well defined.

5.3 Water Quality Index

The water quality index (Bolton et al., 1978) classifies the water into four categories: good (>80), fairly good (> 50-80), poor (25- 50), and grossly polluted (<25) as depicted in Table 2 of chapter 2, section 2.8.3.

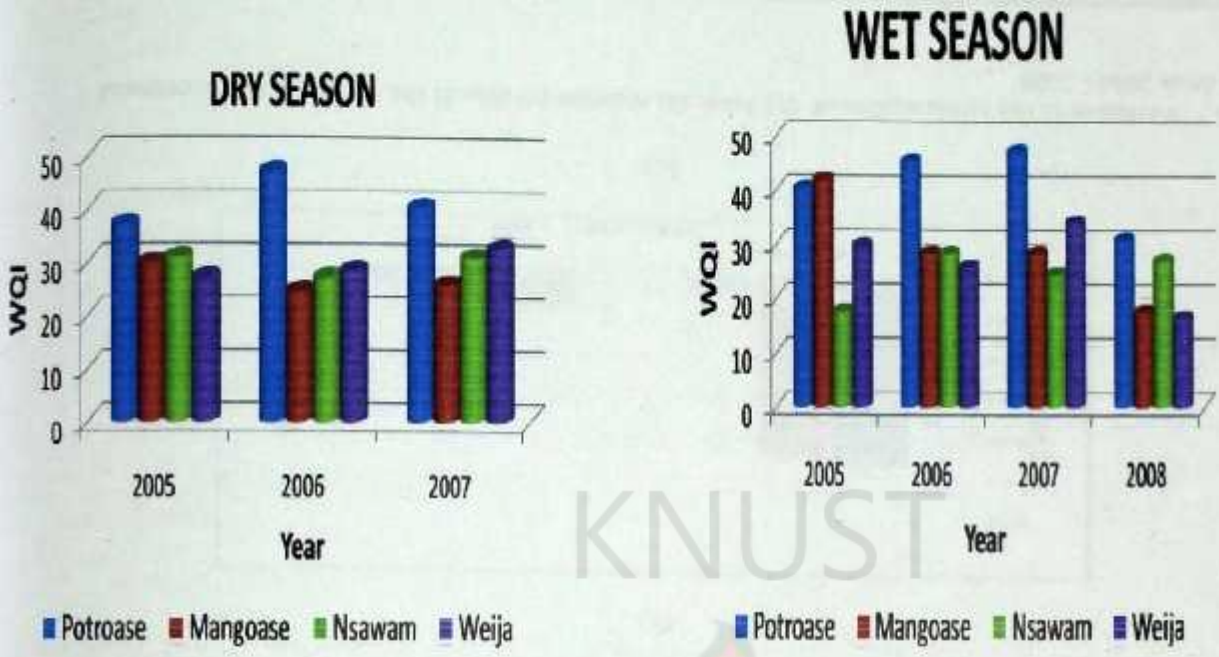
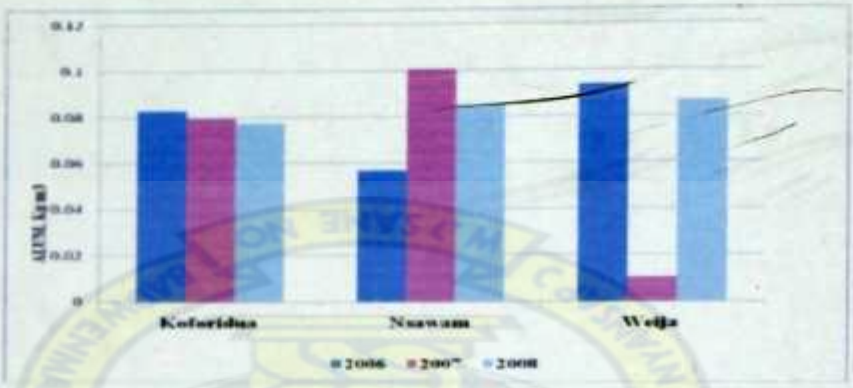


Figure 6: water quality index of the river samples.

