THE CAUSES AND HEALTH EFFECTS OF RIVER POLLUTION: A CASE STUDY OF THE ABOABO RIVER, KUMASI

by

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DECLARATION

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

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DEDICATION

This thesis is dedicated to my parents Mr. Nicholas Danquah and Madam Mary Amoah. Thank you for all your advice, encouragement, prayers and financial support. God richly bless you.

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ABSTRACT

The rivers in the Kumasi Metropolis in recent times have become repositories for filth and human waste. The Aboabo River is one such river that is heavily polluted through varied human activity along its course. Despite the potential health hazards that the pollution of water bodies has for persons who use the water bodies, river pollution persists. A sample of 396 households living in the Aboabo River basin was studied. Structured questionnaires, observation, in-depth interviews and water quality analysis were employed. The study identified rapid population growth, institutional failures and industrial activities as remote anthropogenic causes of pollution of the Aboabo River. The main anthropogenic causes were identified as indiscriminate dumping of refuse, channeling of raw sewage, open defecation, discharge of untreated effluents and dumping of industrial waste into the Aboabo River. Physical tests showed that the Aboabo River was polluted since it had exceeded WHO Drinking water quality guidelines for color, taste, turbidity and odor. Faecal coliform count for water sampled at all stations was above 300 $\times 10^4$ /100ml and had exceeded the WHO Drinking water quality guidelines of 0/100ml indicating pollution from human sources. The pollution of the river reduces its water quality and yields a significant health effect to people living in the river basin. Frequency of playing in the polluted river was positively correlated with occurrence of water related diseases in 322 children who frequently played in the river. The financial and logistical strengthening of institutions as well as proper enforcement of laws were recommended. In addition, the provision of adequate sanitation infrastructure and education was encouraged in order to ensure good healthy environments in the home, neighborhood and community levels.

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LIST OF ABBREVIATIONS

BOD …….. Biochemical Oxygen Demand

COD……Chemical Oxygen Demand

DANIDA ……... Danish International Development Agency

DFID……...Department for International Development

DO ……..Dissolved Oxygen

EPA……Environmental Protection Agency

ISD …….Information Services Department

JICA …….. Japan International Cooperation Agency

KMA……...Kumasi Metropolitan Assembly

KNUST ……. Kwame Nkrumah University of Science and Technology

LDCs ……..Less Developed Countries

MWRWH …….…….Ministry of Water Resources, Works and Housing

MLGRD ……..... Ministry of Local Government and Rural Development

NCCE …… National Commission for Civic Education

NHIS ……. National Health Insurance Scheme

UNDP ……United Nations Development Programme

UNEP …… United Nations Environment Programme

USA ……..... United States of America

USAID …….. United States Agency for International Development

UNDP ……United Nations Development Programme

UNESCO……...….United Nations Educational Scientific and Cultural Organization

WHO ……..World Health Organization

OPERATIONAL DEFINITIONS

Biochemical Oxygen Demand (BOD): The amount of oxygen that would be consumed if bacteria oxidized all the organic matter in one litre of water or wastewater.

Channeling of waste: It is the deliberate use of sewage pipes that have been laid directly into the river as a means of waste disposal. It also includes the direct pouring of faeces from bucket latrines into the Aboabo River.

Chemical Oxygen Demand (COD): The measure of the total quantity of oxygen required to chemically oxidize all organic material into carbon dioxide and water.

Comprehensive Sewage System: The network of sewers that covers all houses in a river basin and carries sewage from point of origin to a sewage treatment plant.

Dissolved Oxygen (DO): The amount of oxygen dissolved in water, wastewater or other liquid. DO is measured in milligrams per liter**.**

Electrical Conductivity: The dissolved solids content of water measured through its ability to conduct an electric current.

Faecal Coliform: Bacteria found in the intestinal tracts of mammals and therefore in faecal matter. Their presence in water is an indicator of pollution and possible contamination by pathogens.

Faecal-oral diseases: Diseases transmitted by the consumption or contact with faecally contaminated water. Examples are cholera, typhoid, amoebic dysentery and diarrhea.

Hardness: The total amount of calcium carbonate in water measured in mg/L $CaCO_3$. Scale of hardness is Soft: 0-60; Moderately hard: 61-120; Hard:120-180; Very Hard: >180.

Household: A person or group of persons who live together in the same house or compound, sharing the same house-keeping arrangements and are catered for as one unit.

Household head: The person responsible for the upkeep of the household and recognized by other household members as the head.

pH: The measure of concentration of hydrogen ions (H+) in water. Where pH is less than 7, the water is acidic and if pH is greater than 7, the water is alkaline.

Refuse: Solid waste that is thrown away and considered as being of no value or use.

River basin: The entire geographic area drained by a river and its tributaries**.**

River pollution: The introduction, by man, of substances or energy liable to cause hazards to human health, harm to living resources, reduction of amenity or interference with legitimate uses of a river.

Septic Tank: A tank used to detain domestic wastes when a sewer line is not available to carry them to a treatment plant.

Sewage: Human and domestic waste matter from houses that is carried away through sewers.

Sewer: A pipe or drain, usually underground, which carries away waste or rainwater.

Sewage treatment plant: A facility designed to receive wastewater from domestic sources and to remove materials that damage water quality and threaten public health and safely discharge into receiving streams or bodies of water.

Turbidity: The amount of solid particles that are suspended in water and that cause light rays shining through water to scatter.

Urban run-off: Water from streets and domestic properties that carries pollutants into the sewer systems and receiving waters.

Waste: Unwanted or unusable liquid or solid matter.

Water-borne diseases: Diseases that are transmitted through the ingestion or direct skin contact with polluted river water. They include diarrhoea, cholera, typhoid, skin infection, eye infection.

Water-related insect vector disease: A disease transmitted through the bite of an insect vector. An example is malaria which is caused by plasmodium. The vector is the female anopheles mosquito.

Water quality: The physical, chemical and bacteriological condition of water with respect to the amount of impurities in it.

Wastewater: The spent or used water from a home, community or industry that is not for reuse unless treated.

CHAPTER ONE

1.0 INTRODUCTION

1.1 General Background

Water is life. Without water, man's existence on the earth would be threatened and he would be driven close to extinction. All biological organisms depend on water to carry out complex biochemical processes which aid in the sustenance of life on earth. Over 70 per cent of the earth's surface materials consists of water and apart from the air man breathes, water is one of the most important elements to man. Early civilizations flourished along the Nile, Tigris and Euphrates in ancient Mesopotamia, Indus in India, and Huang He in China due to their location near water sources (Ayoade, 1988:5). Though water covers about 70 percent of the earth's surface, only 2.53 percent is fresh water while the remaining is salt water (UNESCO, 2003:8). The World Water Council also records that of the 3 percent of fresh water, only 0.3 percent is found in rivers and lakes, the rest being frozen (World Water Council, 2005). This suggests that man has a relatively low amount of fresh water resources with which he can carry out his activities. Unfortunately, man's influence has begun to degrade the fresh water resource available for his development. Pollution is the introduction by man into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structures or amenity, or interference with legitimate uses of the environment (Holdgate, 1979 cited in Alloway and Ayres, 1993). According to UNESCO (2003), some 2 million tons of waste per day are disposed off within

receiving waters, including industrial wastes and chemicals, human waste and agricultural wastes such as fertilizers, pesticides and pesticide residues.

Rivers are potential sources for freshwater and some flow through major cities and towns of the world. Examples of notable rivers include the Nile of Egypt, Indus of India, Rhine of Germany, Thames of London, Potomac of Washington DC (USA) and the Zambezi of Central Africa. UNESCO (2003) indicates that 48 percent of the world's population lives in towns and cities and by 2030, this figure is likely to rise to about 60 percent. Urban areas provide the economic resources to install water supply and sanitation systems but they also concentrate waste. Where good waste management is lacking, urban areas are among the world's most life threatening environments (UNESCO, 2003). Some authorities in rapidly urbanizing cities across the globe and Africa in particular are grappling with the increased demand for social amenities as water, refuse collection, sanitation facilities, decent housing and security. In some cities in Africa, the demand for social amenities has outstripped the ability of city authorities to provide them. Some residential and industrial establishments are situated along waterways taking advantage of rapid urbanization and institutional failures and channeling waste into rivers causing River pollution. According to Dix (1981), 'A river may be said to be polluted when the water in it is altered in composition or condition, directly or indirectly as a result of the activities of man, so that it is less suitable for all or any of the purposes for which it would be suitable in its natural state'.

Where rivers flow through cities, they are likely to be polluted and this may have serious implications for health and socio-economic wellbeing of persons who live in the

immediate vicinity and those who use the water body downstream. Hardoy *et al.*, (2001), indicate that "River pollution from city based industries and untreated sewage can lead to serious health problems in settlements downstream" (Hardoy *et al.*, 2001: 187).

Some rivers lose their quality after they have passed through cities due to a number of human and industrial activities that contribute to their pollution. Settlements downstream that depend heavily on river water for domestic activities are forced to look for more expensive alternatives where such communities are not fitted with pipe borne water. Questions must be raised of the role human and industrial activities as well as institutional and policy failures play in degrading the quality of a river as it flows through a city. Specifically, what human activities within the urban setting constitute a threat to the quality of water that a river carries? What necessitates or precipitates such human activities? The study sought answers to these questions in order to aid in formulating good policies and ensure the protection and sustainable use of our rivers and also contribute to understanding urban river pollution.

1.2 Statement of the problem

The Aboabo River is one of the water resources in the Kumasi metropolis. Reconnaissance surveys conducted in the Aboabo River basin (September-October 2008) revealed that people living in the river basin indiscriminately dump refuse into the Aboabo River and also use the banks of the river as a place of convenience. Studies in December 2008 and January 2009 conducted on water samples collected from the

Aboabo River revealed that the quality of water that the river carried was far below EPA and WHO approved guidelines of drinking water quality. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels recorded 280mg/l and 520mgl respectively in the upper reaches whilst the lower reach recorded 320mg/l and 536mg/l respectively. Dissolved oxygen averaged 0.5 mg/l. In January 2009, the upper reaches of the river recorded BOD and COD levels of 720 and 2832 respectively. The lower reaches recorded BOD and COD levels of 300mg/l and 464mg/l respectively. In addition, Total Dissolved Solids and Total Suspended Solids also read 606mg/l and 280mg/l respectively. Fecal coliform count was over 300×10^4 at both the upper and lower reaches. This indicated that faecal pollutants were being introduced into the river. In addition to the fact that some residents in the river basin used the river as a place of convenience, a number of housing units that had been built close to the river bank channeled their liquid waste into the river at various sections. Small scale industries like saw mills, wood processing industries and palm kennel processing industries used the river as a dumping ground for waste generated in their industrial processes introducing varied amounts of suspended solids into the Aboabo River.

People living downstream in communities as Atonsu and Asago at the time of the reconnaissance survey expressed concern about the polluted nature of the Aboabo River and its inability to be used for domestic purposes. Observations revealed that some people, living in the river basin and downstream, use the river to water their crops which has a potential health hazard. Despite the existence of laws and institutions responsible for the management of water resources in the Kumasi metropolis, pollution still persists

and there are questions of what causes the pollution of the Aboabo River and its effect on the health of residents living in the Aboabo River basin.

1.3 Objectives

The main objective of the study was to identify the causes of pollution of the Aboabo River and identify the health effects on residents of the Aboabo River basin.

The specific objectives were:

1. To ascertain the extent of pollution of the water of the Aboabo River.
2. To find out the causes of the pollution of the Aboabo River in the Aboabo River basin.
3. To identify the health effects resulting from the pollution of the Aboabo River.
4. To find out measures put in place by the government and residents of the river basin to control the pollution of the Aboabo River.

1.4 Methodology

1.4.1 Types of data collected

Data for the research included background information of residents such as age, sex, household size, gender of household head as well as his or her education, occupation and income. The number of households per house as well as the types of sanitation facilities

used by households, the persons who frequently disposed off waste, the most frequent means of disposing liquid and solid waste as well as where refuse and human excreta were deposited was investigated. With reference to health, the prevalent diseases suffered by respondents' household members, NHIS registration, hospital attendance, indications of unhygienic conditions at the home and neighborhood level were investigated.

1.4.2 Sources of data

Data for the research were from primary and secondary sources. Primary data was sourced through the administration of structured questionnaires to respondents sampled within the river basin. Heads of households were interviewed and in the situation where heads of households were not available, an adult household member was interviewed. Water samples were collected and the result of laboratory analysis yielded primary data on pollution levels of the Aboabo River. Primary data was also sourced through interviews of Government officials, municipal authorities and opinion leaders whose inputs were relevant to the research. In addition personal observation was used and the evidence was recorded by means of pictures taken with a camera. Secondary data was sourced from books, relevant articles, journals, maps, hospital records as well as relevant publications and researches conducted on the subject matter by individuals and institutions.

1.4.3 Data Collection Method

Both primary and secondary data was used for the research. Primary data was collected through the use of a structured questionnaire survey of 396 households living in the

Aboabo River basin. Entrepreneurs who had enterprises situated within 0-100 meters of the Aboabo River were interviewed in order to ascertain whether they had permits and how their industrial waste was disposed.

Personal in-depth formal interviews were also employed. This method allowed the researcher to elicit in-depth information from officials at the KMA, EPA, Department of Urban Roads and Assembly men. Non-participant observation was employed to investigate the human activities being carried out within the Aboabo River basin. Due to the sensitive nature of sanitation issues and illiteracy amongst some residents in the Aboabo River basin, a combination of formal and informal interviews were employed to enhance efficiency and reliability of the data. Where the residents were willing to divulge information, an interview schedule was used. At sections where head porters (kayayei) and allied workers lived, the informal interview was used in order to allay their fears of being reported on their activities which degraded the environment in general and the Aboabo River in particular.

1.4.4 Sampling Design

To elicit the data to meet the objectives of the research, households that lived in dwelling units situated within 100m of the Aboabo River constituted a primary source of data. This was so chosen because evidence gathered from field surveys showed that some housing units channeled human excreta directly into the Aboabo-river.

The technique adopted for sampling is described as follows: To aid in easier analysis and identification of the sections of the Aboabo River basin that was being polluted,

communities on the river course were divided into three sections- Upstream, Midstream and Downstream communities. Seven major communities that lay in the river basin were chosen and the total number of households for the sample calculated as shown in table 1.0.

Table 1.0 Sampled communities with their sample sizes in the Aboabo River Basin.

Community	Population (2000)	Total Number of Households (2000)	Percentage (%)	Sample Selected from community.
Selected communities upstream				
Pankrono	36,683	6,591	17	67
Moshie Zongo	34,980	6,794	17	67
Buokrom	12,374	2,235	6	24
Selected communities midstream				
Dichemso	21,281	4,156	10	40
Aboabo	34,206	6,626	17	67
Selected communities downstream				
Asokwa	18,747	3,276	8	32
Atonsu	45,778	9,763	25	99
Total	**204,049**	**39,441**	**100**	**396**

Source: GSS, 2008.

The sampling frame was 39,441 households. The total number of households to be interviewed was determined with the formula:

$n = N / \{1+N (a)^2\}$

Where 'n' was the sample size

'N' was the total number of households.

'a' was the margin of error estimated at 5% (0.05)

$n = 39441/ \{1 + 39441 (0.05)^2\}$

$n = 39441/ 99.6025$

$n = 395.98$

n = 396 households.

Simple proportion was used to calculate the number of households for each selected communities (See: Appendix V). In Pankrono, Moshie Zongo and Buokrom 67, 67 and 24 households were studied respectively. Communities that were selected midstream are Dichemso and Aboabo. From these communities, 40 and 67 households were studied respectively. Downstream the Aboabo River was Asokwa and Atonsu. From these communities, 32 and 99 households respectively were studied. This is shown in Table 1.0.

1.4.5 Water Sampling

Water samples were collected from two sampling sites on the Aboabo River (See. Appendix iv). The water was collected by means of glass bottles, kept in an ice package and sent to the Civil Engineering Department, KNUST for physical, chemical and bacteriological tests. The dry season was selected as sampling period and two months were selected due to limited funds for water sampling. The samples were collected from each site in the months of December 2008 and January 2009 and tested for Temperature,

Color, Electrical Conductivity, Hardness, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids, Total Suspended Solids, Sulphate, Nitrate, Calcium, Magnesium and Faecal coliform counts. Temperature was recorded on site and all other parameters tested in the Department of Civil Engineering, KNUST.

1.4.6 Data analysis

Data collected on the field was inputted into the Statistical Package for Social Sciences (SPSS) software. v.13 and analyzed through the use of correlation and regression. To support data analysis, output data were presented in bar graphs, tables, line graphs and in addition relevant pictures were used to support the analysis.

1.4.7 Water Analysis

Odor: Odor was measured by its threshold number. In this method, the river water was diluted with odor free water and the mixture at which odor became detectable was determined.

Turbidity: The measurement of turbidity was by the visual method by means of a turbidity rod.

Dissolved Oxygen: The amount of dissolved oxygen present in the samples of water was determined by exposing water for 4 hours at a temperature of $27^{o}C$ with 10% acid solution of potassium permanganate. The quantity of oxygen absorbed was then calculated.

Hardness: Standard soap solution was added in the sample of river water and vigorously shaken for 5 minutes. The formation of lather was observed and the difference between the total amount of soap solution and the lather factor indicated the hardness of the river water.

pH: The potentiometer was used to measure the electrical pressure exerted by positively charged H-ions. The pH value was then correspondingly expressed.

B.O.D: The 5 day BOD test was employed. The river water was diluted with water of known content of dissolved oxygen. The diluted river water was then kept for 5 days at 20^{o}C in airtight vessels. The dissolved oxygen was worked out and the loss of oxygen in the river water was found out. This was done by calculating the difference between the original content of oxygen and the residual content of oxygen. The B.O.D in ppm was then worked out by the following equation:

5-day B.O.D = Loss of Oxygen in p.p.m. * dilution ratio.

C.O.D: The C.O.D test was employed. A strong chemical oxidizing agent was used in an acidic medium and the oxygen equivalent of the organic matter that could be oxidized was measured.

Total Solids: The sample of water was taken and most of the liquid was evaporated from it. The residue was dried and the weight represented the amount of total solids.

Suspended and dissolved solids: The difference with the amount of solids obtained (Total Solids) indicated the quantity of suspended solids. The remaining quantity of total solids obtained in (Total Solids) indicated the dissolved solids.

Total Solids = Suspended Solids + Dissolved Solids

Faecal Coliform: The membrane filter technique was employed. The river water was filtered through the membrane and it was incubated for a period of 20 hours. The colonies of bacteria were then counted by means of a microscope.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of literature that is significant in answering the research questions. The review is carried out in a systematic manner with references made to empirical research carried out on the subject matter. Evidence presented in the review includes information in research articles in journals, online journals, abstracts, books as well as relevant publications.

2.2 Pollution

2.2.1 Origins and Definitions

The result of the utilization of the natural resources in man's environment to meet his needs is the generation of waste. Waste in industrial and consumptive processes must be disposed of. The improper disposal of waste results in the 'pollution' of man's environment.

Pollution of man's environment has received attention in recent times due to its increasing threat to the sustenance of life on earth. Dix (1981) defines pollution as the deliberate or accidental contamination of the environment with man's waste. T.J McLoughlin (n.d) also defines pollution as the introduction by man of waste matter or surplus energy into the environment which directly or indirectly causes damage to man

and his environment other than himself, his household, those in his environment, and those with whom he has a direct trading relationship. Holdgate (1979) states that pollution is the introduction by man into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage of structures or amenity or interference with legitimate uses of the environment (Holdgate, 1979, cited in Alloway and Ayres, 1993:4).

Dix (1981) in tracing the roots of pollution provides us with an idea as to how pollution emerged into man's spatial environment. He maintains that 'pollution' must have started at a time when man began to use the natural resources of the environment for his own benefit. As he began to develop a settled life in small communities, the activities of clearing trees, building shelters, cultivating crops, and preparing and cooking food must have altered the natural environment. Later, as the human population increased and became concentrated into larger communities which developed craft skills, there were increasing quantities of human and animal waste and rubbish to be disposed of. In the early days of man's existence the amount of waste was small. It was disposed off locally and had virtually no effect upon the environment. Later, when larger human settlements and towns were established, waste disposal began to cause obvious pollution of streets and water courses (Dix, 1981).

Pollution ends up reducing the quality of air, water, or land from which man draws resources. Of particular concern to the research is water pollution and examples of water resources are rivers, lakes, lagoons, streams, ground water and estuaries. A river may be said to be polluted when the water in it is altered in composition or condition, directly or

indirectly as a result of the activities of man, so that it is less suitable for all or any of the purposes for which it would be suitable in its natural state (Dix, 1981). Meybeck, (1996) however maintains that the concept of pollution is relative in that it reflects a change from some reference value to particular values that causes problems for human use. With reference to water pollution, no reference value exists because of the high variability in the chemical quality of natural waters.

2.3 Water Pollution

Water sustains life. An adequate supply of fresh water is needed for domestic as well as industrial processes. Water bodies have become both resources for fresh water and receptacles for domestic and industrial wastes leading to “water pollution”. According to Chapman (1996:6), “Pollution of the aquatic environment refers to the introduction by man, directly or indirectly, of substances or energy which results in such deleterious effects as harm to living resources, hazards to human health, hindrance to aquatic activities including fishing, impairment of water quality with respect to its use in agricultural, industrial and often economic activities, and reduction of amenities.

Water pollution affects water quality. Water quality refers to the overall quality of the aquatic environment (Chapman, 1996). The description of the quality of the aquatic environment can be carried out through a variety of ways. It can be achieved through quantitative measurements such as physico-chemical determinations (in the water, particulate material, or biological tissues) and biochemical/biological tests (BOD

measurement, toxicity tests) or through semi-quantitative and qualitative descriptions such as biotic indices, visual aspects, species inventories, odor, etc. These determinants are carried out in the field and in the laboratory and produce various types of data which lend themselves to different techniques (Chapman, 1996:7). The quality of freshwater at any point on a landscape reflects the combined effects of many processes along water pathways and both quantity and quality of water are affected by human activity on all spatial scales (Peters and Meybeck, 2000).

2.4 Sources of river pollution

River water pollution is broadly categorized into two sources. Point and non-point sources (Cunningham and Saigo, 1999; Chapman, 1996; Hammer and MacKichan, 1981; Pierce *et al*., 1998). Point sources discharge pollution from specific sources such as drain pipes, ditches, or sewer outfalls. Examples of point sources are factories, power plants, sewage treatment plants, underground coal mines and oil wells. Non-point sources or diffuse sources on the other hand have no specific location where they discharge into a principal body of water. Examples of non-point sources of pollution include run off from farm fields and feed lots, golf courses, lawns and gardens, construction sites logging areas, roads, streets and parking lots (Cunningham and Saigo, 1999; Hammer and MacKichan, 1981). Chapman (1996) asserts that an important difference between a point source and a diffuse source is that a point source may be collected, treated or controlled. Non-point sources of pollution pose a major challenge to environmental management due to the diverse sources of pollution and multiple and often complicated pathways of

pollutant transport. Nitrogen (N) and Phosphorus (P) inputs from agricultural fields and urban lawns greatly increase the N and P pollution in agricultural and urban watersheds (Zhu *et al*., 2008; Hayakawa *et al*., 2006). Vega *et al*., (1998) point out that surface runoff can be considered a diffuse source due to the fact that it is seasonal and affected by climate.

2.5 Causes of river pollution

Anthropogenic factors play a major role in contributing to the pollution of rivers (UNEP, 2008). Anthropogenic factors such as agricultural development, population growth, urbanization, industrialization as well as market policy failures have been identified as the root causes of water pollution (UNEP, 2006).

2.5.1 Agriculture

Agriculture in some settings across the earth requires the use of fertilizers and the application of pesticides. The application of such chemicals leads to the release of toxins as Nitrogen (N) and Phosphorus (P). These toxins leach into soils to contaminate underground water and also lead to the eutrophication of water systems. Eutrophication refers to the nutrient enrichment of water bodies as pools, ponds, lakes, rivers and lagoons. The principal elements responsible for eutrophication are Nitrogen (N) and Phosphorus (P) which are found in detergents, soaps and fertilizers. The eutrophication of surface water causes degradation of aquatic ecosystems and problems such as algal blooms, loss of oxygen, fish kills and loss of biodiversity. Apart from fertilizer

application, sewage disposal from urban areas contribute significantly to nitrogen loadings in river systems leading to eutrophication (Hayakawa *et al*., 2006).

2.5.2 Population growth and urbanization

Population growth and urbanization do have significant roles in contributing to water pollution. An increase in population growth leads to an increase in the demand for housing and an increase in the generation of wastes. A recent study of the Nworie and Otamiri rivers in Nigeria showed a strong relationship between nitrate concentration and urbanization. As urbanization increased, so did the nitrate concentration of the rivers. The increase in nitrate concentration was attributed to surface water flow from farm lands, recreational areas, industrial effluents and the indiscriminate disposal of solid waste into the rivers. Potential sources of these nitrates were identified as being the use of soaps, detergents and agricultural fertilizers (Ibe and Njemanze, 2008).

2.5.3 Industrialization

In less developed countries, many rivers and streams are heavily polluted due to anthropogenic activities (Jonnalagadda and Mhere, 2000). In Malaysia for example, forty-two (42) of fifty (50) major rivers are reported to be "ecological disasters". Residues from palm oil and rubber manufacturing along with heavy erosion from logging of tropical rainforests have destroyed all higher forms of life in most of the rivers' (Cunningham and Saigo, 1999: 483). In 1999 a study by Bichi and Anyata (1999) revealed that three major rivers in the Kano basin - The Salanta, Challawa and Kano Rivers had been heavily polluted by the discharge of industrial effluents from the Sharada

and Challawa industrial estates. Though these rivers were being used for water supply and fishing at the time of the study, the quality of the water was found to be unsuitable for these purposes (Bichi and Anyata, 1999).

Similarly a study to look at the effect of anthropogenic activity on water quality of the Odzi River, concluded that water quality in the upper reaches of the Odzi River was medium to good. After collecting and analyzing water samples from six (6) sampling sites for nine (9) months, the results showed that water quality dwindled due to seepage from abandoned mine dumps and discharges from farm lands (Jonnalagadda and Mhere, 2000). In the year 2005, a study of the impact assessment of industrial effluent on the Alaro River in Nigeria was carried out. In the study, water quality was assessed upstream and downstream after the point of effluent discharge with the view to determining the effect of industrial effluent on water quality. It was realized from the study that the levels of most of the parameters in the effluent exceeded the effluent guidelines for discharge into surface water. Water quality of the Alaro River were adversely affected and impaired by the discharge of industrial effluents. Furthermore, levels of parameters downstream were significantly elevated and the quality of effluent did not meet requirements to be discharged into surface water (Fakayode, 2005). Owen and Pickering, (1994) also maintain that human activities such as mining could cause the release of heavy metals such as lead, mercury, tin and cobalt into rivers. When water from a river which is contaminated with heavy metals is consumed in large enough doses, it could be very lethal.

2.5.4 Institutional and policy failures

In many areas in less developed countries, toilets, latrines or proper drains are non existent or have broken down. Wastes are disposed of near or in the same river, lakes or wells used for drinking and food preparation (Kaufman and Franz, 1996). The laws prohibiting the indiscriminate dumping of refuse or pollution of rivers in Ghana in particular exist but the enforcement of these laws proves difficult. Omane (2002) asserts that water pollution still persists perhaps due to the fact that these laws were varied and each narrowed towards particular purposes other than pollution prevention. In addition, these laws were fragmented under so many governmental departments and they were too many, too weak. In the case of Kumasi, Obuobie *et al*., (2006) indicate that many people attribute the increasing water pollution in the Kumasi metropolis to the failure of KMA to collect, treat and dispose of waste water efficiently. In addition, government institutions like hospitals and learning institutions contribute to water pollution, making the prosecution of individuals, private and public institutions a farce.

2.5.5 Natural Factors

Although the major proportion of all water quality degradation world-wide is due to anthropogenic influences, it is by no means the only cause. Natural events such as hurricanes, mudflows, torrential rainfalls and unseasonal lake outbursts do cause water quality degradation. Some natural events are, however caused by human activities, such as soil erosion associated with heavy rainfall in deforested regions (Chapman, 1996). Letterman (1999) also argues that natural factors such as climate, watershed characteristics, nutrients and wild fires could have significant impacts on water quality.

Periods of heavy precipitation can re-suspend bottom sediments and increase turbidity, microbial loading, color, metals and other contaminants. Dry conditions could also increase the impact of point-source discharges by reducing the effect of dilution by the source water (Atherholt *et al*., 1998 cited in Letterman, 1999).

Topography, vegetation and wildlife are factors that affect the quality of water bodies. During heavy runoff, steep slopes can introduce debris, sediment and nutrients that may affect color, turbidity and the growth of algae. Vegetation could have an effect on water quality by serving as a natural filter for run-off of non-point source contaminants. Some studies indicate that some migratory birds like the water fowl could acquire oocysts from agricultural and recreational areas and travel great distances to pollute other aquatic locations (Fayer *et al*, 1997 cited in Letterman, 1999). The subsurface geology also determines ground as well as surface water quality. Robbins *et al*., (1991) asserted that weathering characteristics of local geology could have an effect on erosion rates. Furthermore, a cohesive soil will resist "splash erosion" more effectively than loose soils thus reducing the amount of soil that gets washed away in runoffs. On the other hand, soils that have shallow depths and low permeability are not well suited for individual septic systems and can contribute to ground water and surface water contamination in urban watersheds (Robbins *et al.*, 1991).

Excessive nutrient enrichment of water bodies lead to Eutrophication. Where a water body has excess of nitrogen and phosphorus from natural sources, it leads to increased nutrient loadings and increased microbiological activity. Eutrophication is associated

with depleted oxygen levels, high turbidity and excessive algae in the water column. Algae blooms may cause phosphorus to be released from bottom sediments and also cause the conversion of nitrate and organic nitrogen to ammonia (Letterman, 1999). This manifests as a major challenge to water treatment and consumption. Wildfires can destroy vegetative cover and increase the potential for erosion. Wildfires also increase peak flows, sediment, turbidity, stream temperature and nutrients (Tiedemann *et al*., 1979 cited in Letterman, 1999).

2.6 Effects of river pollution

2.6.1 Effects on water quality

The primary effect of river pollution is the reduction in the quality of water being carried by the river. In the less developed countries of South America, Africa and Asia, 95 per cent of all sewage is discharged untreated into rivers, lakes or the ocean and in India for example it is estimated that two-thirds of the surface waters are contaminated sufficiently to be considered dangerous to human health. The Yamuna River in New Delhi had 7,500 coliform bacteria per 100 ml (thirty-seven times the level considered safe for swimming in the United States) before entering the city. The coliform count increased to 24 million cells per 100 ml as the river picked 20 million liters of industrial effluents every day from New Delhi. Mortality rates were thus high and life expectancy low in those areas (Cunningham and Saigo, 1999). Also, a 2008 study of the Huluka River in Ethiopia revealed a worsening trend of pollution from the upstream to the downstream end of the river. Water samples collected and analyzed downstream revealed eight to ten times

higher values of BOD and COD and in addition, measured ions also showed an increasing trend (Prabu *et al*., 2008). Thus research evidence suggests that the effects of the degradation of a water resource are not limited to the area of discharge but could have widespread implications for the entire watershed. Users of polluted or degraded water resources could suffer negative effects downstream (Peters and Meybeck, 2000).

2.6.2 Features of Water Quality

The principal features of water quality in streams, rivers and lakes with which water engineers are most concerned are categorized into three main groups- Physical, Chemical and Biological (Tebbutt, 1977 cited in Shaw, 1994).

2.6.2.1 Physical Features

Solids form the most common matter to be carried along by a flowing river. These solids could be from organic or inorganic sources. Examples include refuse, tree barks, tree trunks, silt, and boulders. When evaluating water quality, suspended solids (SS) are measured in mg l^{-1} (Shaw, 1994).

Color, taste and odor are properties that are subjectively determined. They are caused by dissolved impurities either from natural sources or from the discharge of noxious substances like excreta, oil, bathwater into the water course by man (Shaw, 1994).

Turbidity refers to the cloudiness of water due to fine suspended colloidal particles of clay or silt, waste effluents or micro organisms and is measured in turbidity units (NTU) (Shaw, 1994).

Electrical conductivity (EC) is a physical property of water which is dependent on the level of dissolved salts. It is measured in microsiemens per centimeter (μS cm^{-1}) and it gives a good estimate of the dissolved salt content of a river.

Temperature is measured in °C and is a good measure for assessing the effects of temperature changes on living organisms (Shaw, 1994).

2.6.2.2 Chemical Features

The chemical features worth studying in water quality analyses are very extensive since water is a universal solvent and many chemical compounds can be found in solution in naturally occurring water bodies (Shaw, 1994). As such, only a selection of the most significant would be discussed.

pH measures the concentration of hydrogen ions (H+) and it is an indicator of the degree of acidity or alkalinity of water. On the scale from 0 to 14 a pH of 7 indicates a neutral solution. Where pH is less than 7, the water is acidic and if pH is greater than 7, the water is alkaline (Shaw, 1994).

Dissolved Oxygen (DO) plays a key role in the assessment of water quality. Fish and other forms of aquatic life require dissolved oxygen for their sustenance. Dissolved oxygen affects the taste of water and high concentrations of dissolved oxygen in domestic supplies are encouraged by aeration. Dissolved Oxygen is measured in $mg1^{-1}$(O2) (Shaw, 1994).

Nitrogen may be present in the form of organic compounds usually from domestic wastes. Examples of these compounds are ammonia or ammonium salts. Nitrogen could be in the form of nitrites or fully oxidized nitrates. Measures of nitrogen give an indication of the state of pollution by organic wastes. It is measured in mg 1-1(N) (Shaw, 1994).

Chlorides are found in brackish water bodies contaminated by sea water or in ground water aquifers with high salt water content. The presence of chlorides (mg 1-1Cl) in a river is indication of sewage pollution from other chloride compounds (Shaw, 1994).

2.6.2.3 Biological Features

Some harmful diseases are transmitted by water-borne organisms. An example is Bilharzia caused by schistosoma. The common organism found in all human excreta is Escherichia coli (E.Coli) and this gives an indication of sewage pollution or pollution from human sources. This is measured in Most Probable Number (MPN) per 100ml which is determined statistically from a number of water samples (Shaw 1994).

2.6.3 Effects on water quantity

Peters and Meybeck (2000) assert that water quality degradation is a principal cause of water scarcity and could reduce the amount of freshwater available for portable, agricultural and industrial use (Peter and Meybeck, 2000). The quantity of available freshwater is thus linked to quality which may limit its use (Chapman, 1996). Human activity such as the indiscriminate dumping of refuse and the channeling of untreated domestic and industrial effluents into rivers reduce water quality, reduce water quantity and also reduce the uses to which water can be put.

2.6.4 Effects on human health

Man's health to a large extent is dependent on access to clean potable water. Unfortunately, not every one on the planet has access to this precious resource. Some persons have access to water but such water is polluted. Polluted water could be a carrier of many diseases and when it is ingested into the human system, it could have negative implications for human health. Persons who use polluted water are in danger of contracting water-borne, water-hygiene, water-contact or water-habitat vector diseases. Water borne infectious diseases are those in which the pathogen is present in water and ingested when the water is consumed. Most of the pathogens could be from human faeces and diseases transmitted by the consumption of faecally contaminated water are known as "faecal-oral" diseases. Examples of faecal-oral diseases include cholera, typhoid, amoebic dysentery and diarrhea. Water-hygiene diseases are ones which occur due to the lack of adequate clean water for maintaining personal hygiene and cleanliness. Examples of such diseases are tinea, scabies, pediculosis (lice) and skin and eye infections. Water-contact diseases are contracted when an individual's skin is in contact with pathogen infested water. An example is schistosomiasis (bilharziasis) in which the eggs of the pathogen (*schistosoma* spp.) are present in the faeces and or urine of an infected individual. Water-habitat vector diseases are transmitted by insect vectors that spend all or part of their lives in or near water. Examples include malaria and filariasis as well as onchocerciasis which has the aquatic fly as its vector (Bartram and Balance, 1996).

According to UNDP estimates, more than 1 billion people are denied the right to clean water and 2.6 billion people lack access to adequate sanitation (UNDP, 2006: v). In Sub-Saharan Africa, it is estimated that 42 per cent of the population is without improved

water (WHO, 2004:2). The absence of improved water sources puts people's health at risk and may force them to extract water from alternative, unsafe sources, exposing them to diseases such as diarrhea, dysentery, cholera, typhoid and schistosomiasis (WHO, 2001). The WHO estimates that as many as 80 percent of all infectious diseases in the world are associated with insufficient and unsafe water (Smet and Van Wijk, 2002: 16). Furthermore in less developed countries (LDCs), it is estimated that 25 million people per year die from contaminated water; three-fifth of whom are children and worldwide, every hour 1,000 children die from diarrhea related diseases (Kaufman and Franz, 1996).

An adequate provision of good drinking water is therefore essential for the promotion of good health and sanitation. Where there is too little water for washing oneself, flushing toilets, properly cleaning food, utensils and clothes, the likelihood of contracting diseases as diarrhea could be very high. According to Wolff (1999), when significant improvements in the quality and quantity of water are made in less developed countries, there would be about 2 million fewer deaths from diarrhea among children. In addition, research showed that access to safe water reduced child death rates by more than 20 percent in Cameroon and Uganda whilst in Egypt and Peru, the presence of flush toilets in the house reduced the risk of infant death by more the 30 percent (UNDP, 2006).

2.6.5 Socio-economic implications

The pollution of rivers also has socio-economic implications. An inadequate supply of water and sanitation facilities could reduce the likelihood of safe disposal of human waste thereby increasing risks or exposure to disease and death. An adequate water supply

promotes good health and improves the prospects of new livelihood activities which are otherwise denied and are a key step out of poverty (UNESCO, 2006). Where water and sanitation investments are not made, the likelihood of contracting diseases such as diarrhea, dysentery, cholera, typhoid and schistosomiasis is high. When the 'bread winner' or household head becomes victim to these diseases, it has implications for the livelihood of the household, particularly that of the poor. Working days as well as productivity are lost and household incomes are greatly reduced where alternative sources of income are limited or non-existent. Household incomes might not be able to support the buying of water from expensive alternatives thus the house hold is caught up in the cycle of poverty due to the lack of good quality water for drinking, irrigation and sanitation (WHO, 2001). Majority of those who suffer this trend are women. According to the WHO, almost 70 percent of the 1.3 billion people living in extreme poverty are women and often trapped in a cycle of ill health (WHO, 2001). The World Bank (2008:6) also maintains that "labour is often the only asset that poor households have and that sickness and death can have intergenerational effects. Any improvements in environmental health can have long-term impacts on households' ability to move out of poverty". An improved water supply could therefore trigger a reduction in working hours and increase rest for women and children who hitherto, had to walk long distances or join long queues to fetch water of questionable quality. For poor rural women, the time saved could be used for household child care, the collection of more water for hygiene or the engagement in productive activities as trading to supplement household incomes. In addition, children could gain more time to attend school (Smet and Van Wijk, 2002).

2.7 Water Pollution in Ghana.

Water pollution is defined in Ghana's water policy to mean any direct or indirect alteration of the physical, thermal, chemical, or biological properties of the water resource so as to make it less fit for any beneficial purpose for which it is or may reasonably be expected to be used; or harmful to the welfare, health or safety of human beings, any aquatic or non-aquatic property or the environment (MWRWH, 2005: 66).

Access to Ghana's water resources are not evenly distributed at the spatial level. The 2000 census estimated that at the national level, only 39.9 percent of households had access to pipe borne water. Two (2) percent got water supply from tanker services whilst three other sources wells, boreholes, and rivers/streams account for 16 percent each (GSS, 2005). Furthermore, access to pipe-borne water as a source of drinking water was 67.8 percent in urban areas compared to 14.9 percent in rural areas. At the national level, 42 percent did not have access to good safe drinking water. In Accra, over 91 percent of households had access to pipe-borne water in the year 2000 with 43.6 percent having pipe-borne inside their houses (GSS, 2005).

On the other hand the waste management and sanitation situation in Ghana is quite precarious. About 20 percent of households in Ghana have no toilets with the percentage increasing to about 70 for the three Northern Regions. In addition, only 5 percent of the population disposes their liquid waste through sewage networks connected to treatment plants, 38 percent throw liquid waste on the streets whilst 21 percent throw it directly into

gutters. Furthermore, 35 percent dispose liquid waste in the compound and 1 percent in other places (Obuobie *et al*., 2006).