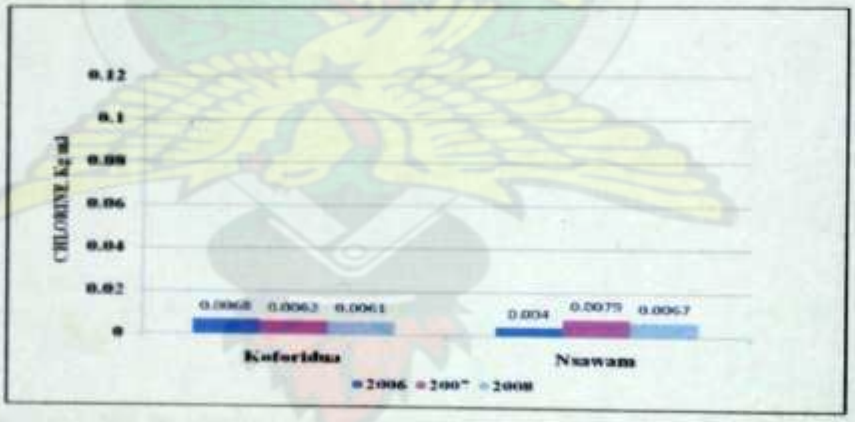
Potroase have WQI values of ranging from 30- 45; Mangoase 15 -40; Nsawam 15- 30 and Weija 15- 32(figure 6). Despite the various IWRM interventions the WQI remained poor for all the communities studied over the period.

5.4 Trend in chemical consumption at the treatment plant

There are three water treatment plants on the Densu River. These are situated in Koforidua, Nsawam and Weija. Improvement in water quality is expected to reflect upon the consumption of water treatment chemicals like alum, chlorine, lime etc.



(a)



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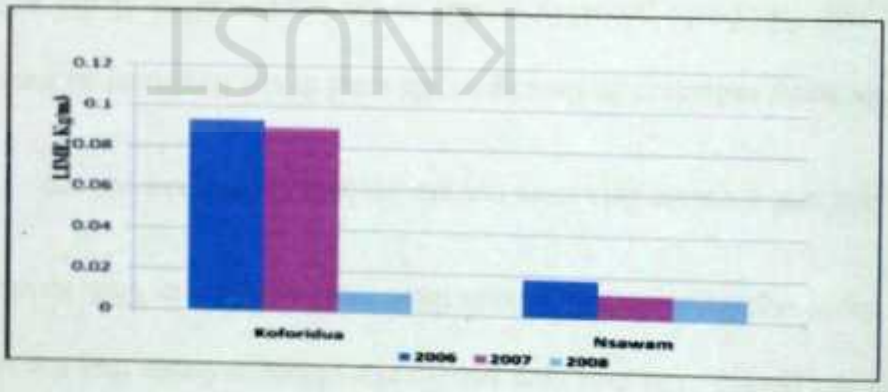

(c)

Figure 7 ;Variation in the consumption of (a) Alum (b) chlorine (c) lime at the various water treatment plants from 2006 - 2008

Figure 7 indicates the consumption pattern for the various treatment plants for 2006-2008. At Koforidua headworks, the amount of alum used in treating a cubic metre of raw water from the river reduced by 6.42 %. This could probably due be to the reduction in TSS upstream (Potroase). The amount of chlorine and lime consumed also reduced by 10.29% and 89.25% respectively over the period. The Nsawam headworks values indicate that the use of alum and chlorine did not show any regular trend, though there was reduction in TSS, turbidity and TDS.

For Weija, adequate and accurate data were not available to explain the pattern.

Generally there is some reduction in the chemicals used in the treatment of the raw water from the Densu River and this could probably be due to the improvement of the water quality. The improvement of the water quality may be attributed to the impact of the IWRM activities being implemented.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. IWRM activities identified being implemented in the Densu river basin were found to be with immediate cost but long term benefit hence all though the activities might be improving the quality of the water, this is very slow and probably explain the low correlation between the activities and the impact of the water quality .