In Kumasi, 38 per cent of the residents use public toilets equipped with flush toilets, holding tanks or improved pit latrines. Most of the remainder of the population uses private facilities of which 12 per cent use bucket or pan latrines, 10 per cent pit latrines and 26 per cent household water closets linked to septic tanks ("man-holes") and seepage pits. Only 8 per cent of the population has toilets connected to a sewerage system, and the remainder has no toilet facilities at all (Keraita *et al*., 2003: 173)

According to the Ghana Statistical service (2005), inadequate logistics and lack of adequate education on proper waste disposal have contributed to the development of waste problems that the country faces. Waste managements systems are inadequate to support the growing population hence creating an environmental management disaster. The Environmental Protection Agency of Ghana (EPA) also maintains that developing countries like Ghana have very little capacity for treating their effluents consequently large volumes of untreated effluents are discharged into water bodies and open drains (EPA, 2002). In Kumasi, urban wastewater is generated mostly from domestic sources. Population increase and lack of investment have overstretched the few available sanitation facilities, and large volumes of untreated or partially treated wastewater end up in nearby streams (Keraita *et al*., 2003). The principal generators of industrial waste waste are two breweries, a soft drink bottling plant and an Abattoir. Together they generate about 1000m^3 of effluent daily, all of which end up in the city's drains without treatment. Light industrial activities in Suame Magazine and saw dust from some saw

mills also generate significant amounts of waste oil and leachate adding to environmental pollution (Simon *et al*., 2001; cited in Obuobie *et al*., 2006). Nsiah-Gyabaah, (2001) in describing the problem that people in peri urban areas face said that " in many urban and peri-urban areas, it has been observed that rivers, streams and aquifers are increasingly being contaminated in their recharge areas through human activities. Many urban and rural communities constantly struggle with prolonged drought and aridity, water pollution, water shortage and rising costs of providing water. In addition they face the problems of fast rapid population growth and urbanization that are putting extreme pressure on available water resources leading to water pollution and water shortage in the peri-urban interface" (Nsiah-Gyabaah, 2001:72). In Kumasi for example, Nsiah-Gyabaah (2001), maintains that inhabitants of the city pollute the rivers and streams used by inhabitants in the peri-urban interface by dumping night soil and waste tips close to sources of water supply. This has implications for the health and socio-economic well being of people living in the peri-urban areas of Kumasi where rivers and streams as the main sources of water supply. Thus due to rapid urbanization, inadequate supply of waste management facilities and poor waste management infrastructure, rivers in Ghana and Kumasi to be specific have not been spared of pollution.

2.8 Water Legislation in Ghana

A number of legislations have been enacted that give protection to rivers and other water bodies in general. Some of these legislations are more than a half century old and though

they were intended for good purposes pollution still persists due to the fact that those laws were:

1. Varied and each narrowed towards particular purposes other than pollution prevention.

2. Fragmented under so many governmental departments.

3. Too many and too weak.

Acts that lend themselves to water supply, water quality and use for navigation are:

1. The Rivers Ordinance, 1903, Cap 226 (1951 Revised) for dredging and diverting of rivers, river navigation etc.

2. The Oil in Navigable Waters, Act 235 of 1964 implementing the 1954 International convention and extending it to navigable inland rivers.

3. Forests Ordinance Cap 157 (1951 Revised) to safeguard water resources in a forest reserve

4. Mosquitoes Ordinance Cap 75 (1951 Revised) to prevent contamination of water by mosquito larvae (Omane, 2002)

5. The Ghana Water and Sewerage Corporation Act 310, 1965 which gives the corporation the mandate to provide, distribute and conserve the supply of water in Ghana for public, domestic and industrial purposes. Recent legislature that lend themselves to the protection of the environment in general and water resources in Ghana include: The Environmental Protection Agency Act 490, 1994 which establishes The Environmental Protection Agency, The Water Resources Commission Act 522, 1996 which establishes

the Water Resources Commission and The Environmental Sanitation Policy of the Ministry of Local Government and Rural Development (MLGRD), 1999 which assigns the principal responsibility of waste management, and protection of the environment to the District Assemblies. This policy mandates the EPA to play a monitoring role and provide technical assistance where necessary (Omane, 2002).

2.9 HYPOTHESES

Hypotheses were formulated to serve as a guide to the study and they were stated as follows:

1. Ho: The Aboabo River water is not polluted.

   Ha: The Aboabo River water is polluted.

2. Ho: Human activities carried out in the Aboabo River basin are not the main causes of the pollution of the Aboabo River.

   Ha: Human activities carried out in the Aboabo River basin are the main causes of the pollution of the Aboabo River.

3. H_O: There is no positive relationship between frequency of playing in the Aboabo River and the occurrence of water borne diseases in children.

   H_A: There is a positive relationship between frequency of play in the Aboabo river and the occurrence of water borne disease in children.

2.10 Conceptual framework

The conceptual framework showing the relationship between population factors, the environment and mediating factors is shown in fig 2.1.

Fig 2.1 Framework for Population and Environment Linkages

Source: UNFPA (2001:10)

The UNFPA framework shows that the size or growth, distribution as well as composition of population have an influence on environmental factors. Environmental factors include quality and quantity of land, air and water resources. Mediating factors are institutions, policy contexts, science and technology and cultural factors.

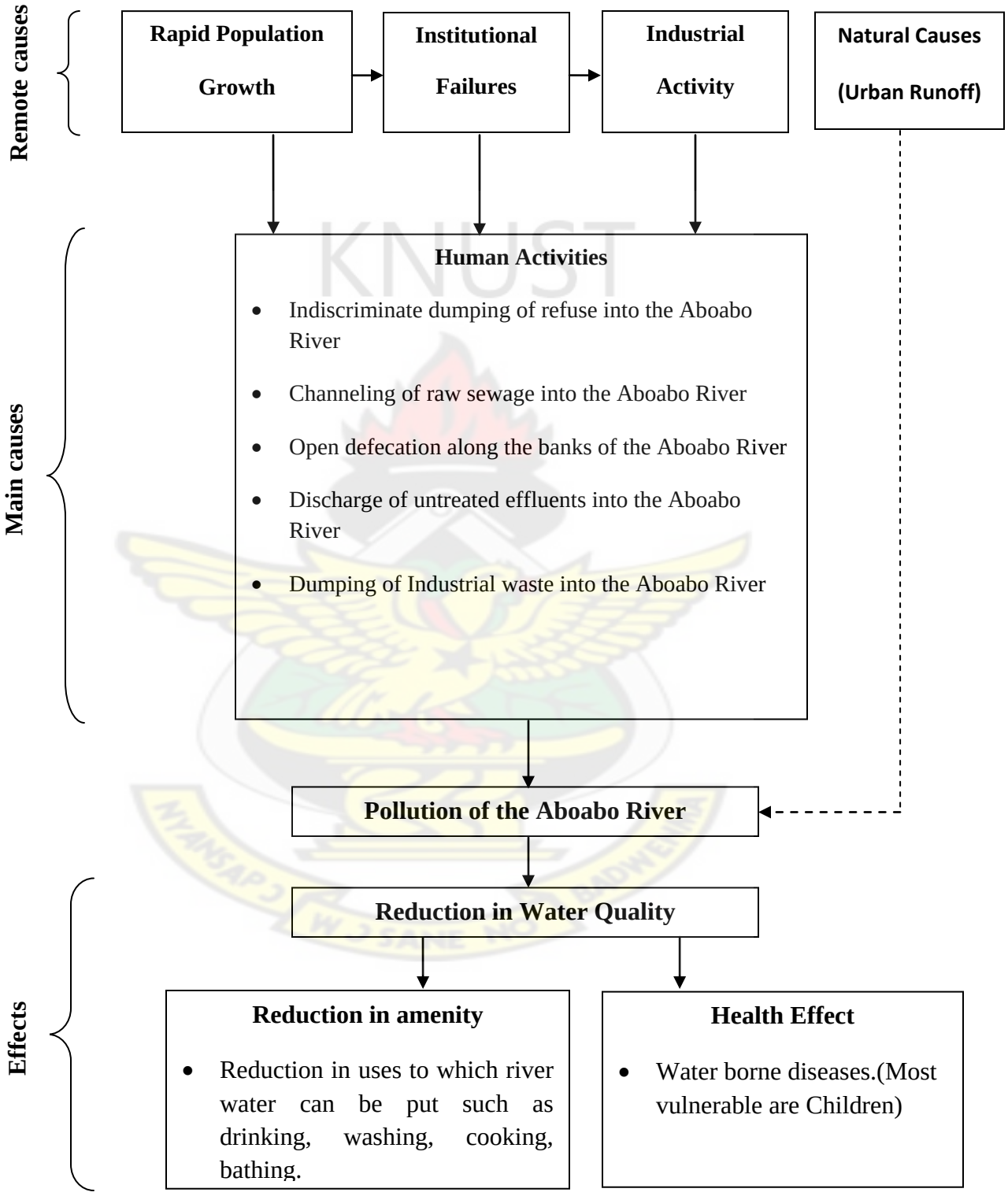
Population distribution affects the distribution of environmental pressures. Rapid urbanization poses environmental challenges such as generation of wastes which leads to land air and water pollution. Society policies, institutional structures, politics, power

relations and culture serve as mediating factors. In other words, the mediating factors influences or regulates the rate at which the environment is degraded and the mediating factors also influences the size, distribution and composition of the population. For example, policies can influence deforestation through government subsidies for logging, building of houses and road construction through forested areas. In addition, degradation of the environment is also a function of the science and technology applied. Countries that use sophisticated technology and are heavily industrialized emit huge volumes of sulphur and carbon dioxide into the air polluting it (UNFPA, 2001:10).

The reciprocal relations amongst the population, mediating factors and the environment depicted by the UNFPA (2001) framework has been further adapted to explain the causes and effects of river pollution in the Aboabo River basin.

The conceptual framework for the study is based on the interplay of factors such as rapid population growth, institutional failure and industrial activity. These factors are not mutually exclusive but they work together to induce behavioral patterns. The interplay of the remote anthropogenic causes yields the main anthropogenic causes. The main causes are: indiscriminate dumping of refuse; channeling of raw sewage; open defecation; discharge of untreated effluents and Dumping of Industrial waste into the Aboabo River.

Fig.2.2 CAUSES AND EFFECTS OF THE POLLUTION OF THE ABOABO RIVER



Source: Adapted from UNFPA (2001:10).

From fig 2.2, rapid population growth is a cause of institutional failures. Funding from government and other donor institutions is not able to meet the budgetary needs of government departments and agencies due to rapid increase in population. This makes it difficult to enforce bye-laws on environmental protection and sanitation, build sewage systems and monitor river water quality. The increasing numbers of people living in the river basin triggers an increase in demand for sanitation and waste management services. The mismatch between sanitation infrastructure and population growth affords some residents take advantage and dump rubbish as well as domestic waste into the Aboabo River.

Institutional failures also lead to the establishment of illegal industrial activity. Lack of regular monitoring and inspection of permits as well as poor enforcement of metropolitan bye-laws affords individuals the opportunity to establish small scale enterprises along the banks of the river. By so doing, they use the river as a source of water for industrial purposes and as means of disposing industrial waste.

The interplay of rapid population growth, institutional failure and industrial activity yield a variety of behavioral patterns which lead to the pollution of the Aboabo River. These behavioral patterns include the indiscriminate dumping of refuse into the river, channeling of raw sewage into the river, open defecation into or along the banks of the river and the dumping of industrial waste into the river.

These behavioral patterns of residents living in the Aboabo River basin contributes significantly to reducing the quality of water the river carries and this has far reaching implications for persons living in the river basin as well as communities downstream.

One of the far reaching implications is that of health. The pollution of the river leads to the breeding of vectors which transmit varied water related diseases such as malaria, typhoid, cholera, amoebic dysentery and diarrhea. Children are mostly vulnerable to water related diseases because they play regularly in the polluted river and this involves direct body contact and ingestion when swimming in the river.

CHAPTER THREE

3.0 THE STUDY AREA

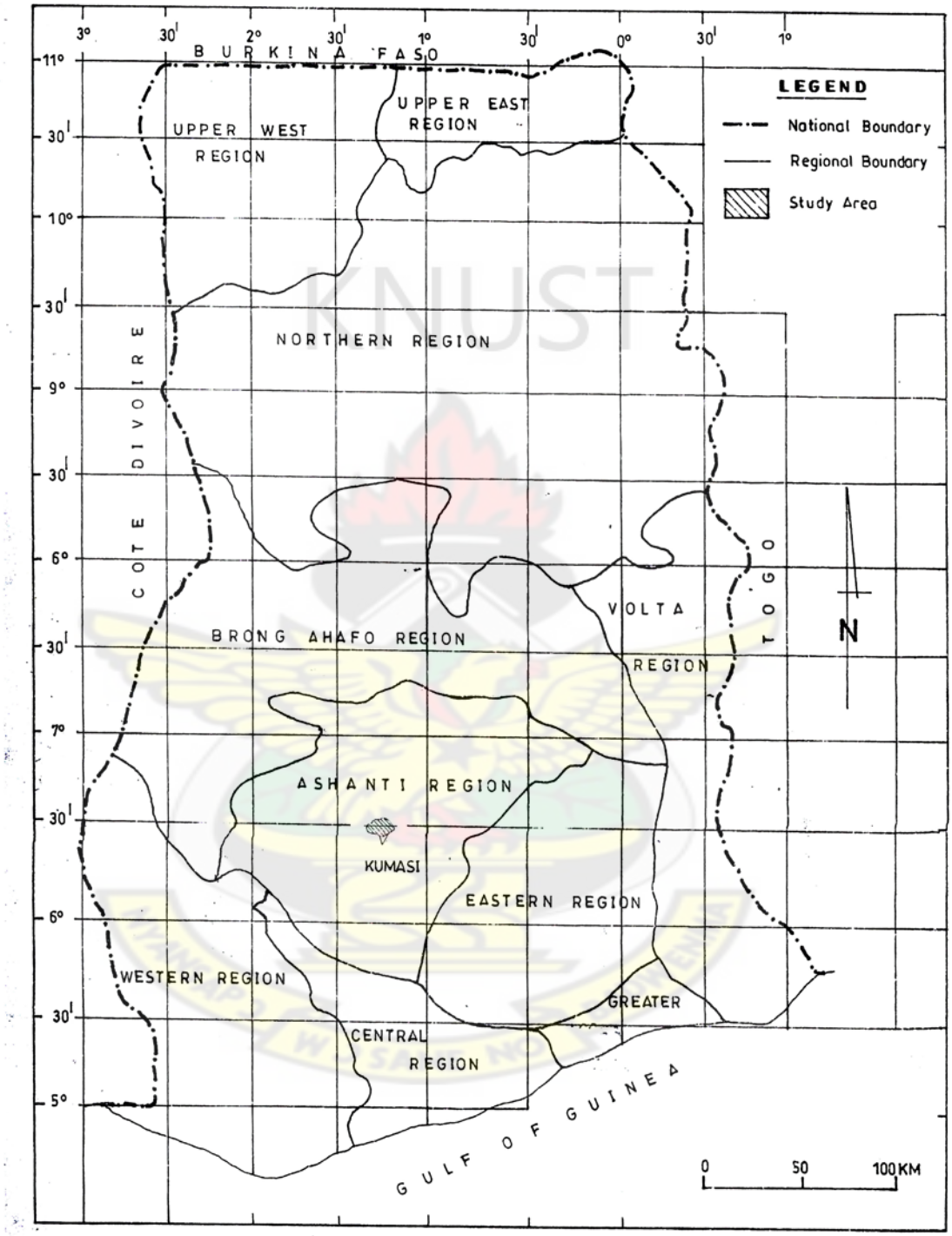
3.1 Introduction

This chapter presents the physical background of Kumasi Metropolitan Area in which lies the Aboabo River basin. The location, size, population characteristics, climate, and drainage characteristics of the river basin are discussed. The chapter also presents a discussion on the socio-economic characteristics of the study area based on primary and secondary sources of data gathered during the study.

3.2 Location and Size

Kumasi is the capital of the Ashanti region of Ghana and is located about 270km North-West of Accra, the capital of Ghana. Kumasi is located between latitude 6° 35' – 6° 40' and longitude 1° 30' – 1°35' (Map.3.1) having an approximate area of 254 sq km and a 2009 estimated population of about 1,915,179 (KMA, 2006). Kumasi functions as a nodal town as roads from the north, south, east and western parts converge on it and it serves as a crucial link between the northern part of Ghana and the southern part. This central function of Kumasi has the potential of attracting trade and commerce form all parts of the country. Administratively, the Kumasi Metropolitan Assembly governs the metropolis and the metropolis is divided into 10 sub-metropolitan areas for effective administration. These sub-metropolitan areas are Bantama, Suame, Manhyia, Tafo, Kwadaso, Nhiyaeso, Subin, Asokwa, Asawase, and Oforikrom.

MAP 3.1 STUDY AREA IN NATIONAL CONTEXT



SOURCE: Department of Geography, KNUST 2009

The Kumasi Metropolitan area is bordered by five districts namely Kwabre East to the North, Atwima Nwabiagya to the west, Atwima Kwanwoma to the South West, and Ejisu-Juaben to the East and Bosomtwe to the South (Map. 3.2).

3.3 Climate

The Kumasi metropolis falls within the Wet sub equatorial climatic region and has an average minimum temperature of 21.5°C and an average maximum temperature of 30.7°C. On the average humidity is about 84.16 percent at 0900 GMT and 60 percent at 1500 GMT. The Kumasi metropolis experiences a double maxima rainfall regime (214.3mm in June and 165.2mm in September). The first rainy season is from mid–march to early July whilst the second starts from late August to early October. The dry season is experienced from November to early march (Suraj, 2004).

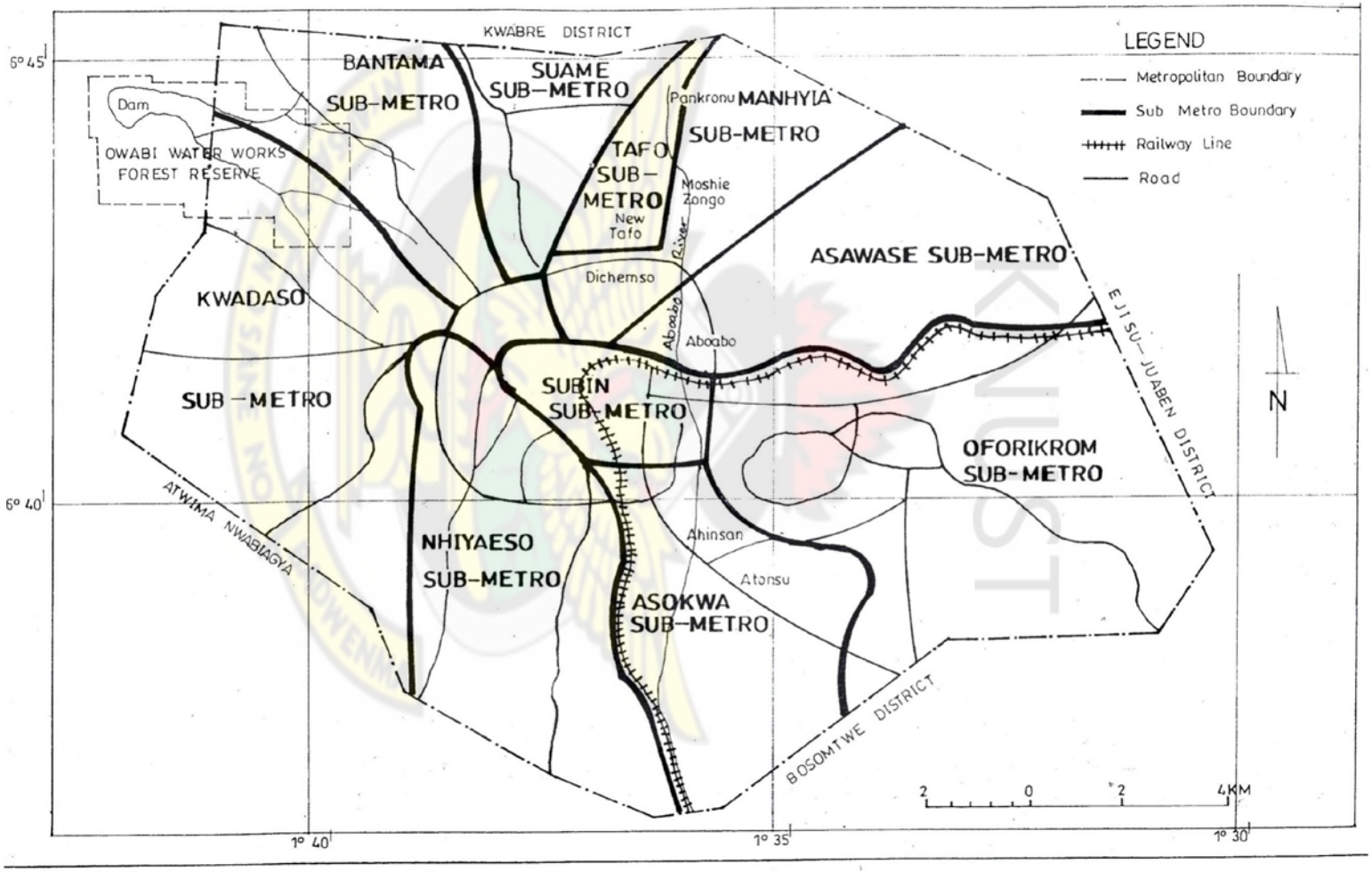
3.4 Vegetation

The Kumasi metropolis falls within the moist semi-deciduous forest zone of Ghana (Dickson and Benneh, 1988). Trees mostly found in Kumasi are Ceiba, Triplochlon and Celtis. In the wet season the vegetation is lush and the presence of rich soils coupled with adequate rainfall supports the growth of vegetables, plantain and tubers as cassava and cocoyam. The impact of human activity as indiscriminate tree felling for lumber is having a toll on the forest resources.

3.5 Geology and Soils

Kumasi has an undulating topography and it lies on a watershed approximately 282 meters high (Nsiah-Gyabah, 2000 cited in Suraj, 2004).The Middle Precambrian Rock is

MAP 3.2 KUMASI SUB-METROPOLITAN AREAS



Source: Department of Geography, KNUST 2009

the dominant geological formation in the Kumasi Metropolitan Area with the major soil type being Forest Ochrosol. The detailed soil associations include Kumasi-Offin compound Association; Bomso-Offin compound association; Nhyanao-Yinkong Association; Bomso-Suko Simple Association and Bekwai-Akumadan-Oda compound association. Soils in some peri-urban areas are developed on Granites or Phyllites. Those developed on Granites are acidic whilst those on the Phyllites are less acidic. Soil classes found in the Kumasi metropolis include Haplic Acrisols, Eutric Gleysols, Gleyic Arenosols and Gleyic Cambisols. The most common soil group is Ferric Acrisols (CEDAR, 1999 cited in Suraj, 2004). A number of industries as quarrying and sand winning have emerged due to the presence of the Precambrian rocks and good soils. However the uncontrolled activities of these contractors are contributing to the degradation of the environment (KMA, 2006).

3.6 Population

The 2000 population and housing census estimated the population of Kumasi to be 1,170,270 (GSS, 2005:26).

Table 3.1 Regional and National population estimates 1960-2009.

	1960	1970	1984	2000	*2006	*2009
Kumasi	218,172	346,336	487,504	1,170,270	1,625,180	1,915,179
Ashanti Region	1481698	2,090,100	2,984,161	3,612,950	3,899,227	4,050,762
Nation	6,726,320	9,632,000	12,296,081	18,912,079	22,225,625	24,094,135

Source: (KMA Medium Term Development Plan, 2006-2009)

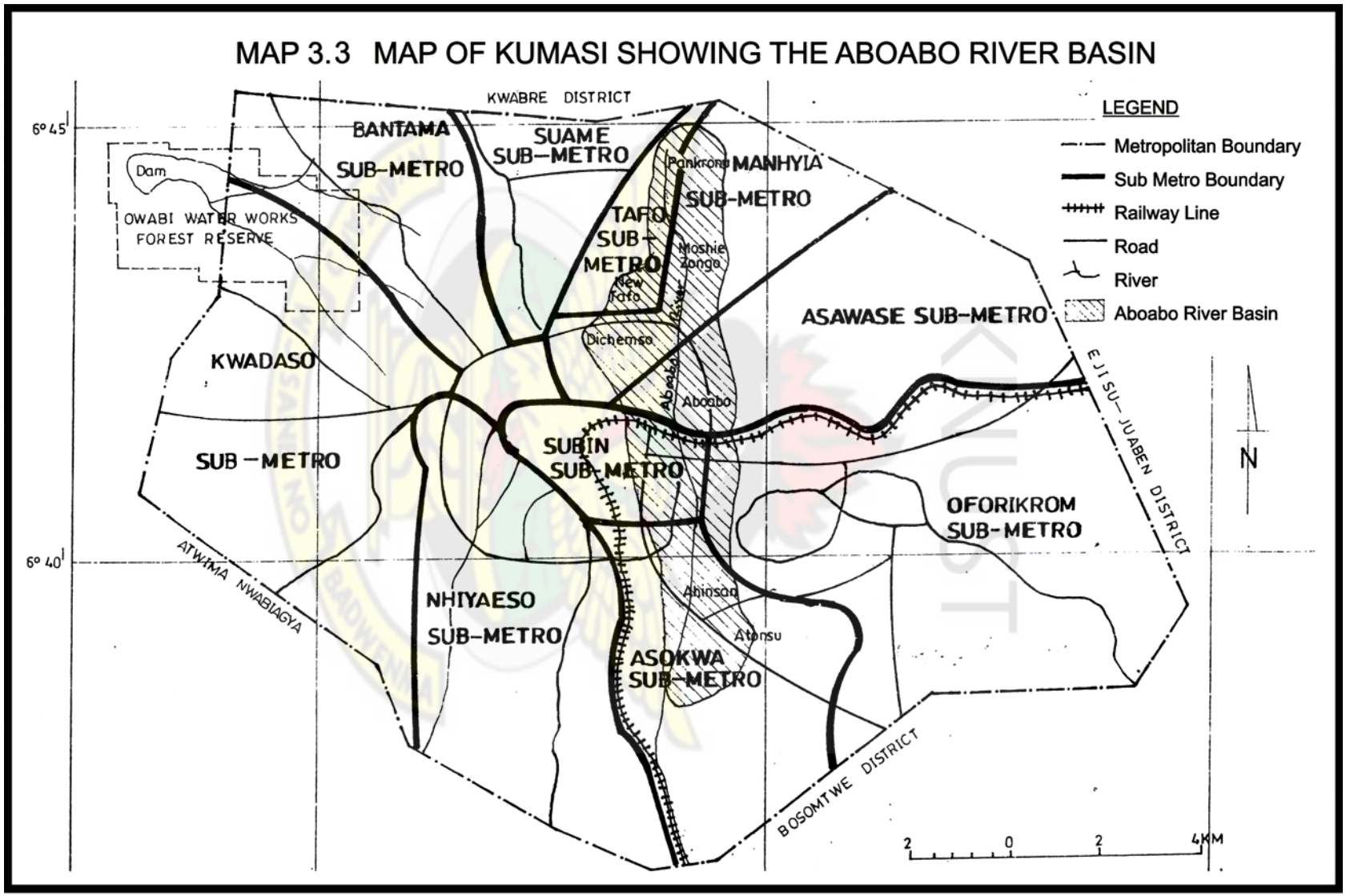
**Projected*

In 1970 and 1984, the population of Kumasi was 346,336 and 487,504 respectively (Table 3.1).

Population density of the Kumasi metropolis was recorded as 5,319 persons per sq km in the 2000 Ghana Population and housing census. This was second to that of Accra, the capital of Ghana, which recorded at 5,530 in 2000. The Ashanti region on the other hand recorded 148 persons per sq km (GSS, 2005). The Kumasi metropolis is densely populated partly due to the reason that it has the second largest urban economy in Ghana attracting trade and commerce in industry, services and government administrative functions (KMA, 2006). The total number of houses was estimated in the year 2000 to be 67,434 with a total number of 231, 653 households. The average household size was also recorded as 5.1 (GSS, 2005).

The Aboabo River Basin (Map. 3.3) has a very large percentage of the population of the metropolis. In 1984 and 2000 the population of the basin was 95189 and 251,510 respectively. By the year 2000, the population more than doubled, about 2.6 times that of the population in 1984. It is estimated that about 449,692 persons live in the basin making a quarter of the total population (23%) of the Kumasi metropolis (Table 3.2).

MAP 3.3 MAP OF KUMASI SHOWING THE ABOABO RIVER BASIN



SOURCE: Department of Geography, KNUST 2009

Table 3.2 Population of communities in the Aboabo River basin (1984-2009)

Section of river basin	Community	1984	2000	Rate	*2006	*2009
Upstream	Pankrono	5,670	36,683	0.1167	73,883	104,854
	Moshie Zongo	12,097	34,980	0.0664	52,089	63,564
	Buokrom	3,627	12,374	0.0767	19,605	24,678
Midstream	Dichemso	14,695	21,281	0.0231	24,451	26,209
	Aboabo	22,636	34,206	0.0258	39,934	43,148
Downstream	Asokwa	8,123	18,747	0.0523	25,653	30,008
	Atonsu	4,178	45,778	0.0149	112,341	175,987
	Total	**71,026**	**204,049**	**-**	***347,956**	***468,448**
	Kumasi Metropolis	**487,504**	**1,170,270**	**-**	***1,625,180**	***1,915,179**

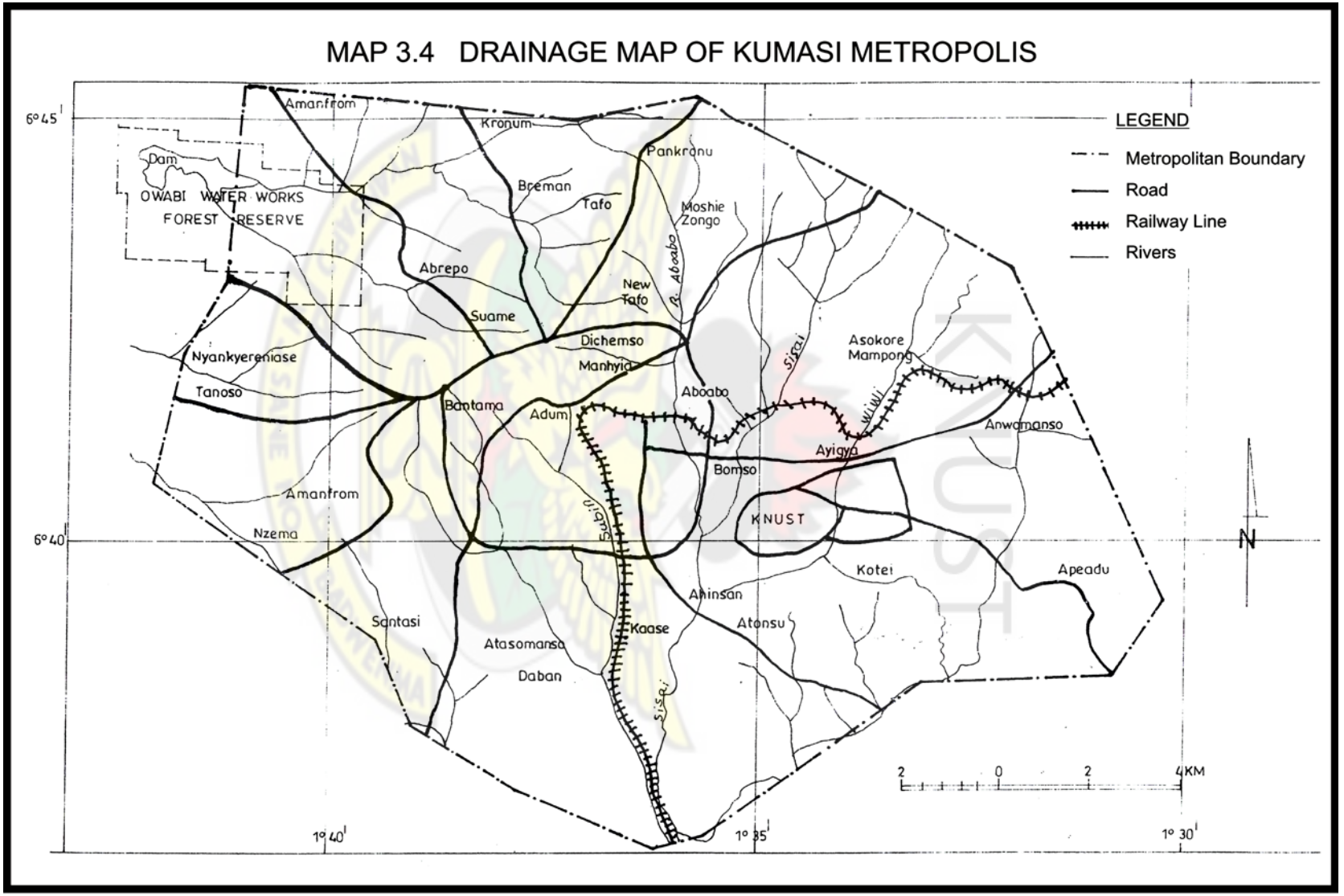
Source: KMA Medium Term Development Plan 2006-2009
**Projected*

Table 3.2 shows that from 1984 to 2000 the population of the basin increased from 71,026 to 204,049 indicating a 187 percent increase. The increase in the population over the years has necessitated the provision of social amenities such as schools, hospitals, roads, water, public toilets and better housing. The Metropolitan authority asserts that it is faced with financial constraints when it comes to the provision of sanitation facilities and it also find it difficult to meet the increasing demand due to rapid urbanization of the metropolis. As a result, about 25 to 30 percent of households lack access to safe water, electricity, bathrooms or toilets (KMA, 2006).

3.7 Rivers in the Kumasi Metropolis

Kumasi is drained by a number of rivers running north to south revealing a dendritic pattern as depicted in Map. 3.4. A number of rivers and their tributaries run through the metropolis but the major ones significant to the study include Subin, Sisa, Aboabo, Daban and Wiwi. These rivers converge into the Sisa and it joins the Oda at Asago, a village about 9km south of Kumasi (Cornish *et al.,* 1999). The Subin takes its source from the central part of the Kumasi metropolis and it flows through Asafo, to the Kaase industrial area and it joins the Daban at Sokoban. At various sections, the Subin measures speeds of 0.39m/s to 0.47m/s (Omane, 2002). The Sisa River takes its source from Kenyase in the Ejisu –Juaben district. It enters the city from Duase and Sepe Timpon and then takes as southward course through the industrial areas of Asokwa, Ahensan and Kaase. The Sisa River is the swiftest and measures speeds of 0.85m/s to 0.89m/s at various sites along its course (Omane, 2002). The Aboabo River originates from Tafo-Pankrono at the northern part of the Kumasi Metropolis. It flows through Moshie Zongo, Buokrom, to Aboabo Anloga and joins the Sisa at a confluence at Asokwa. At varied points, the Aboabo River yields and average of 0.87m/s. River Daban is located to the south west part of the Kumasi metropolis. It flows in a south easterly direction and it joins the Subin at a confluence at Sokoban a few meters from the Kaase industrial area. The Wiwi River has been deemed to be the least polluted river compared to the Subin, Sisa, Aboabo and Daban (Omane, 2002). It can be located to the South East part of the Kumasi metropolis. It flows in a south westerly direction through Kwame Nkrumah University of Science and Technology (KNUST) and joins the Sisa at Ahensan.

MAP 3.4 DRAINAGE MAP OF KUMASI METROPOLIS



SOURCE: Department of Geography, KNUST 2009

The rivers in the Kumasi metropolis have become receptacles for rubbish and human waste. At various sections of these rivers, the river channels are choked with filth and with the onset of heavy rains, some communities as Aboabo in the metropolis get flooded due to the presence of choked gutters and river channels.

Drainage in the Aboabo River basin can be described as being poor and the manner in which the drains have been constructed has implications for river pollution. First, drains in the river basin are open and they have been turned into receptacles for refuse. Secondly, there is no comprehensive drainage system and residents in the river basin use the open drains as a means of disposing grey water and in some cases human excreta. Field observations (September-October 2008) revealed that almost all drains end up emptying their contents into the river due to the absence of a comprehensive sewage network and a functional sewage treatment plant. Plate 3.0 shows an open drain that has its terminal point in the Aboabo River.

Plate 3.0 A drain empties water with refuse into the Aboabo river - Royal Bridge, Aboabo.

Source: Authors Field Investigation, September, 2009

Good drainage ensures that waste water is safely carried away from homes into the municipal drains (Hardoy *et al*., 2001). Unfortunately, the communities studied do not have a comprehensive drainage or sewer system. As a result poorly constructed drains and gullies have become receptacles for refuse and liquid waste from households. These drains have their terminals at varied sections of the Aboabo River and therefore the river has been turned into the system that takes away waste (liquid and solid) from the communities.

3.8 Settlements and Housing

The major settlements within the river basin are 8 namely Pankrono, Moshie Zongo, Buokrom, New Tafo, Dichemso, Aboabo, Asokwa and Atonsu. Some portions of settlements as Aboabo, Moshie Zongo in the basin exhibit nucleation whilst others are dispersed. Majority of the housing units located in places like Aboabo and Moshie Zongo are described as substandard (KMA, 2006). The average household size in the Kumasi metropolis is 5.1, average number of persons per house is 25.7, average occupancy rate is 2.7 whilst the average number of rooms per house is 9.8 (KMA, 2006:120). Also, a research by Whittington *et al*, (1992) revealed that 95 percent of households live in compound houses with some housing units being occupied by more than 100 people. The house holds in the river basin also exhibit similar characteristics. Households in the river basin have an average size of 7.8. Compound and Separate housing units can be identified in each of the communities in the river basin. Most residents in the river basin live in compound houses with high room occupancy rates and large numbers of households per house. In Aboabo some of the housing units have been built close to the

river and when it rains, these houses get flooded. A number of people in the river basin also sleep in kiosks and containers. Typical among these are the poor who cannot afford better housing and are under threat of eviction. At Aboabo, head porters popularly known as ‘kayayei’ make their homes in make shift structures that have no plumbing or sewage connection. As a result some of the households dump waste indiscriminately and others have turned not only the Aboabo River but most water courses and drains into sewers.

3.9 Health

There are government and private medical facilities located within the river basin that caters for the health needs of the residents. An estimated number of 49 medical facilities are located in the communities that lie in the river basin; 48 private health facilities and 1 government hospital (Tafo Government hospital) meets the health needs of residents in the river basin. The residents living within the basin are plagued with diseases such as diarrhea, cholera, typhoid but the most prevalent is malaria. The incidence of environmentally related diseases is high (GHS, 2009). This may be partly due to the low amount of sanitation facilities available, the choking of gutters and refuse which serve as receptacles for malaria vectors. In communities as Aboabo and Moshie Zongo, diseases like cholera, fever, diarrhea and malaria are common. Children are sometimes found playing on rubbish dumps and in polluted water ways increasing the risk of exposure to pathogens that cause diseases like hookworm, diarrhea, malaria and cholera.

3.10 Water and Sanitation

Water is essential in the lives of man as it an essential component used to maintaining good personal hygiene. Water is supplied to residents of the river basin by the Ghana Water Company Limited. The main sources of water supply to the Kumasi metropolis are the Owabi and Barekese headworks located about 10km and 16km respectively. A number of households have wells in their homes on which they rely in the event of a water shortage. A number of housing units store water in large concrete tanks in their homes and sell at a fee of 20 to 30 pesewas per bucket and in some cases, 50 pesewas per bucket. Few Low income households in the river basin are linked with piped water and therefore they buy water from vendors. Very few households in the basin have access to sanitation facilities as toilets. The toilet facilities provided in the community are not enough to meet the demand. This is evidenced in the queues that develop in the early mornings and evenings at Aboabo, Moshie Zongo and Asokwa. The sanitation characteristics of the river basin follow that of the Kumasi metropolis. The KMA asserts that the housing environments of places like Moshie Zongo, Aboabo and other parts of the metropolis are unsightly and characterized by poor drainage and sanitation.

Maintaining a good and clean sanitary environment is a concern to not only the KMA but the residents of the Aboabo River basin as sanitation has the potential of affecting human health and productivity. Residents who used public toilets pay fees between 2 pesewas and 5 pesewas. Omane (2002) explains that the reason why Kumasi and Aboabo River basin have not had elaborate sewage systems could be attributed to high costs or non-committal national policies.

3.11 Solid and liquid waste management

The by-product of the distributive and consumptive activities that occur in the Aboabo River basin is the generation of waste. The KMA has a waste management department that is responsible for managing liquid and solid waste. The Aboabo River basin generates an estimated amount of 270 metric tons per day, approximately 40 percent of the total amount of waste generated by the Kumasi metropolis per day. At the rate of 0.5kg/person/day (Omane, 2002), Table 3.3 shows the estimated distribution of waste generated in the Aboabo River basin per day.

Table 3.3 Estimated amounts of waste generated in the Aboabo River Basin.

Communities	Estimated Waste Generation/Day (kg)	Percentage (%)
Pankrono	52,427	19.5
Moshie Zongo	31,782	11.8
Buokrom	12,339	4.6
New Tafo	34,743	12.9
Dichemso	13,104.5	4.9
Aboabo	21,574	8
Asokwa	15,004	5.6
Atonsu	87,993.5	32.7
Total	**268,967**	**100**

Source: Authors Field Survey, 2008.

The metropolitan authority has over sight responsibility over two types of waste collection. These are house-to-house solid waste collection and communal solid waste collection. A number of private waste management firms run house-to-house services at a

fee to residents who engage such services. It ranges from GHC1 to GHC3. About 33 percent of the population is covered under this scheme but services are sometimes reported by residents to be irregular. The communal waste collection system, metal containers called skips are positioned at KMA designated sites which are shared by a number of houses within that community. Waste management firms are contracted to remove the skips on a regular basis and transfer the refuse to a landfill site located at Dompoase a few kilometers away from Kumasi. The total quantity of waste carried by the waste disposal trucks is weighed and an amount of GHC 9 is paid per tone. Unfortunately, a number of housing units are being built close to the landfill site and this poses a health threat to the residents who live in the area (KMA, 2006). It is also estimated that Kumasi's households produce in total about 255,000 tones of solid wastes per year (700 tons per day). Kumasi central market produces 53,000 tones per year. Whilst the solid waste generated at the Kumasi central market is collected every day, the capacity of the Waste Management Department (WMD) is able to maximally address 110,000 tones of household waste per year representing 43 percent of total solid waste generated by households per year. The rest of the uncollected waste is 145,000 tones amounting to about 57 percent per year. Some of the uncollected wastes end up being burnt, buried or indiscriminately dumped into water courses. Others are left in the open and may be carried of in runoffs into nearby streams (Suraj, 2004).