2. Water quality index values were in the range of 15 - 45 and according to the Solway's classification the river is poor especially midstream where the human activities are pronounced. The water quality can be enhanced by sustaining the IWRM activities being executed.

3. Consumption of alum, chlorine and lime reduced by (6.42%, 10.29% and 89.25 % respectively) from 2006 to 2008 at the Koforidua headworks. At Nsawam, alum and chlorine did not show a well defined trend, but lime showed a downward trend over the studied period.

6.2 Recommendation

- The activities, especially awareness programs and solid waste management programs should be intensified.

- Policies at the initial stages should be concluded and implemented to restrict people from performing activities that will be detrimental to the water body.

- Stakeholders especially communities members should be made responsible for their environs in terms of sanitation and provide household latrine, since most inhabitants rely on public place of convenience.

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Appendices

Appendix 1- Water quality parameters

Table 5: Water quality parameters for dry season 2005,

	Potroase	Mangoase	Nsawam	Weija
Parameter	Dry Season 05	Dry Season 05	Dry Season 05	Dry Season 05
pH	7.615	7.78	7.375	8.36
Cl^-, mg/l	11.9	41.2	54.85	47.65
Alkalinity, mg/l	70	128	116	110
Na+, mg/l	7.75	44.55	51.8	40.6
SO42-, mg/l	9.485	37.95	48.9	10.225
K+, mg/l	1.3	8.45	9.55	6.65
F^-, mg/l	0.3675	0.04	1.6	0.144

Table 6: Water quality parameters for dry season 2006

	Potroase	Mangoase	Nsawam	Weija
Parameter	Dry Season 06	Dry Season 06	Dry Season 06	Dry Season 06
pH	6.925	7.03	7.04	7.645
Cl^-, mg/l	9.9	23.3	22.35	45.15
Alkalinity, mg/l	61	105	101	95
Na^+, mg/l	19.85	28.65	32.2	36.65
SO_4^{2-}, mg/l	12.75	15.85	38.95	10.65
K^-, mg/l	3.45	2.8	4.53	3.02
F^-, mg/l	0.338	0.68	0.355	0.4055

Table 7: Water quality parameters for dry season 2007

	Potroase	Mangoase	Nsawam	Weija
Parameter	Dry Season 07	Dry Season 07	Dry Season 07	Dry Season 07
pH	7.115	7.1	7.07	7.19
Cl^-, mg/l	12.4	33.75	36.05	28.25
Alkalinity, mg/l	69	121	137	94
Na^+, mg/l	12.05	25.15	38	32.15
SO_4^{2-}, mg/l	8.875	9.53	10.25	15.8
K^+, mg/l	2	10.9	9.9	6.3
F^-, mg/l	0.159	0.18	0.4035	0.2295

Table 8: Water quality parameters for wet season 2005

Parameter	Potroase	Mangoase	Nsawam	Weija
pH	7.76	8.23	7.43	8.67
Cl^-, mg/l	12.9	47.3	63.13	45.63
Alkalinity, mg/l	69.33	141.33	180.67	100
Na^+, mg/l	8.8	28.07	38.8	26.27
SO_4^{2-}, mg/l	10.59	13.9	24.5	16.08
K^+, mg/l	10.1	4.53	6.65	4.27
F^-, mg/l	0.61	0.92	0.7	2.11

Table 9: Water quality parameters for wet season 2006

Parameter	Potroase	Mangoase	Nsawam	Weija
pH	6.86	7.21	7.04	7.5
Cl^-, mg/l	8.6	13.9	16.53	38.07
Alkalinity, mg/l	68	90.2	95.33	99.33
Na^+, mg/l	19.5	20.53	28.6	41.73
SO_4^{2-}, mg/l	22.21	26.2	22.17	12.16
K^+, mg/l	2.67	3.87	3.75	4.38
F^-, mg/l	0.27	0.62	0.38	0.48