The KMA is responsible for the management of waste in the river basin. In all eight major communities that lie in the basin, KMA runs house-to-house collection and communal collection systems. Where the KMA is not able to provide door-to-door services, skips are placed at KMA approved dumping sites where residents are expected

to dispose of their refuse. Due to the poor road network and unplanned nature of the housing units, the metropolitan authority finds it difficult to run house-to-house services in areas as Aboabo and Moshie Zongo. Some residents complain that the dumping sites are far of from their homes. As a result some residents dispose of refuse into water courses and in the open. Some also resort to burning the refuse which causes atmospheric pollution. There is no comprehensive sewage system in any of the communities that lies in the river basin. Households have the option of channeling waste water and sewage into drains, into the Aboabo River, onto streets, usage of septic tanks and usage of public toilets. The public toilets are poorly maintained and have become health threats in themselves. All liquid waste collected by cesspit services are taken to the Dompoase waste treatment facility where it is pretreated and discharged into the Oda River.

3.12 Economic activities.

Persons living in the river basin engage themselves in a number of economic activities to earn a living. These include urban agriculture, quarrying, manufacturing, construction, wholesale, retail trade, hotel and restaurant, transportation, storage, communication, real estate, public administration and education. Small scale and large scale industries are located within the Aboabo River basin providing employment to many. The small scale industries include palm kennel oil extraction at Atonsu and Moshie Zongo, wood processing industries at Anloga, Atonsu, Asokwa and Ahensan, charcoal producing businesses at Atonsu and Anloga and metal cooking pots production at Aboabo. In

addition, large scale industries like wood processing industries and soap manufacturing companies are located at Aboabo and Asokwa respectively.

CHAPTER FOUR

4.0 THE CAUSES AND HEALTH EFFECTS OF THE POLLUTION OF THE ABOABO RIVER

4.1 Introduction

This chapter presents the analysis of the data gathered through the use of observation, interviews, structured questionnaires and water quality tests of water sampled from the Aboabo River. Interpretations and discussions of the data are made on the causes and effects of the pollution of the Aboabo River as well as attempts made by the government and residents to control pollution of the Aboabo River.

4.2 Water quality test

The water in the Aboabo River was sampled and subjected to water quality tests. In order to ascertain the quality of water, it was subjected to physical, chemical and bacteriological tests.

4.2.1 Physical characteristics

In conducting the physical test, water sampled from the Aboabo River was tested for temperature, color, taste, turbidity, odor and electrical conductivity and the characteristics were compared to that of pure water. Table 4.0 shows the results of the tests in comparison to WHO Drinking water standards.

Table 4.0 Values of physical parameters for sampling stations on the Aboabo River.

Water Quality Parameter	*Sampling Site 1		*Sampling site 2		**WHO Drinking Water Standards
	December 2008	January 2009	December 2008	January 2009	
Temperature ^{0}C	27	27.0	27.2	27.3	-
Color (Hazens H)	Objectionable (Blackish)	Objectionable (Blackish)	Objection-able (Blackish)	Objection-able (Blackish)	No visible color. Acceptable to consumers.
Taste	Objectionable	Objectionable	Objection-able	Objection-able	Acceptable to consumers and no abnormal change
Turbidity	Objectionable	Objectionable	Objection-able	Objection-able	Acceptable to consumers and no abnormal change
Odor	Objectionable	Objectionable	Objection-able	Objection-able	Acceptable to consumers and no abnormal change
Electrical Conductivity	1060	1403	972	1205	2500µS/cm @ 20°C

Source: * Field investigation, 2008-2009; ** WHO, 2006b

- Represents no set guideline.

From the results shown in table 4.0, all standards on parameters were exceeded except Electrical conductivity. The WHO specifies a maximum limit of 2500 µS/cm @ 20°C but on the average a value of 1160 µS/cm was recorded showing that the electrical conductivity limit was not exceeded. On the other hand, color, taste, turbidity and odor standards were unacceptable to consumers. The color of the river at all sampled stations and downstream was black whilst upstream it was light brown showing a breach of WHO standards which specifies pure water to have no visible color. Furthermore taste, turbidity and odor were objectionable. In other words they were unacceptable to consumers and

fell short of WHO standards when compared to pure water which is odorless, tasteless and colorless.

4.2.2 Chemical characteristics

In the Chemical test, water sampled from the Aboabo River was tested for Hardness, Hydrogen ion concentration (pH), Dissolved Oxygen, Total Dissolved solids, Total Suspended Solids, Phosphate, Sulphate, Nitrate, Calcium and Magnesium.

Table 4.1 Values of chemical parameters for sampling stations on the Aboabo River.

Water Quality Parameter	*Sampling Site 1		*Sampling site 2		**WHO Drinking Water Standards
	December 2008	January 2009	December 2008	January 2009	
Hardness	112	76	120	72	-
pH	7.39	6.75	7.36	7.20	≥ 6.5 and ≤ 9.5
Dissolved Oxygen((mg/l)	0.5	0.4	0.4	0.5	-
Biochemical Oxygen Demand (BOD) (mg/l) #	280	720	320	300	-
Chemical Oxygen Demand (COD) (mg/l) #	520	2832	536	464	-
Total Dissolved Solids	530	709	468	606	1200 mg/l
Total Suspended Solids	209	2495	186	280	50 (EPA)
Phosphate (mg/l)	16.6	30.8	10.6	18.8	-
Sulfate SO_4 (mg/l)	10	25	40	72	250
Nitrate NO_3 (mg/l)	1.1	12.5	1.0	10.0	11
Calcium (mg/l)	9.6	12.83	11.2	8.02	-
Magnesium (mg/l)	21.4	10.70	22.4	12.64	-

Sources: * Field Survey 2008-2009; **WHO, 2006b, #EPA (2009).

- Represents no set guideline.

The pH of the Aboabo River at both sampling stations was found to be acceptable within the limits of WHO guidelines (≥ 6.5 and ≤ 9.5). The dissolved oxygen content of the water was low at all stations. Consequently, high BOD and COD levels were recorded

each exceeding the maximum threshold for BOD (50mg/l) and COD (250mg/l) respectively (Table 4.1) set by the EPA. The high values of BOD and COD at both sampling sites indicate that the water has a low potential to support aquatic life such as fish. Total dissolved solids at both stations did not exceed the WHO guidelines of 1200mg/l but the presence of high values indicates that the water is polluted. Total suspended solids averaged 1352 mg/l and 233mg/l at S1 and S2 respectively. Each site exceeded EPA guidelines which set the maximum limit for total suspended solids at 50 mg/l at all sampling sites giving an indication that the river is polluted. The chemical tests showed that three (3) out of twelve (12) parameters exceeded WHO and EPA guidelines and these were BOD, COD and Total Suspended Solids.

4.2.3 Bacteriological Test

Bacteriological tests are noted to disclose with ease and great reliability the immediate or recent causes of water pollution. With reference to bacteriological tests, the faecal coliform count of the water being carried by the river was investigated because faecal coliform count gives an indication of pollution being caused by human waste (Rangwala, *et al.*, 2007).

Table 4.2 Faecal coliform count compared to WHO drinking water standards.

Water Quality Parameter	*Sampling Site 1		*Sampling site 2		**WHO Drinking Water Standards
	December 2008	January 2009	December 2008	January 2009	
Faecal Coliform N/100ml	325×10^4	435×10^4	312×10^4	410×10^4	0

Sources: *Authors field Survey 2008-2009; ** WHO, 2006b.

Faecal coliform count for the sampling sites exceeded the maximum limit of 0 per 100ml as given by the WHO. On the average faecal coliform counts were above 300×10^4 for each sampling site giving indication of pollution through human excreta. The sources of such excreta included the recurrent emptying of bucket latrines into the river, indiscriminate open defecation along the river as well as the channeling of raw sewage into the river.

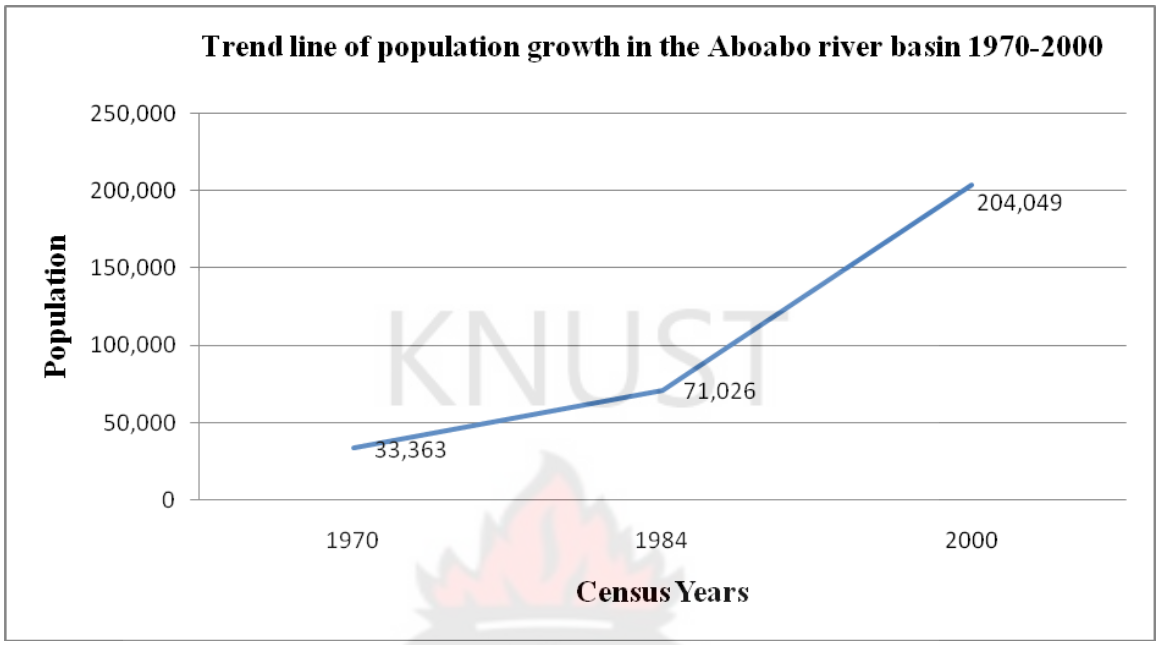
4.3 Causes of the Pollution of the Aboabo River.

The physical, chemical and bacteriological tests proved that the Aboabo River is polluted and the causes of the pollution were investigated through the use of interviews, observation and administration of structured questionnaires to persons living in the Aboabo River basin. The study established that the causes of the pollution of the Aboabo River are rapid population growth, institutional failures, industrial activity and natural causes.

4.3.1 Rapid population growth

Most developing countries have failed to ensure that rapid urban growth is accompanied by investments into services. Population increases have numerous implications for environmental sanitation, provision of social amenities and the capacity of city authorities to deal with the wastes generated (Hardoy *et al*, 1990). Population in the Aboabo River basin has increased rapidly over the 30 year period (1970-2000).

Fig 4.1 Trend line of population growth within the Aboabo River basin 1970-2000



Sources: Ghana Statistical Services, 1987; KMA, 2006.

Fig 4.1 shows that from 1970 to 1984, the population of the river basin increased from 33,363 to 71,026 indicating a 113 percent increase. From 1984 to 2000 the population of the basin increased from 71,026 to 204,049 indicating a 187 percent increase. Thus from 1970 to 2000, the river basin has had a 512 percent increase in its population. The increase in population in the river basin means an increase in generation of liquid and solid waste and therefore an increase in demand for adequate sanitation infrastructure. The increase in demand for sanitation infrastructure resulting from increased population growth has not been ably matched due to financial constraints faced by the municipal authority. The most essential of sanitation infrastructure is a comprehensive sewage system that would carry human excreta as well as effluents from domestic activities like washing, bathing and cooking. Unfortunately this system is not present and the Aboabo

River has been used as an alternative by, 23 (6%) respondents to channel human excreta whilst 39 (10%) and 36 (9%) dispose bathwater and domestic wastewater respectively directly into the river.

The head of research at the Waste Management Department (KMA), in a personal interview, mentioned that the reason for dumping waste into the river is that the KMA faces difficulty in raising adequate funds to provide proper and efficient waste management infrastructure for residents of the Aboabo River basin. Secondly, due to the rapid population growth, there has been an increase in the demand for housing and the consequent springing up of illegal housing units in the river basin. Evidence gathered from the field observation showed that residents who did not have proper means of disposing refuse, human excreta, bath water and domestic waste water used the river as an alternative as shown in Table 4.3

Table 4.3 Usage of the Aboabo River as a primary means of waste disposal.

Types of waste disposed	Number of respondents	Percentage of total number of respondents
Channeling of human excreta.	23	6
Disposal of bath water	39	10
Disposal of domestic waste water	36	9
Disposal of refuse	173	44
Total	**271**	**68**

Source: Author's field survey, 2009

From Table 4.3 it is observed that a total of 23 (6%) respondents mentioned that they channeled human excreta directly into the river whilst 39 (10%) and 36 (9%) dispose bathwater and domestic wastewater respectively directly into the river. Furthermore 173 (44%) regularly disposed off refuse into the river or along its banks. The method often applied was the collection of refuse in black polythene bags and throwing them into the river early in the morning and at night. Reasons cited by the residents include inadequacy of sanitation infrastructure, long distance taken to reach dumping sites and inability to afford the use of sanitation facilities such as public toilets.

4.3.2 Institutional Failures

Institutions and policy frameworks are essential in the coordination of efforts towards pollution control in general and river pollution in particular. Where the institutions do not carry out their mandate efficiently, it leads to disruptions, burdening of other institutions and environmental degradation. With reference to the Aboabo River, the institutions responsible for the control of river pollution have failed to provide adequate infrastructure, enforce bye-laws on housing and sanitation, regulate and monitor housing, adequately monitor river water quality, educate residents and liaise with interrelated institutions.

4.3.2.1 Failure to provide adequate infrastructure

In the less developed countries of South America, Africa, and Asia, it is estimated that 95 percent of all sewage is discharged into rivers, lakes or the ocean. The reasons being low technological capabilities, inadequate funds for pollution control, burgeoning

populations, rapid urbanization and industrialization (Cunningham and Saigo, 1999). This assertion holds true to a large extent in the Aboabo-river basin as the basin is without a key sanitation infrastructure such as a comprehensive sewage system. The KMA is mandated to manage solid and liquid waste in the Aboabo River basin. Due to the inadequacy of these infrastructure and sanitation services, untreated waste end up being burnt, buried, dumped into gutters, left in the open and sometimes carried off into the Aboabo River by runoff and so polluting it.

Residents were asked about sanitation facilities in their houses and 325 (82%) had toilet facilities in their houses whilst 62 (16%) did not have. Of the 82% who had toilets in their houses, 314 (97%) and 11(3%) indicated that their toilets were water closets that were connected to septic tanks and bucket latrines respectively. A total of 9 (2%) respondents had no answer for the sanitation facilities in their houses. There were a large number of septic tank users due to the fact that there was no comprehensive sewerage system in the river basin as shown in table 4.4

Table 4.4 Most frequent type of toilet facility used by household respondents.

Type of toilet facility	Total Number	Percentage
Water closets connected to septic tanks	316	80
Public toilets	67	16
Bucket latrines	7	2
Open defecation	6	2
Total	**396**	**100**

Source: Authors field survey, 2009.

Table 4.4 shows that 316 (80%) used water closets connected to septic tanks, 67 (16%) used public toilets, 7 (1.8%) used bucket latrines which were emptied into the Aboabo River very early every morning whilst 6 (1.5%) respondents indicated that they practiced open defecation in or along the banks of the river.

The low response to the question about open defecation was due to the fact that respondents were reluctant to mention that they openly defecated. However observation in the river basin revealed that residents practiced open defecation and it was most often done at dawn and night.

Plate 4.1 Open defecation being practiced in the river basin

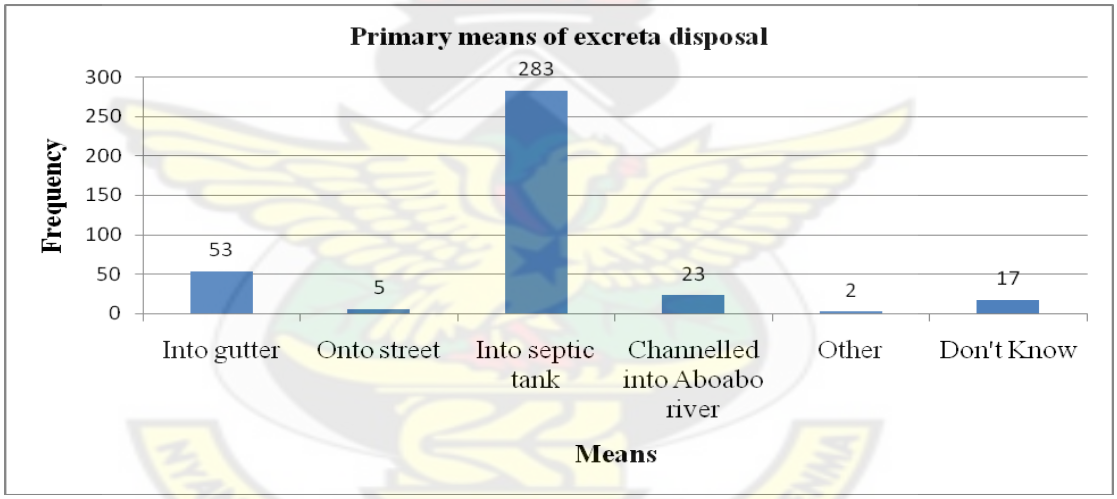
A. **B.**

Source: Author's field observation, 2009.

Plate 4.1A shows two persons practicing open defecation on the bank of the river and Plate 4.1B shows a young boy openly defecating into an uncovered drain that empties liquid waste into the Aboabo River.

It is worth noting that household respondents had various reasons for choosing between the use of public toilets, household toilets and open defecation. Observations revealed that the public toilets were not well maintained and they had become health hazards. Secondly, long queues had to be joined in the mornings and evenings for the use of toilets and thirdly, residents did not appreciate the need to pay for the removal of waste from their human system. Open defecation and the daily emptying of bucket latrines into the river leads to the pollution of the river and this is a contributory factor to the high faecal coliform counts that were recorded in the water analysis (See Table 4.2).

Fig. 4.2 Primary means of excreta disposal.



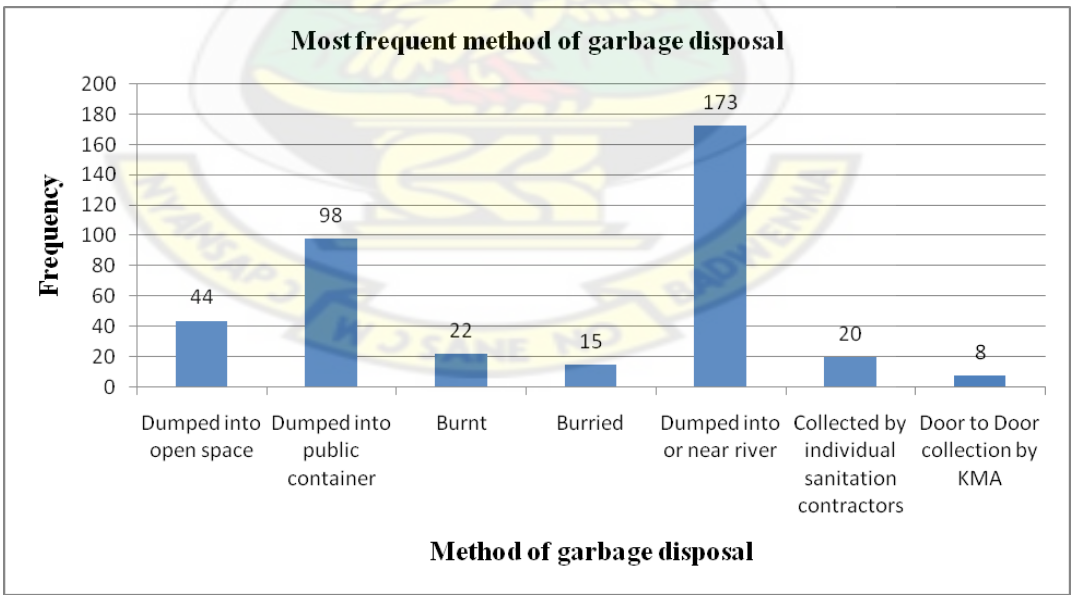
Source: Authors field survey, 2009.

From figure 4.2, 283 (72%) households primarily disposed of human excreta using septic tanks. In addition, 53 (13.4%) dispose of human excreta into gutters which lead into the Aboabo River. Also, 23 (6%) disposed of excreta by means of channeling it directly into the Aboabo River by means of PVC pipes.

4.3.2.1.1 Reasons for indiscriminate disposal of garbage

A total of 173 (44%) residents indicated that though the KMA had designated dumping sites located in the communities in the basin, they were far from their houses and to save time and the arduous task of carrying refuse over a long distance, they resort to packaging refuse in polythene bags and disposing them into the river. Another alternative was the engagement of the services of individual sanitation contractors who send the refuse to the collection sites or dispose them indiscriminately. Furthermore the perception was held that the river will carry the refuse away when it rained hence their dumping of refuse into the river. In addition, respondents who had low incomes found it difficult to pay the 10 pesewas that was collected at the dump sites. They did not understand why 'waste' that must be disposed of must be paid for.

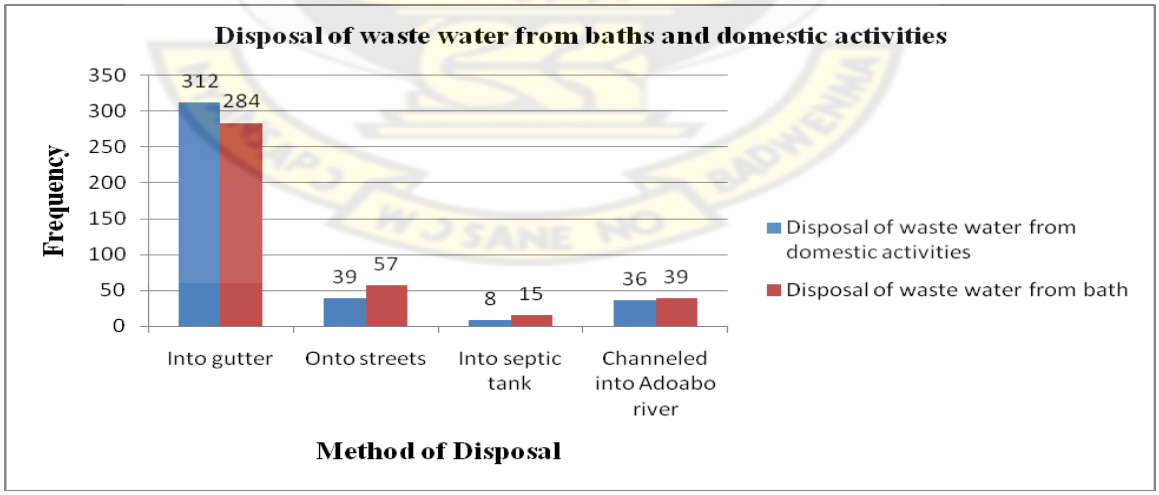
Fig. 4.3 Most frequent method of garbage disposal.



Source: Author's field survey, 2009

Fig.4.3 shows that 254 households representing 64 percent of households interviewed, disposed their refuse in environmentally unfriendly ways that included uncontrolled burning, burying, dumping into open space and dumping into or near the Aboabo River. Dumping of refuse into or near the Aboabo River pollutes it because dumping into the river increases the amount of total suspended solids, reduces the amount of oxygen and increases the BOD of the river when organic matter in refuse decompose. Refuse that is dumped along the banks are most frequently washed into the river when it rains and in addition, water from the refuse dumps leaches into the river as well as the ground they cover. The absence of a comprehensive sewage system in the river basin has negative implications for how wastewater from domestic activities and from baths are disposed.. With reference to disposal of waste water from baths, 284 households (71%) used gutters, 57 (14.4%) disposed unto streets, 15 (4%) used septic tanks and 39 (10%) channeled directly into the Aboabo River as shown in Fig. 4.4.

Fig 4.4 Disposal of waste water from baths and domestic activities.



Source: Author's field survey, 2009

With reference to disposal of waste water from domestic activities, a similar trend emerged. Three hundred and twelve (312) households (79%) used gutters, 39 (9.8%) disposed unto streets, 8 (2%) used septic tanks and 36 (9%) channeled directly into the Aboabo River. It therefore shows that gutters served as the major means of disposal of waste water because over 70 % of the households surveyed in the river basin used it as a primary means of disposing waste water from their baths and domestic activities. Field observation and interviews revealed that the gutters used by households to dispose waste water have their terminal points in the river and therefore when waste water is disposed into gutters they flow directly into the Aboabo River. Wastewater from the identified sources is a major source of nutrients, bacteria, viruses, parasites, organic matter and chemical contaminants. The decomposition of the organic matter contributes to the increase in the BOD, COD and a reduction in the Dissolved Oxygen content of the river leading to unpleasant odors and giving the river a dark color (Shaw, 1994). The presence of Phosphorus and Nitrates stimulates the growth of bacteria and fungi and due to the large volume of waste water generated each day in the river basin the river loses its ability to recharge itself as it flows through its basin

The inability of the KMA waste management department to adequately manage waste has been attributed to financial constraints by a resource person at the Waste Management Department. In a personal interview, The Head of research at the Waste Management Department, KMA, also mentioned that the KMA faces financial constraints in its bid to manage waste in the Kumasi metropolis. Money is needed for the purchasing of waste management equipment such as collection trucks, refuse containers and increasing the provision of approved dumping sites in each community in the river basin. However

financial constraints do not permit the assembly to do so. In response to this challenge, the KMA has enlisted private contractors to manage waste with the oversight supervision from the KMA. Unfortunately these private contractors do not regularly meet their schedules and this results in the overspill of refuse at refuse dump sites. Due to institutional failure largely brought about by financial constraints, the KMA has not been able to provide comprehensive sewage systems in all the communities through which the Aboabo River flows. Thus over 70 percent of households studied had channeled their liquid waste using inappropriate means to dispose of waste water from their baths and domestic activities into the river. In Moshie Zongo for instance there is no comprehensive drainage or sewage network and the residents have turned the streets and gulleys into dumping grounds for their liquid waste and refuse as shown in Plate 4.2

Plate 4.2 Gutters used as an entry point for bath water and receptacle for refuse.

Source: Authors field survey, 2009

4.3.2.2 Failure to enforce KMA bye laws.

The KMA has been given powers to enact and enforce bye-laws by section 79 of the Local Government Act, 1993 (Act 462). The Kumasi Metropolitan Assembly (Sanitation) bye-laws, 1995 states in sections 3 and 6 respectively that

3. 'No person shall cause a nuisance in any public or open space'

6. No person shall deposit litter, refuse or other matter which may cause nuisance or block the passage provided for a gutter or drain.

Also, KMA 'Cleansing' bye-laws mentions in article 4 that any person who throws litter, refuse or other matter which may cause nuisance or block the water passage provided by a gutter or drain shall be guilty of an offence.

Evidence gathered through observation and interviews in the river basin showed that not only are the KMA bye laws flouted, they are also poorly enforced by the assembly. According to KMA prosecutors at the Ashanti Newtown Circuit Court Kumasi, in a year, about an average of just 50 cases of flouting of KMA bye-laws on sanitation are reported. Unfortunately though sanitary inspectors go on regular inspections, they are few in number and cannot cover every place in the river basin. Also when arrests are made, some residents resort to payment of bribes and the calling of 'big men' to intervene on their behalf leading to out of court settlements. Furthermore the punishments for breaking the law are weak. One pays GHC 5 or suffers a term of imprisonment not exceeding three months. In addition, the bye-laws have not been reviewed since 1995 when the laws were promulgated. Thus due to poor enforcement of the bye laws and weakness of

punishments, 70 % of residents take advantage and indiscriminately dump untreated liquid waste whilst 64% also disposed solid waste in environmentally unfriendly ways and nothing is done to persons who engage in these practices (Fig.4.3, Fig.4.4).

4.3.2.3 Failure to regulate and monitor housing

The Town and Country Planning Department and the KMA have also failed to adequately regulate the siting of housing units in the river basin. Housing units (Kiosks, Containers, make shift structures and cement block houses) have been sited in places that have been demarcated by the Town and Country Planning Department as a flood plain. Reconnaissance surveys at Aboabo (September – November, 2008) revealed that some of these housing units are flooded and submerged when ever it rains and most often these housing units have no form of drainage or sanitation facilities. Residents of the housing units use the river as a public place of convenience due to the absence of toilet facilities in their houses, the proximity of their houses to the river, and the relatively long distance they might have to cover in order to access a public toilet.

The average household size in the basin is 7.8 whilst the average number of households living in a house is 7.5 which is higher than that of the entire Kumasi metropolis which is 3.4 households per house. This has serious implications for usage of sanitation facilities, waste generation and disposal at the household level. Field investigations revealed that in about 88 (22.2%) houses, over 10 households had to share one toilet and bath and this did not augur well for good health and sanitation at the household level. Investigations revealed that the KMA does not regularly monitor the sanitation infrastructure in houses in the river basin. Therefore some land lords, after receiving their building permits,

converted their toilets and bathhouses into rooms and rented them out and this is in contravention of building regulations and KMA bye-laws on housing. In addition, there have been little attempts made by the government to provide low income housing to low income groups who live in places like Aboabo and Moshie Zongo. Therefore the absence of a regular monitoring scheme affords people to live in houses that do not have toilets. Residents are therefore forced to use public toilets, practice open defecation along the banks of the river or dump human excreta into the river which leads to its pollution.

4.3.2.4 Failure to regularly monitor river water quality

Monitoring of the quality of the water carried by the Aboabo River is in the domain of the EPA. The EPA is mandated to ensure the protection of the Environment. The EPA could carry out regular monitoring of the water quality of the Aboabo River and relay such information to the KMA for appropriate mitigation measures to be taken in the event that water quality levels are at perilously low levels. An environmental officer at the EPA indicates that it is the desire of the institution to carry out regular monitoring of the Aboabo River but this is not done regularly due to financial constraints. The financial cost of conducting water quality studies does not afford regular monitoring. It is the EPA's responsibility to monitor industries that operate along the river and to ensure that the ways in which they dispose of their waste does not degrade the environment and the Aboabo River in particular. Unfortunately, due to this constraint, industrial activities such as leather tanning, washing bays, palm kennel processing and wood processing industrial activities continue to be carried out along the banks and the owners of these industries use the river as a means of disposing the waste from their industrial processes.

4.3.2.5 Failure to educate residents

The primary role of education is to make the residents aware of the negative implications that their behaviors or activities could have on the river and how such effects could affect them in the long run. Inadequate education is carried out by the NCCE, ISD, EPA and KMA. Consequently, 356 (90%) residents who were interviewed were not aware of any bye-laws on environmental sanitation or river pollution nor had they heard or witnessed any educational campaigns by the EPA, NCCE, KMA or ISD. Personal in-depth interviews of opinion leaders revealed that the EPA, NCCE, KMA, and ISD had done little to impress on members of their community to desist from activities that lead to the pollution of the river. In addition, due to the fact that members of their households practiced open defecation and disposed of refuse along the banks of the river they also found it difficult to advise others in the community to desist from such practices. In some cases, wives and children of the opinion leaders engaged themselves in open defecation along the banks and they found it difficult to ask members of the community to desist from the practice. The opinion leaders expressed the concern that upon attempting to encourage members of the community to desist from practices that degrade the environment and the Aboabo River in particular he was greeted with insults and indifference. This therefore means that residents of the river basin have not been conscientised about the need to desist from practices that degrade that environment and the Aboabo River in particular and this is aggravated by the inadequacy of sanitation infrastructure and increasing population.

4.3.2.6 Failure to liaise with allied institutions

The major institutions responsible for the monitoring and for the protection of water bodies in general in the Kumasi metropolis are the KMA and the EPA. A number of institutions also contribute to the protection of water bodies and these are the National Commission for Civic Education (NCCE), the Water Resources Commission, The Ministry of Water Resources, Works and Housing and the Information Services Department (ISD). These institutions must collaborate in a manner that will protect the Aboabo River from pollution. Unfortunately, the building of houses in the flood plain of the river basin, the building of housing units in water ways, the dumping of refuse and human excreta is an indication that the institutions responsible for ensuring minimum pollution of the Aboabo River are not collaborating well enough to control pollution of the river. The Ministry of Water Resources, Works and Housing in collaboration with the National Commission for Civic Education and the Information Services Department are to carry out regular education campaigns on the need to abstain from dumping refuse or pouring human excreta into the water courses but this is not done. The NCCE, ISD and MWRWH are to play complementary roles in supporting the efforts of the KMA and EPA. Respondents were aware that pollution of the river was not a right thing to do and it had some implications for users downstream. However, pollution of the river continued due to minimal education about the consequences of polluting the Aboabo River coupled with the poor implementation of the sanitation and housing bye-laws.

4.3.3. Industrial Activity

Industrial activities along the banks of the river contribute to the pollution of the Aboabo River by introducing varied amounts of suspended solids, particulate matter and chemicals such as lead, mercury, nitrates, sulphates and phosphates. A number of small scale industries are sited close to the Aboabo River. Entrepreneurs running such businesses use the river as a source of water and a dumping ground for the waste generated. Examples of such industry are the leather tanning industry at Aboabo, Palm Oil processing industry at New Tafo (Upstream) and Ahensan (Downstream). At New Tafo washing bays have been sited close to the river. These washing bays do not have paved or cemented compounds. In addition, due to the fact that most drains have their terminal points in the river, waste water from the washing of vehicles and the unpaved floor get washed directly into the river. Also, the wood industry at Anloga is a huge threat to the quality of water of the Aboabo River (Plate 4.3).

Plate 4.3 Wood processing and charcoal production on the banks of the Aboabo River

Source: Author's field survey, 2009

Midstream at Anloga, the wood entrepreneurs use the banks of the river as a dumping ground for saw dust and wood waste. Portions of the saw dust get carried by the river and this contributes to the total suspended solids in the river water. A charcoal producing industry has also emerged behind that Anloga wood processing centre. These charcoal producers take advantage of the wood waste products and process them into charcoal. Unfortunately, this industry is sited just at the edge of the river. When it rains, runoff washes sawdust, charcoal and soot into the river causing pollution.

4.3.4 Natural Causes.

The Aboabo River runs through the city of Kumasi in a north-south direction. As it flows through various communities in the river basin, a cocktail of pollutants are washed into the river through natural factors as well. A major natural source of pollutants is runoff which carries debris, sand, silt and nutrients into the river that that affects color and turbidity. Field Observation revealed showed that when it rains, elements such as silt and sand carried by runoff increases because the communities within which the river flows have little paved or tarred roads. Secondly rain water erodes parts of drains that have not been cemented carrying along some amount of soil and organic matter. Heavy precipitation also causes bottom sediments to be suspended and this increases turbidity.

4.4 Effects of the pollution of the Aboabo River.

Field observation, interviews and investigations revealed the effect of a reduction in the quality of the river and therefore a reduction in the uses to which the river can be put.

Secondly the pollution of the river has the effect of causing water-borne diseases to people who frequently come into contact with the river water, most of whom are children who frequently play in the river.

4.4.1. Reduction in the quality of water

Water quality refers to the suitability of water to sustain various uses or processes (UNEP, 1996:15). Due to the fact that various uses or processes require some physical, chemical or bacteriological characteristics, the presence of color, bad odor, particulate matter, high BOD and COD levels, low amounts of dissolved oxygen, high counts of faecal coliform reduces the uses to which residents of the river basin would want to put the Aboabo River. Interviews revealed that residents in the river basin wanted to use the river for washing, cooking, drinking and bathing but they perceived that the river was polluted due to its black color and evidence of open defecation and the dumping of refuse into the river and therefore this prevents them from using the river as such. A total of 64 percent argued that the river could have served as an alternative to water supply provided by private water vendors. The reason being that they had large household sizes and paid high amounts of money between 20 pesewas and 50 pesewas for a bucket of water translating into a financial burden on their households. A comparison of physical, chemical and bacteriological parameters with that of the WHO drinking water guidelines reveals that the water in the Aboabo River cannot be used for drinking purposes (Table 4.2). The WHO drinking water guidelines define a quality of water that can be safely consumed by humans throughout their lifetime and water sampled from the Aboabo falls short of this criteria as shown in table 4.5.

Table 4.5 Classification of raw waters according to bacterial numbers (as proposed in the WHO European standards)

Classification	Total Coliform bacteria per 100ml	Faecal Coliform bacteria per 100ml
1. Bacterial quality applicable to disinfection treatment only	0-50	0-20
2. Bacterial Quality requiring conventional methods of treatment (Coagulation, filtration, disinfection)	50-5,000	20-2,000
3. Heavy pollution requiring extensive types of treatment	5,000-50,000	2,000-20,000
4. Very heavy pollution, unacceptable unless special treatments designed if such water are used. Source to be used only when unavoidable	Greater than 50,000	Greater than 20,000

Source: *Twort et al. (1985) Water Supply. 3rd ed. Edward Arnold, London.*

The results of water sampled from the Aboabo River revealed high values of faecal contamination ranging between 312×10^4 per 100ml and 435×10^4 per 100ml. These values are far above '0 per 100ml' approved by the WHO guidelines of drinking water quality. In addition, when the average faecal coliform value of the Aboabo River water (370×10^4) is compared with the WHO's European classification of raw waters according to bacterial numbers (Table 4.5), it becomes evident that the Aboabo River falls in the category of being very heavily polluted because the value recorded is higher than 20,000 per 100ml. The Aboabo River water is therefore unacceptable to be used for any domestic purpose as drinking and cooking due to the excessive amounts of faecal coliform which also exceeds the '0' limit set by the WHO (WHO, 2006b).

4.4.2. Health effects of the pollution of the Aboabo River.

The pollution of the Aboabo River yields a negative health effect on the residents of the Aboabo River basin. The most vulnerable are children who frequently play in the polluted Aboabo River. A total of 322 (81%) respondents indicated that children in their household played in the river frequently. Out this number, 151 (47%), 130 (40%) and 41 (13%) indicated that children played in the river Very often, Often and Less often respectively. The high amounts of faecal coliform indicated pollution from human faeces. According to Adekunle *et al*, (2007), 'coliform populations give an indication of the presence of pathogenic organisms usually present in the faeces of humans and animals'. Human waste in water causes water borne diseases such as diarrhoea, typhoid and hepatitis. There was therefore an indication that children who frequently played in the river were at risk of contracting 'faecal-oral diseases' such as cholera, typhoid, diarrhea, skin and eye infections. In addition, residents living in the river basin are at risk of contracting water-habitat vector diseases, particularly malaria. This is because solid waste comprising of tins, cans, bowls, buckets and plastic bags and other forms of receptacles are dumped into the river by some residents and these materials collect water and block the flow of the river to form pools of water and so serve as breeding grounds for mosquitoes.

When asked about the incidence of disease in their households, 356 (90%) heads of households mentioned that children in their households had suffered at least one of such diseases as malaria, diarrhoea, cholera, dysentery, eye infections and skin diseases three months before the survey whilst 16 (4%) children of heads of households said their

children had not suffered any of such diseases three months before the survey. A total of 24 (6%) of the respondents, on the other hand, declined to give a response.

Effects on the health are manifested in the incidence of water related diseases such as diarrhoea, cholera, typhoid, skin infection and eye infection amongst children in the river basin. Field observations and interviews revealed that children aged between 4 and 12 years frequently played in the river. Such play often involved swimming and walking in the river indicating the risk of infection through body contact or water ingestion during swimming.

Table 4.6 The distribution of children who frequently played in the river

Frequency of playing in river per week.	**Total number**	**Percentage (%)**
Very Often (5 times or more)	151	40
Often (3-4 times)	130	34
Less often (1-2 times)	41	10
Do not play in river	62	16
Total	**384**	**100**

Source: Author's field survey, 2009

Table 4.4 shows the distribution of children who frequently played in the river. A total of 322 (84%) children played frequently in Aboabo River whilst 62 (16%) did not play in the river in the three months preceding the study. A total of 151 (40%) played in the river 5 times or more and another 130 (34%) played 3-4 times a week. On the other hand, 41 (10%) played once or twice in a week.

On the other hand, the frequency of attending medical facility for treatment of water related diseases was also investigated as shown in Table 4.7.

Table 4.7 Frequency of attending medical facilities for treatment of water related diseases.

Attendance at medical facility for treatment of water related diseases	**Frequency**	**Percentage**
Three times and above in three months	115	36
Twice in three months	70	22
Once in three months	107	33
No visits in three months	30	9
Total	**322**	**100**

Source: Author's field survey, 2009

It was revealed that 115 (36%) of respondents' children had attended a medical facility at least three times or more in the three months preceding the study. Also, 70 (22%) and 107 (33%) had been to a medical facility twice and once respectively in the three months preceding the study. Therefore in order to know the exact number of children who had played frequently in the river water and frequently attended medical facilities for the treatment of water related diseases, a crosstabulation was carried out as shown in table 4.8.

Table 4.8. Crosstabulation of frequency of playing in river and attendance at medical facilities for water related diseases.

Frequency of playing in river water. (Average number of times per week)	**Attendance at medical facility for water related diseases**				Total
	No visits in three months	Once in three months	Twice in three months	3 times and Above in three months	
Less often (1-2)	13	63	17	10	**103**
Often (3-4)	13	25	40	19	**97**
Very often (≥5)	4	19	13	86	**122**
Total	**30**	**107**	**70**	**115**	**322**

Source: Author's field survey, 2009.