Table 10: Water quality parameters for wet season 2007

Parameter	Potroase	Mangoase	Nsawam	Weija
pH	7.4	7.05	7.37	7.35
Cl^-, mg/l	9.23	22.53	19.5	37.07
Alkalinity, mg/l	64	102	242	104
Na^+, mg/l	11.07	24.73	0.3199	38.73
SO_4^{2-}, mg/l	15.32	20.33	10	18.13
K^+, mg/l	2.57	15.27		6.81
F^-, mg/l	0	0.36		13.59

Table 11: Water quality parameters for wet season 2008

Parameter	Potroase	Mangoase	Nsawam	Weija
pH	7.59	7.45	7.41	8.78
Cl^-, mg/l	23.5	38.5	21.87	31.5
Alkalinity, mg/l	152	455	111.33	322
Na^+, mg/l	48.2	0.177	27.97	37.25
SO_4^{2-}, mg/l	8	13	25.07	9
K^+, mg/l			16.87	
F^-, mg/l			0.41	

Appendix 2- Questionnaire

Stakeholders' Questionnaire

Date: .... **Time:**..... ..... **Interview Number:** ....
Community:..... ....

Respondent: ....

DA

1. What are main activities being under taken to protect the water body?
   - Buffer zone creation, Fish farming monitoring
   - Sanitation Crop farming monitoring
   - Frequency of dredging (No. of times per year)
2. Has the District Assemblies been strengthened to prepare and enforce byelaws to regulate the use of the natural resources of the basin?
   - Regular meetings Gender issues / representation
   - Capacity building Mandate / designations for enforcement
3. How are your waste managed? Are there programmes and policies for managing agricultural, municipal and industrial effluent?
   - Skips and Dump sites / landfills Levies for waste disposal
   - Who a/c for what
4. What was the target to achieve since 2005?
5. Do you have challenges in achieving your target?

EPA

1. What is the level of involvement in managing the Densu River?
   - Monitoring Workshops organization
   - Handbill Sampling for PAHs
2. What are main activities being under taken to protect the water body?
   - Industrial waste disposal and pollution control
   - What is the punishment for offenders.- legal action, fines/ polluter pays.
3. Is waste from industries being monitored?
4. Is mandatory preparation of EMPs for development projects being enforced

MOFA

1. Is there introduction of environmental and farmer friendly system of agricultural production (crops and livestock).

WRC

Water Management Programmes/Policies/Strategies/Measures	Not relevant	Under Consideration		Partially	Fully implemented
Water Use					
Water demands survey in different water using sectors.					
Programmes and policies for managing agricultural, municipal and industrial effluent.					
Programmes and policies for managing other water uses.					
Monitoring, Information Management and Dissemination					
Functional hydrological and hydro-meteorological monitoring networks.					
Programmes for information exchange and knowledge sharing about good practices.					
Monitoring and reporting system to determine impact of IWRM reforms.					
Capacity Building and Enabling Environment					
Assessment of capacity building needs in the Densu basin					
Capacity building programs on different aspects of water resources management at the Densu basin					
Establishment of river basin management institutions.					
Institutional reforms to enhance the effectiveness/accountability of institutions in the Densu basin					
Institutional co-ordination mechanisms for water resources management.					
Mechanisms to link water resources management to other economic sectors.					
Assessment of water management research needs and gaps.					
Mechanisms to enforce water legislation.					
Programmes for providing advisory (extension) services on WM issues to end users.					
Pro-poor policies and programmes in the Densu basin.					
Stakeholders Participation					
Decentralized water resources management structures.					
Programmes for gender mainstreaming in all aspects of WRM.					
Partnerships for water resources management.					

Farmers' Questionnaire

Date: .... **Time:**..... ..... **Interview Number:** ....
Community:..... ....

Respondent: ....

1. What do you use the water from the river?
2. Are you being charged for the use of the Water? [ ] Yes [ ] No
3. If yes, then how much.....
4. Do you think the charge is Ok? [ ] Yes [ ] No
5. If no, what do you think should be done?
6. Do you think it is justified venture on the part of the part of the authorities?
7. What are the tools, chemicals and other inputs you use in your farming activities?
8. Do MOFA give advice through their extension officers on how to farm to avoid destruction of the river body?
9. Have they introduced you to any environmental friendly species? [ ] Yes [ ] No.
10. If yes, has it reduced the amount of pesticides used in farming?
11. Do you use organic manure on your farming? Do you prefer that to inorganic fertilizers?
12. Are you aware there should be a distance between the river and your farm
13. Do you know the distance you have to leave between the river and your farm?