From the crosstabulation shown in table 4.8, it is evident that 63 children who played less often in the river had attended a medical facility once for the treatment of water related disease whilst 10 children who less often played in the river has attended a medical facility at least three times in the three months before the survey. On the other hand, 19 children who had frequently played in the river had attended a medical facility once for the treatment of water related disease. However table 4.8 shows that a total of 86 (26%) children who played very frequently (5 times or more) in the Aboabo River had attended a medical facility three times or more in the three months preceding the survey. In other words, 26% of children who had the greatest frequency of contact with the polluted river water also had the greatest frequency of attendance at medical facility for treatment of water related diseases.

To further explore the relationship between frequency of contact with the polluted river water and occurrence of water borne disease, the hypothesis was formulated and tested

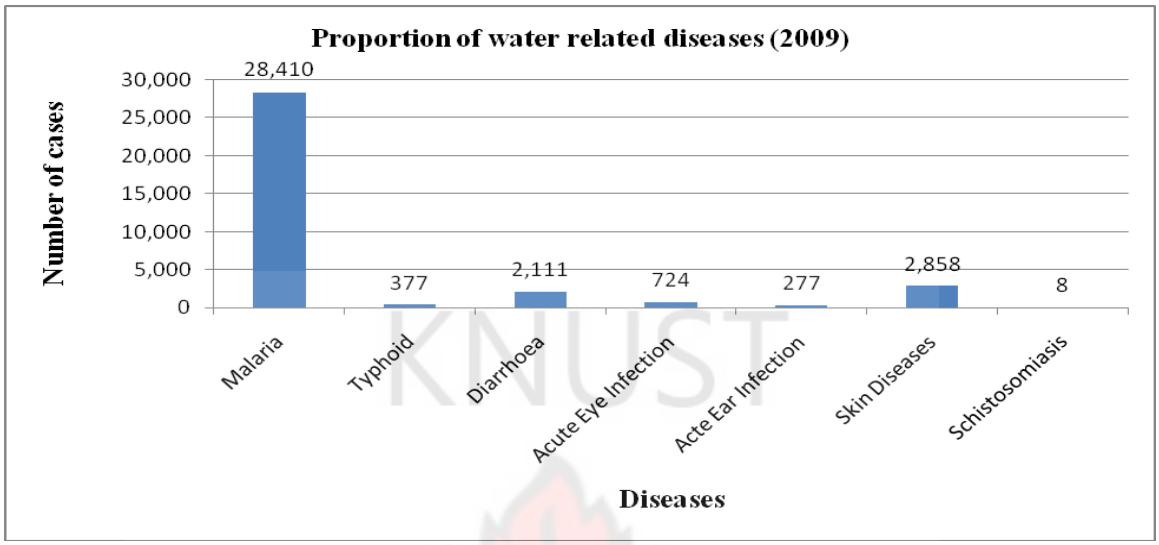
using correlation. Correlation shows that that frequency of play in the river and incidence of water borne disease in children were significantly positively correlated (0.516) and the correlation was significant at the 0.01 level (2-tailed).

The model indicated that though there was a positive relationship between playing in the river and occurrence of water borne disease, about 26% percent of the data could be adequately explained whilst 74% is left to chance. It therefore means that though playing in the river leads to water borne diseases amongst children, there are other factors that leads to the occurrence of the diseases and not playing in the river alone. Examples of such factors or variables include safe stool disposal, hand washing, quantity of potable water available, pathogen levels in water and household income. Consequently, the null hypothesis H_O is rejected and the alternate hypothesis H_A is accepted. There is therefore a positive relationship between frequency of play in the Aboabo River and the occurrence of water related disease in children.

4.4.2.1 Proportions of water related diseases

The researcher conducted an investigation to collect morbidity data on the water related diseases from hospitals in the river basin. Three major hospitals; Tafo Government Hospital (overnment owned), Adab Sab Maternity Home (private) and Boakye Danquah (private) had information readily available on morbidity cases in the year 2009. The fourth medical facility visited was Prince of Peace Clinic, in Aboabo. Fig.4.5 illustrates the proportions of water related diseases in the medical facilities in the river basin.

Fig. 4.5 Proportion of water related diseases (2009)



Source: Health Information Unit, GHS, 2009.

Malaria was identified as the leading form of water related disease reported in the medical facilities. In order of magnitude, malaria contributed 28,410 (82%) cases to a total of 34,757. This was followed by 2858 cases of skin diseases which amounted to 8.2%. Diarrhoea, Acute eye infection and typhoid contributed 2111 (6%), 724 (2%) and 337 (1%) respectively. In addition, ear infections and schistosomiasis contributed 277(0.8%) and 8(0.02%) cases respectively. Informal discussions with the principal nursing officers revealed that poor environmental conditions in the river basin as well as frequent disposal of garbage into the river contributed to the high incidence of malaria. The garbage blocked portions of the river and containers served as good breeding grounds for mosquitoes. Thus in a month, an average of 789 cases of malaria are recorded in the medical facilities whilst 79 cases of skin diseases and 58 cases of diarrhea are recorded respectively in a month.

4.4.2.2 Distribution of water related diseases by age group.

The age distribution of water related diseases in the medical facilities in the river basin was investigated and the results are show in table 4.9.

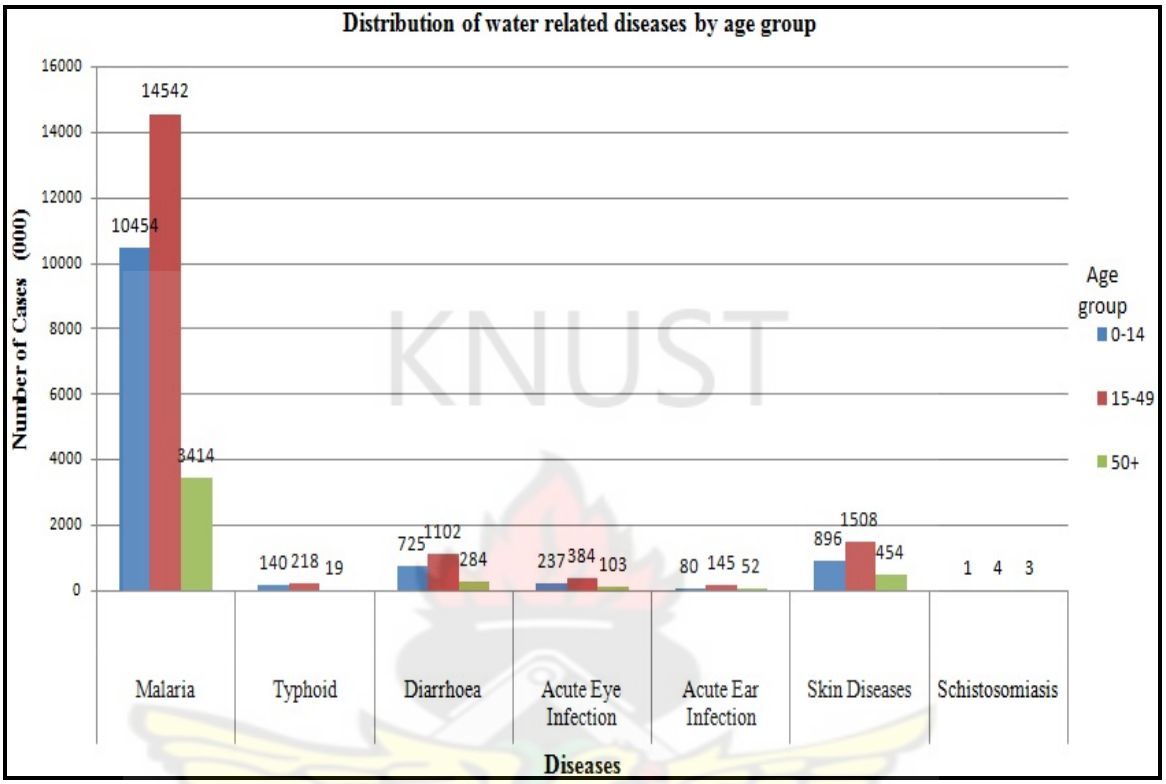
Table 4.9 Distribution of water related diseases by age group.

Age Group	Malaria	Typhoid	Diarrhea	Acute Eye Infection	Acute Ear Infection	Skin Diseases	Schistos-omiasis	Total
0-14	10,454	140	725	237	80	896	1	**12,533**
15-49	14,542	218	1,102	384	145	1,508	4	**17,903**
50+	3,414	19	284	103	52	454	3	**4,329**
Total	**28,410**	**377**	**2,111**	**724**	**277**	**2,858**	**8**	**34,765**

Source: Health Information Unit, GHS, 2009.

Table 4.9 shows the distribution of ages of the cases of water related diseases from the health centers in the river basin. The data is shown in a bar graph format in figure 4.6. From fig.4.6 it is evident that the most frequent case of water related disease is malaria. There are more cases of malaria amongst persons aged 0-14 than any other disease. Persons aged 0-14 in order of magnitude, experience malaria, skin disease and diarrhea. This is in consonance with the prevalent disease that respondents reported that their children suffered. Health data showed that no case of cholera was reported in the year 2009. The reason is that respondents resorted to traditional medical practitioners to be treated. An informal interview with the principal nursing officer of Prince of Peace Clinic at Aboabo indicated that the most prevalent water related cases were Malaria, diarrhea and meningitis.

Fig. 4.6 Distribution of water related diseases by age group (2009)



Source: Health Information Unit, GHS, 2009.

Schistosomiasis cases were the least reported amongst the age groups; 0-14 had 1 case whilst 15-19 and 50+ had 4 and 3 cases respectively. Acute ear infection cases were low as compared to eye infections. Age groups 0-14 had 80 cases representing 29% of all acute ear infections whilst 15-49 and 50+ had 52% and 19% respectively. The Age groups 0-14 had 31% of all cases of skin disease whilst 15-49 and 50+ had 53% and 16% respectively. This is significant because children between the ages of 0-14 suffer more cases of skin diseases apart from adults aged 15-49. There were more cases of skin diseases amongst children aged 0-14 than typhoid and diarrhea combined. Skin diseases accounted for 7% of all morbidity cases in age group 0-14. Thus skin diseases are a significant factor contributing to morbidity amongst children in the river basin. This was

however second to malaria which accounted for over 83% of all morbidity cases in age group 0-14. Diarrhoea on the other hand accounted for 6% of 0-14 morbidity cases.

4.4.2.3 Comparison of child morbidity in 2008 and 2009.

Table 4.10 Morbidity cases at the Tafo Government Hospital 2008 and 2009.

Disease	Total number of reported cases (2008)	Percentage of cases that were children	Total number of reported cases (2009)	Percentage of cases that were children
Malaria	29,230	10,571 (36%)	26,343	9,632 (37%)
Typhoid/Enteric Diseases	111	36 (32%)	311	125 (40%)
Diarrhea diseases	1,805	852 (47%)	2028	664 (33%)
Acute eye infections	395	211 (53%)	710	234 (33%)
Acute ear infections	251	119 (47%)	273	80 (29%)
Skin Diseases	4,677	1,502 (32%)	2814	845 (30%)
Total	**36,469**	**13,291 (36%)**	**32,479**	**11,580 (36%)**

Source: Health Information Unit, GHS, 2009.

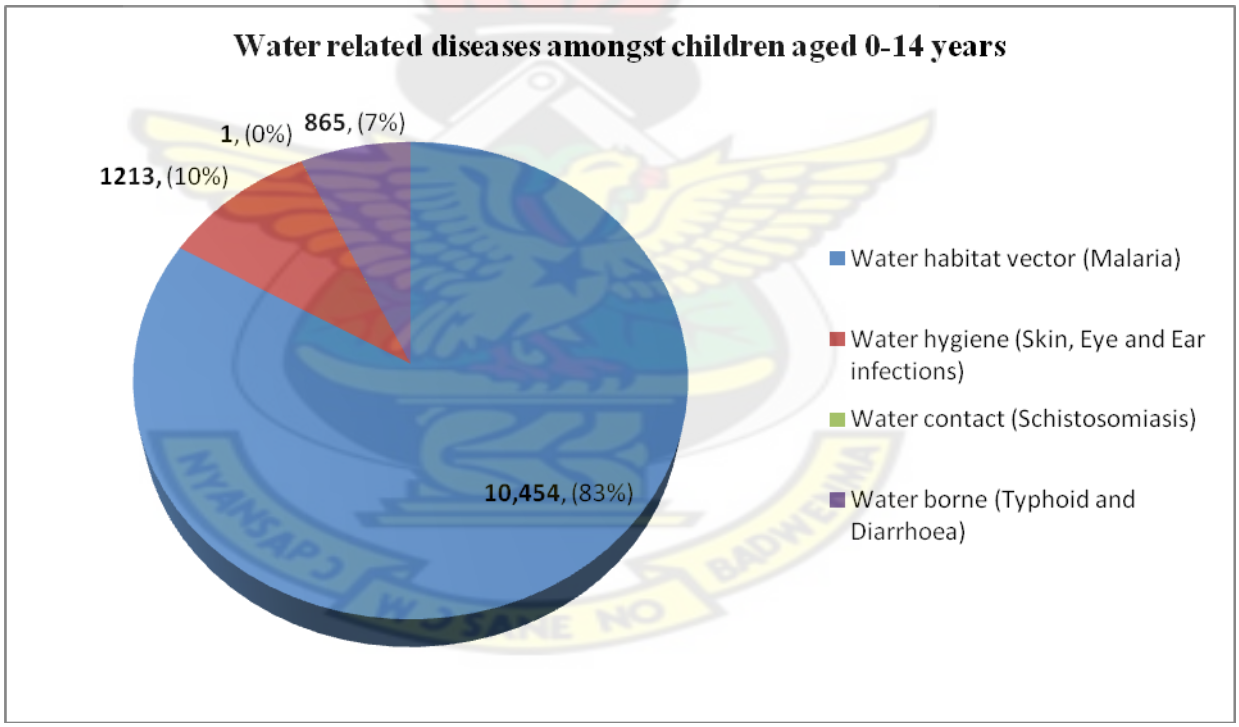
Table 4.10 shows that 36% and 37% of all malaria cases in 2008 and 2009 were child related. Also 32 and 40% of all typhoid cases were child related cases. Child related cases of diarrhea in 2008 were 47% of all total reported cases whilst that for 2009 was 33%. Data from the table therefore suggests that from 2008-2009 at least 30% of all water related diseases were child related cases. Of importance is acute eye infections in which over 50 percent of all cases in 2008 was child related. On the other hand, in 2009, 40% of

all typhoid/enteric cases were children. Typhoid recorded the highest incidence of water related diseases in children in 2009 whilst in 2008 it was acute eye infection. The children who frequently played in the river contributed to the incidence of water related diseases especially typhoid and acute eye infection cases.

4.4.2.4 Categories of water related diseases

Data from the river basin has thus been categorized into the various water related diseases suffered in children 2009 as shown in fig4.7

Fig 4.7 Water related diseases amongst children aged 0-14 years



Source: Health Information Unit, GHS, 2009.

Fig.4.7 shows that water-habitat vector diseases are mostly suffered by children in the river basin. Water-habitat vector diseases (malaria) accounts for 83% of all water related

diseases amongst children. Secondly, water hygiene diseases such as skin, eye and ear infections also contribute 10% to water related diseases amongst children. Water borne diseases and water contact diseases contributed 7% and 0% respectively.

Children were most vulnerable to these water related disease due to their naturally curious habits. They play in the river by swimming, play on rubbish dumps and on open ground which is often littered with human excreta. Rubbish that is recurrently dumped into the river and serves as good breeding grounds for mosquitos. This contributes to the incidence of malaria amongst children in the river basin. Correlation and hospital records showed that that there was a positive relationship between river pollution, playing in the river water and water related diseases that were reported by respondents.

4.5 Measures put in place to control the pollution of the Aboabo River

The Government of Ghana through its mandated agencies such as the EPA, KMA and related Ministries, departments and agencies are responsible for the control of the pollution of the Aboabo River. Interviews with officials of the KMA revealed that the Government had made some interventions by initiating the construction of a 2.5 km storm drain at Aboabo which is hoped to control flooding and pollution of the Aboabo River. Secondly, the Government in collaboration with the French government has created the Sokoban wood village which is meant to be a permanent place where wood workers at Anloga would carry out their business. The eviction of the wood workers is serving as pollution control measure on the Aboabo River as the volume of saw dust and

wood offcuts that are poured into the river will be greatly reduced. Thirdly the concept of sanitary inspectors has been revived by the government in order to ensure environmental cleanliness and control pollution of the Aboabo River. Sanitary inspectors go round on inspections in households in the river basin but according to KMA officials, they are few in number and cannot regularly ensure pollution control in the evenings.

Residents of the Aboabo River basin have also done little to control the pollution of the Aboabo River. Control of the pollution of the Aboabo River was perceived by the residents as the duty of the central government and for that matter the KMA. Some residents use moral persuasion as a means of encouraging friends and family to desist from the practices that reduce the quality of the river water. In the river basin, there was no evidence that suggested that residents had been organized or had organized themselves to control the pollution of the Aboabo River.

4.6 Respondent's perceptions about solutions to the pollution of the Aboabo River.

Interventions to solve the problem of river pollution must not only come from the municipal or national administrative hierarchy but also from local level residents so that the interventions would best serve the interest of those immediately affected.

Residents living in the river basin suggested a number of interventions to be made by the government and NGOs to curtail the incidence of river pollution. Most of the residents, 237 (60%), considered the arrest and prosecution of persons who flout KMA bye-laws on sanitation (Table 4.11).

Table 4.11 Respondent's perceptions of interventions to be made to control pollution of the Aboabo River.

	Prosecute Offenders	Provide Drains	Provide Education	Provide Sanitation Infrastructure	Total
Pankrono	53	3	5	6	**67**
Moshie Zongo	48	4	5	10	**67**
Buokrom	20	4	0	0	**24**
Dichemso	15	16	4	5	**40**
Aboabo	21	23	6	17	**67**
Asokwa	24	0	0	8	**32**
Atonsu	56	18	8	17	**99**
Total	**237**	**68**	**28**	**63**	**396**
Percentage	**60**	**11.4**	**2.6**	**13**	**100**

Source: Author's field survey, 2009

Also, 68 (17%) respondents considered the construction of adequate drains, 63 respondents (16%) the construction of an efficient sewerage system and 28 respondents (7%) considered the education of residents on river pollution. This gives an indication that residents of the Aboabo River basin perceive that the main way of curbing the incidence of practices that leads to the pollution of the Aboabo River is the enforcement of bye-laws on sanitation and river pollution. If drains are constructed and adequate waste management systems are provided and the laws are not strictly enforced, with arrests and prosecutions, attempts at controlling river pollution would be stalled. Some residents would blatantly flout the regulations.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The research sought to find out the causes of the pollution of the Aboabo River, the effect such pollution has on the health of residents living in the river basin and to find out measures put in place by both government and residents to control the pollution of the Aboabo River. This chapter presents a summary of the research findings, conclusions and recommendations.

5.1 Summary of research findings

Water plays a crucial part in the development and sustenance of man. The rivers which flow through the Kumasi metropolis are being polluted mostly through human activities which have serious health implications for persons living in the city and beyond.

The water of the Aboabo River was subjected to physical, chemical and bacteriological tests. The tests showed that the water from the river did not meet WHO drinking water standards as well as EPA guidelines of effluent water quality. Faecal coliform count was the parameter that did not meet WHO standards the most $300*10^4$ and this indicated that the river was mainly polluted through human sources. The study identified the main causes of pollution of the Aboabo River to be indiscriminate dumping of refuse into the river, channeling of raw sewage into the river, open defecation along the banks, discharge of untreated effluents into the river and indiscriminate dumping of industrial waste into

the Aboabo River. The main causes are induced by remote causes, namely rapid population growth, institutional failure and industrial activity.

Rapid population growth is a remote cause of pollution. The Aboabo River basin has experienced a rapid growth of its population. This increase in population has triggered an increase in demand for sanitation services with population of the river basin outstripping the sanitation facilities available. The municipal authorities indicate that they are not able to meet the increasing demand primarily due to financial constraints and secondly rapid population growth in the Aboabo River basin (a percentage increase of 512 from 1970-2000).

Institutional failures are remote causes of pollution. There are institutions that have been charged with the responsibility of managing waste and protecting water resources in the Kumasi metropolis and the Aboabo River basin to be specific. These institutions include the EPA, KMA, Town and Country Planning, The Police Service, Hydrological Services Department, the Water Resources Commission, National Commission for Civic Education and the Information Services Department. Essentially due to financial and logistical constraints coupled with rapid population growth, the fore-mentioned institutions have failed to; provide adequate sanitation infrastructure; enforce KMA bye-laws on housing and sanitation; to regularly monitor the Aboabo River water quality and liaise with interrelated institutions.