FGD

Date: .... **Time:**..... ..... **Interview Number:** ....
Community:..... ....

1. What do you use the water from the river for?
2. Aside farming what other use do you put the water to?
3. Are you being charged for the use of the Water? [ ] Yes [ ] No

   A. If yes, then how much.....

   B. Do you think the charge is Ok? [ ] Yes [ ] No

   C. If no, what do you think should be done?

4. What tools, chemicals and other inputs are used for these activities in this community:

a. Farming .....

b. Fishing.....

c. Other:.....

5. Do farmers still farm close to the river? [ ] Yes [ ] No.

   If yes, what does the community do when people do farm close to the river?

   .....

Water management

6. Who is responsible for the management of the water bodies in your communities?

a.....

b.....

7. List the laws and traditional rules that you know regarding the use of the river and the land around it?.....

8 Who is to ensure that these laws are observed?

.....

9. List your recommendations for changes in the laws/management:

   .....

10. Do you get any medium/opportunity to present your opinion on the management of the river?

Yes [ ] No [ ]

11. Are you involved in the protection of the water body? Yes [ ] No [ ]

If YES, what do you do?

.....

.....

12. If NO, you are not involved in protecting the water body, do you want to be involved?

Yes [ ] No [ ]

If YES, in what way do you want to be involved?

.....

13. Is there a fair representation of both men and women on your management committees

Sanitation

13. Where do you dispose off refuse in this community?

- Are you been charge?
- How much?

14. Are there enough place of convenience in the community?

- Are you been charge?
- How much?
- How far is it from the community
- Is the place clean?

15 Do people still defecate in to the river? [ ] Yes [ ] No

16 Is it a common practice for inhabitants to defecate in the open?

Appendix 3

List of people interviewed

Christian Obiri - Mensah	Blue skies Industry, Doboro.
Ronald Abraham	Densu Basin Officer, Koforidua
Adwoa Paintsil	Water Resource Commission (WRC)
Emelia Apio	Ministry of Food and Agriculture, Nsawam.
Idrisah Yusif Musah	Ministry of Food and Agriculture, Nsawam
Kwame Safo- Brobbey	Akuapim South Municipal Assembly
Abubakar Johnston	Akuapim South Municipal Assembly
Kwabena Esubonteng	Akuapim South Municipal Assembly.
Amihere Mensah	Ghana Water Company Limited, Weija
Tulashie	Ghana Water Company Limited, Koforidua.
Mr. Boakye	New Juaben

Table 12: Rating Table for Weighted Arithmetic and Weighted Solway WQIs

Weighted Water Quality Rating (q_i x w_i)	DO (per cent saturation)	BOD (mg/l)	Amm-N (mg/l as N)	Faecal Coliform (Counts/100ml)	pH	NO_3-N (mg/l as N)	PO_4-P (mg/l as P)	SS (mg/l)	Conductivity (µS/cm)	T (°C)
18	93-109									
17	88-92 110-119									
16	85-87 120-129									
15	81-84 130-134	0-0.9								
14	78-80 135-139	1.0-1.9								
13	75-77 140-144	2.0-2.4								
12	72-74 145-154	2.5-2.9	0-0.09	0-249						
11	69-71 155-164	3.0-3.4	0.10-0.14	250-999						
10	66-68 165-179	3.5-3.9	0.15-0.19	1 000-3 999						
9	63-65 180^+	4.0-4.4	0.20-0.24	4 000-7 999	6.5-7.9					
8	59-62	4.5-4.9	0.25-0.29	8 000-14 999	6.0-6.4 8.0-8.4	0-0.49	0-0.029			
7	55-58	5.0-5.4	0.30-0.39	15 000-24 999	5.8-5.9 8.5-8.7	0.50-1.49	0.030-0.059	0-9		
6	50-54	5.5-6.1	0.40-0.49	25 000-44999	5.6-5.7 8.8-8.9	1.50-2.49	0.060-0.099	10-14	50-180	
5	45-49	6.2-6.9	0.50-0.59	45 000-79 999	5.4-5.5 9.0-9.1	2.50-3.49	0.100-0.129	15-19	0-49 190-239	25^+
4	40-44	7.0-7.9	0.60-0.99	80 000-139 999	5.2-5.3 9.2-9.4	3.50-4.49	0.130-0.179	20-29	240-289	23.0-24.9
Weighted Water Quality	DO (per cent	BOD	Amm-N (mg/l as	Faecal Coliform	pH	NO_3-N (mg/l as	PO_4-P	SS	Conductivity	T

$(q_i \times w_i)$										
3	35-39	8.0-8.9	1.00-1.99	140 000-249 999	5.0-5.1 9.5-9.9	4.50-5.49	0.180-0.219	30-44	190-379	21.5-22.9
2	25-34	9.0-9.9	2.00-3.99	250 000-429 999	4.5-4.9 10.0-10.4	5.50-6.99	0.220-0.279	45-64	380-539	19.5-21.4
1	10-24	10.0-14.9	4.00-9.99	430 000-749 999	3.5-4.4 10.5-11.4	7.00-9.99	0.280-0.369	65-119	540-839	17.5-19.4
0	0-9	15.0^{+}	10.00^{+}	$750\ 000^{+}$	0-.3.4 11.5-14	10.00^{+}	0.370^{+}	120^{+}	840^{+}	0-17.4

Note: If some parameters are missing, the arithmetic weighted WQI as calculated from Table 12 has to be corrected by multiplying the Index by 1/x, where x is the sum of the weightings of the parameters being considered. The adjusted arithmetic weighted index should be used, where appropriate, in the calculation of Solway weighted index.

Solway Index (weighted) = $1/100(q_i w_i)^2$

Where q_i and w_i represent the quality and weighting, respectively, of the n^{th} parameter

For Available values:

Solway Index (weighted) = $1/A (q_i w_i)^2$

Table 13: Values for calculating WQI for Potroase (2005)

	March 05	May 05	July 05	Sept 05	Nov 05	Dry Season 05	Wet Season 05
Parameter							
Temp °C	26.6	24.8	23.6	24.5	24	25.3	24.30
pH	7.58	7.65	7.66	7.83	7.8	7.69	7.71
TSS, mg/l	2	2	10	8	7	4.5	6.67
BOD, mg/l	2.6	1.7	2.8	2.9	5.2	3.9	2.47
DO, mg/l	7.9	6.2	5.3	6.6	7.5	7.7	6.03
Conductivity µS/cm	201	202	263	218	205	203	227.67
NO_2-N, mg/l	0.001	0.016	0.001	0.001	0.021	0.011	0.01
NH_3-N, mg/l	0.9	0.491	0.856	0.31	0.518	0.709	0.55

Table 14: Sample calculation WQI for Potroase (2005)

Dry Season 2005					Wet Season 2005				
parameter	**value**	**score**	**max score**	**available**	**parameter**	**value**	**score**	**max score**	**available**
DO	7.9	0	18	0	DO			18	
BOD	3.9	10	15	15	BOD	2.47	12	15	15
NH	0.709	4	12	12	NH	0.55	5	12	12
pH	7.59	9	9	9	pH	7.12	9	9	9
NO3- N	0.011	8	8	8	NO3- N	0.01	8	8	8
FC			12		FC			12	
PO4-P			8		PO4-P			8	
SS	4.5	7	7	7	SS	8.67	7	7	7
Conductivity µS/cm,	203	5	6	6	Conductivity, µS/cm	227.67	5	6	6
temp	25.3	5	5	5	temp	24.3	4	5	5
TOTAL		48	100	A=62	TOTAL		50	100	62
		$(q_i w_i)^2 = 2304$	WQI=37.16129032				$(q_i w_i)^2 = 2500$	40.32258	