Another remote cause of pollution is industrial activity. The weaknesses of the institutions responsible for protecting water bodies in the metropolis has been capitalized upon by entrepreneurs of small scale industries all of who have no permits or licenses to

operate. For example, industrial activities such as wood works, charcoal production, palm kennel extraction, car washing and leather tanning are carried out along the banks of the Aboabo River at less than 100 meters at several portions. The proprietors of the small scale enterprises indiscriminately use the river as a dumping ground for waste. Examples of the pollutants that are introduced are detergents, oil, grease, sawdust, pieces of wood, charcoal and chaff from palm kernel.

The interplay of rapid population growth, institutional failure and industrial activity creates an enabling environment for residents of the Aboabo River basin to engage in human activities that lead to the pollution of the Aboabo River. These activities include the indiscriminate dumping of refuse into the river, channeling of raw sewage, open defecation, discharge of untreated effluents and dumping of industrial waste into the Aboabo River. For example, through observations and interviews with residents it was revealed that human excreta is introduced into the river regularly and leads to increase in the BOD, and COD levels with a reduction in the DO content of the river. This is confirmed by the high recordings of faecal coliform counts (over 370×10^4/100ml) in water sampled from the Aboabo River.

The Aboabo River is not only polluted through anthropogenic causes but through natural causes as well. When it rains streets, lawns, roofs, pavements and compounds of homes are washed and urban runoff carries sand, silt, particulate matter and organic matter into the Aboabo River.

The pollution of the Aboabo River has the effect of reducing the quality of the water. Reduction in the quality of the river water translates into a loss of amenity such as

drinking, cooking, washing and bathing. In addition, pollution of the Aboabo River has contributed to the incidence of water related diseases. Children who came into contract with the river water indicated that they experienced water-related diseases as malaria, skin infection, eye infection and diarrhea. A correlation of the frequency of coming into contact with the polluted river water and the incidence of water related diseases amongst 322 children proved positive.

The research has also established that some efforts have been put in place by the government to control pollution of the Aboabo River. Due to financial constraints and the lack of coordination between agencies of pollution control, river pollution still persists in the river basin. The interventions being made are that of the 2.5km storm drains being constructed at Aboabo and the Sokoban wood village which is to house the wood workers at Anloga. However, residents in the basin have not organized themselves to control or check river pollution in the river basin. In order for interventions at solving community problems to last and be accepted by the community, researchers must investigate to know the kinds of interventions needed by the members of that community. A total of 71 percent of the residents interviewed in the Aboabo River basin indicated that in order of priority, the laws concerning river pollution must be strictly enforced. Secondly, a storm drain should be constructed in order to reduce the incidence of pollution and flooding in the river basin. Thirdly, the residents require that people living in the basin should be educated on the hazards and effects of polluting the Aboabo River.

5.2 Conclusions

In the light of the research findings, the following conclusions are drawn:

1. It is established that the Aboabo River is polluted. This is because when the physical, chemical and bacteriological tests were conducted on the water of the Aboabo River, the results were compared to WHO Drinking water standards. Comparisons showed that the drinking water parameters are below internationally accepted standards. Thus the Aboabo River cannot be used for domestic purposes such as drinking, washing, cooking and bathing.

2. The hypothesis that human activities carried out in the Aboabo River basin are the main causes of the pollution of the Aboabo River is validated. The researcher has thus classified the causes of the pollution of the Aboabo River into two categories based on a behavioral approach. These are Main Causes and Remote Causes.

3. There is a positive relationship between frequency of play in the Aboabo River and the occurrence of water related disease in children. The correlation between frequency of play in the Aboabo River water and incidence of water related disease is positive indicating that frequent play in the river leads to the occurrence of water related diseases amongst children in the Aboabo River basin.

The Municipal authority, the EPA and all allied institutions need to be strengthened to enable them carry out the mandate of protecting not only the Aboabo River but the water resources of the Kumasi Metropolis. Without such essential interventions of financial and material support from the central government and the private sector, these organizations

cannot do their work effectively. If the phenomenon of river pollution is not checked or given the necessary attention it deserves, the rivers would die off and we many not be able to leave behind any river for posterity.

5.3 Recommendations

In order to address the problem of the pollution of the Aboabo River, it is strongly recommended that attempts must be made in a holistic manner. The problem of river pollution is not limited to one institution, one activity or limited to a specific time period. It is multidimensional and interventions to address the problem should be made as such taking into consideration long-term and short-term interventions.

5.3.1 Short-term recommendations

In the short term, there is the urgent need for the central government to be made aware of the extent of pollution of rivers in the Kumasi metropolis and Aboabo River in particular so as to be able to plan and weigh the mitigation measures against budgetary allocations. This thesis in part will serve as an information tool to enable government have an appreciation of the fact that the Aboabo River is polluted and has negative health effects on the residents of the Aboabo River basin.

Secondly, it is recommended that the central government must increase budgetary allocations to the KMA and allied institutions such as the EPA in their bid to control river pollution. This could be done by taking a percentage of the communications tax, VAT and import duties and channel it into a fund for environmental protection. From this fund

a percentage should be given to the Water Resources Commission which would administer the monies to the KMA and EPA after considering their budgets. Through this means, KMA and allied institutions will have the financial support to provide adequate skips, create safe waste dump sites, increase coverage of door to door collection, regularly monitor river water quality and strictly enforce zoning regulations in the Kumasi metropolis and the Aboabo River basin in particular. Also in the government's bid to address the financial and infrastructural constraints, it must allow the allied institutions greater autonomy to seek foreign donor support from multilateral agencies as the UNDP, UNEP, Green Peace, Stockholm Environment Institute, WHO, DANIDA,USAID and JICA. Private sector participation in the waste management industry should be encouraged by the provision of an incentive such as tax holidays in order to share the burden placed on the metropolitan authority.

Thirdly, financial interventions must be followed with strict monitoring and evaluation. Such monitoring should be two fold. The first is for the KMA, EPA and allied institutions and should comprise the monitoring of finance and making sure that all money intended for river pollution control is used for its intended purpose and not diverted. Personnel should be adequately remunerated and encouraged to maintain high standards of professionalism on field inspections and in their offices. The second place of monitoring should be on the activities that are carried out in the river basin that have negative effects on the river such as leather tanning. Permits must be inspected and all enterprises found culpable must be ejected.

Fourth, one must take cognizance of the fact that the pollution of the Aboabo is not only due to an infrastructural or institutional inadequacy but also linked to human attitudes. Where the quantum and quality of infrastructure are increased, there is the need for education. Users should be educated as to how to use them so that they will last and do not become health threats in themselves. Education must also be given by the NCCE and ISD on the negative effects that polluting the Aboabo River has on their health and that of users downstream. Just as budgetary allocations are sought from international institutions in support of HIV/AIDS awareness and National Road safety campaigns, the role of education through the media must be given the needed attention.

Furthermore, it is strongly recommended that the KMA must intensify their routine sanitary inspections in the river basin and where residents are found to have broken the bye laws, offenders should be arrested and prosecuted. The penalties must be reviewed upwards from GHC 5 and made tougher as a deterrent to others. Defaulters must be made to engage in community service as sweeping, weeding and cleaning their communities. Clean up campaigns and dredging of the river channel should be regularly engaged in.

5.3.2 Long-term recommendations

In the long term, the role of research must be made prominent. Research should play the role of informing policy and this should be carried out by the Government agencies such as the Water Resources Commission, KMA and EPA, NGOs, Universities, research institutions and individuals. Essentially issues relating to the implications that increasing population growth will have on the Aboabo River and other water resources in the country should be taken into consideration. Further research should be carried out into the

effect that the pollution of the Aboabo River has on biota as well as the socio-economic ramifications of pollution for inhabitants living downstream of the Aboabo River basin.

Policy refers to the programme of actions that an institution adopts to achieve specific objectives. The central government must consider the drawing of a National Water Pollution Policy and in it clearly define its criteria of ensuring the protection of water resources in the all regions and also the institutions responsible for carrying out objectives. In addition, the National Water Pollution Policy should promote healthy environments for both adults and children at the household, community and national levels. The Water Resources Commission must be strengthened financially to coordinate the activities of the Institutions responsible for water pollution control effectively. The commission must bring together all stake holders at an annual conference that will deliberate on the state of water bodies, assess the progress made at water pollution control and seek solutions to administrative, technical or logistical problems.

Lastly, in the long term, the central government must consider the provision of a comprehensive sewage system which has its terminal at a waste treatment plant in the Kumasi Metropolis. The sewage system will serve the purpose of carrying sewage or water from homes to the waste treatment plant and all drains to be constructed in undeveloped areas must be channeled directly into this sewage system. According to Hardoy *et al*, 2001, sewer systems have three great advantages of eliminating the need for anyone to handle human excreta by removing excreta from the residential area, they need less maintenance since there is no septic tank or pit that has to be emptied and they remove household waste water. Though installing one will be costly, in the long run, the

benefits will outweigh the costs. The benefits will be reflected in the reduced incidence of environmental and water related diseases, the promotion of good health of the residents of the Aboabo River basin and a reduction of the pollution of the Aboabo River.

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APPENDIX I

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
Faculty of Social Sciences
Department of Geography and Rural Development

"Causes and Effects of River Pollution: A case study of the Aboabo River Basin."

QUESTIONNAIRE SURVEY FOR THE INHABITANTS OF THE ABOABO RIVER BASIN

The purpose of this questionnaire is to elicit information on the causes of the pollution of the Aboabo river and its effect on the health of residents of the river basin. The information provided will be used solely for academic purposes and would be treated as confidential. Thank you for your cooperation.

Please tick or fill in where appropriate.

A. Background information

1. Sex a. Male ( ) b. Female ( )

2. Age : Below 10 ( ) b. 11- 20 ( ) c. 21-30 ( ) d.31- 40 ( ) e. 41-50 ( )
f. 51- 60 ( ) g. Above 60 ( )

3. Marital Status: a. Married ( ) b. Single ( ) c. Divorced ( ) d. Widowed ( )
e. Others (Specify)…….

4. Are you employed? A. Yes ( ) B. No ( )

5. What is the nature of your work?
a. Trading ( ) b. Services ( ) c. Government ( ) d. Artisan ( ) e. Farming ( )
f. Transport ( ) g. Student ( ) h. Apprentice ( ) i. Other (Specify)……

6. If yes, what is your monthly income in GhC?
a. Below 50 ( ) b. 50- 150 ( ) c. 151- 250 ( ) d. 251-350 ( ) e. Above 351 ( )

7. How long have you lived in this dwelling unit?
a. < 3months ( ) b. 3 - 11months ( ) c. 1-5yrs ( ) d. 6- 10yrs ( ) e. above 10 yrs ( )

8. Where did you live before settling in your dwelling unit? .....

9. What is the highest level of education you have attained?

a. Primary ( ) b. JHS ( ) c. SHS ( ) d. College ( ) e. Middle school ( ) f. University ( ) g. Never Schooled ( ) g. Other (Specify)……

B. Causes of the pollution of the Aboabo River

1. In which type of dwelling do you live?

a. Rented ( ) b. Personally built ( ) c. Family House ( ) d. Other (specify)

2. What is the number of households in your home?

a. 1 ( ) b. 2-5 ( ) c. 6-9 ( ) d. 10 and Above ( )

3. What is the average number of persons in each household?

a. 1 ( ) b. 2-5 ( ) c. 6-9 ( ) d. 10 and Above ( )

4. How many persons are there in your household?

a. 1 ( ) b. 2-5 ( ) c. 6-9 ( ) d. 10 and Above ( )

5. Do you have a bathing facility in your house? A. Yes ( ) B. No ( )

6. If yes, which of the following best describes the bathing facility used by your household?

a. Shared by household alone ( ) b. Shared by entire house ( ) c. Outside of house ( ) d. Public bath ( )

7. Does your house have a shower?

a. Shared by household alone ( ) b. Shared by entire house ( ) c. Shared with other near by houses ( ) d. Public bath ( ) e. Other ……..

8. Is your dwelling connected to a sewage network? a. Yes ( ) b. No ( )

9. What is the primary means by which wastewater from your bathing facility is disposed off?

a. Into public sewage network ( ) b. Into gutters ( ) c. Unto the streets ( )

d. Into septic tank ( ) e. Channeled into Aboabo river ( ) f. Other

10. What is the primary means by which wastewater from other domestic activities is disposed off? a. Into public sewage network ( ) b. Into gutters ( ) c. Onto the streets ( )

d. Into septic tank ( ) e. Channeled into Aboabo river ( ) f. Other

11. Does your house have its own private toilet? a. Yes ( ) b. No ( )

12. If yes, which of the following best describes the type of toilet in your house?
a. Water closet connected to public sewage network ( ) b. Water closet connected to septic tank ( ) c. Service or bucket latrine ( ) d. Others ……

13. Does your community have a public toilet facility? a. Yes ( ) b. No ( )

14. Which type of toilet does your household use most frequently?
a. Water closet connected to public sewage network ( ) b. Water closet connected to septic tank ( ) c. Service or bucket latrine ( ) d. Public toilet ( ) e. Open defecation in river or near the river ( ) f. Open defecation on refuse dumps ( ) g. Other

15. What is the primary means by which toilet from your household is disposed off?
a. Into public sewage network ( ) b. Into gutter ( ) c. Unto street ( )
d. Into septic tank ( ) e. Channeled into Aboabo river ( ) f. Other ..…….
g. Don't know ( )

16. Are there any reasons for channeling sewage into the Aboabo river?
a. Yes ( ) b. No ( )

17. If yes, what are those reasons?
……
……
……
18. Do you join a queue when you use a public? A. Yes ( ) B. No ( )

19. If yes, how long do you usually wait in the queue? ……..

20. At what period in the day are there long queues?
a. Morning ( ) b. Afternoon ( ) c. Evening ( ) d. Night ( )

21. Do you pay for the use of the toilet facility ? a. Yes ( ) b. No ( )

22. If yes, how much do you pay? GH C. ……..

23. How do children in your household pass stool?
a. Use of toilet sanitary pads ( ) b.cloth or napkins ( ) c. Chamber pot ( )
d. Use of adult toilet seat ( ) e. Others ……..

24. What is usually done to dispose off the stool of children in your household?
a. Put/rinsed into toilet or latrine ( ) b. Put/rinsed into drain or ditch ( ) c. Thrown into household litter bin ( ) d. Burried ( ) e. Thrown into river or along its banks ( ) f. left in the open ( ) g. Others ……

25. What is the most frequent means by which your household disposes of refuse?
a. Dumped into open space ( ) b. Dumped into public container ( )
c. Burnt ( ) d. Composted ( )
e. Burried ( ) f. Dumped into or near the Aboabo river ( )
g. Collected by individual sanitation contractors ( )
h. Door to door collection by KMA ( )
i. Other (specify)……..

26. Why do you use this means of disposing off refuse as mentioned in question 25?
……

27. Which member of your household usually disposes off household waste?
a. Adult man ( ) b. Adult woman ( ) c. Female child under 15 years ( )
d. Male child under 15 years ( ) e. Others ……

C. HEALTH
1. Which of the following is the most common illness in your community?
a. Malaria ( ) b. Diarrhea ( ) c. Cholera ( ) d. Fever ( ) e. Typhoid ( ) f. Others...…….
2. What illnesses have you suffered in the last three months? (Please, you may tick more than one option)
a. Malaria ( ) b. Diarrhea ( ) c. Cholera ( ) d. Fever ( ) e. Typhoid ( )
f. Catarrh ( ) g. I've not suffered any illness ( ) h. Other…….

3. What in your view were the causes of the illnesses in question 2 above?
a. Poor sanitation in neighborhood ( ) b. presence of mosquitoes ( ) c. Poor personal hygiene ( ) d. Contact with river water ( ) e. Other ……

4. Do children in your household play in the Aboabo river?
a. Yes ( ) b. No ( )

5. If yes, how often?
a. Very Often ( ) b. Often ( ) c. less often ( )

6. Do you know of any illnesses suffered by any of the children in your household in the last three months? a. Yes ( ) b. No ( )

7. If yes, which one? (Please, you may tick more than one option)
a. Malaria ( ) b. Diarrhea ( ) c. Cholera ( ) d. Fever ( ) e. Typhoid ( ) f. Catarrh h. Skin disease ( ) Other (Specify)……

8. How often do you attend the hospital in a year?
a. Once ( ) b. Twice ( ) c. Three times ( ) d. Four times ( ) e. Other…….

9. In the past three months, how many times has your child been diagnosed with the disease mentioned in Q7?
a. Once ( ) b. Twice ( ) c. Three times ( ) d. Four times ( ) e. Other…….

10. Have you registered with the NHIS? a. Yes ( ) b. No ( )

11. Please give reasons for your answer in question 10
……
.....
12. Do you use the Aboabo River for any purpose? a. Yes ( ) b. No ( )

13. If yes please indicate which purpose(s) (
a. Water crops ( ) b. Fishing ( ) c. Washing ( ) d. Disposing waste ( ) e. Drinking ( ) f. source of water for industry ( ) h. Others …….

14. Please mention in your view the most important cause of pollution of the Aboabo river. …….
15. Do you know of any laws that prohibit the pollution of rivers?
a. Yes ( ) b. No ( )

16. Which of the following uses would you put the Aboabo river to if it was not polluted
(Please indicate 1st, 2nd,3rd, in order of most frequently)
a. Washing …. b. Cooking …. c. Drinking …. d. Bathing ….. e.Fishing….e. Other ……..
17. Do persons in your house eat food crops watered with the river water ? a. Yes ( ) b. No ( )
If yes how often? A. Very often ( ) b. Often ( ) c. Less Often ( )

18. Do persons in your house eat fish caught from the river? a. Yes ( ) b. No ( )
If yes how often? A. Very often ( ) b. Often ( ) c. Less Often ( )

D. Measures put in place to control pollution.

1. Do you know of any measures put in place by residents of your community to control pollution of the Aboabo river?

a. Yes ( ) b. No ( )

2. If yes, what are these measures?

……
……

3. Do you know of any measures put in place by the government to control the pollution of the Aboabo River?

a. Yes ( ) b. No ( )

4. If yes, what are these measures?

……
……

5. What in your view should be done to control the pollution of the Aboabo River?
(Please rank 1st, 2nd 3rd etc)

a. Arrest offenders ……..
b. Construct drain ……
c. Educate residents on the need to protect rivers …….
d. Provision of enough drainage systems ……..
e. Others ……

6. Further comments/Recommendations

……
……

APPENDIX II

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
Faculty of Social Sciences
Department of Geography and Rural Development

"Causes and Effects of River Pollution: A case study of the Aboabo River Basin."

QUESTIONNAIRE SURVEY FOR THE EPA

The purpose of this questionnaire is to elicit information on factors which induce residents to engage in activities that pollute the Aboabo River and residents perceptions of what must be done to solve the problem. The information provided will be used solely for academic purposes and would be treated as confidential. Thank you for your cooperation.

1. What role does your institution play in the protection of Rivers in Ghana and Kumasi to be specific?

……
……
……
……

2. Are there laws that exist on the protection of rivers?

a. Yes ( ) b. No ( )

3. If yes what are these laws?

.....
.....
.....
.....
.....

3. Are these laws being enforced?

a. Yes ( ) b. No ( )

4. What are the challenges the EPA faces with the enforcement of laws concerning the protection of the Aboabo River?

……
……
……

5. Is your institution aware of the fact that the Aboabo river is polluted?

a. Yes ( ) b. No ( )

6. Has your institution carried out any analysis on the quality of water in the Aboabo River or any river in the Kumasi metropolis?

a. Yes ( ) b. No ( )

7. If yes when were they carried out?

……
……
……
……

8. What were the conclusions on each?

……
……
……

9. What induces people living along the Aboabo River to engage in activities that lead to the pollution of the Aboabo River?

……
……
……
……

11. Does the pollution of the Aboabo River have any consequences for users downstream?

a. Yes ( ) b. No ( )

12. If yes, what are these consequences?

……
.....
.....

13. What is your agency doing to solve the problem of the pollution of the Aboabo River through human activities?

……
……
……

APPENDIX III

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
Faculty of Social Sciences
Department of Geography and Rural Development

"Causes and Effects of River Pollution: A case study of the Aboabo River Basin."

QUESTIONNAIRE SURVEY FOR THE KMA

The purpose of this questionnaire is to elicit information on the causes of the pollution of the Aboabo river and its effect on the health of residents of the river basin. The information provided will be used solely for academic purposes and would be treated as confidential. Thank you for your cooperation.

1. What role does your institution play in the protection of Rivers in Ghana and Kumasi to be specific?

……
……
……
……

2. Does the KMA have any by laws pertaining to the protection of rivers from being polluted?

a. Yes ( ) b. No ( )

3. If yes, what are these by laws?

……
……
……
……
……

a. In your view are these laws being enforced?

a. Yes ( ) b. No ( )

4. If no, what are the constraints your institution faces with regard to law enforcement?

……
……
……
……

5. How many waste treatment facilities are in Kumasi? ……

6. Where are these located?

7. Please mention the functional ones and their capacities.

8. Please describe briefly the waste management services in the following communities by filling the form below.

Community	Waste management services provided	Number of Public toilets	Number of KMA approved dumping sites	How frequently is solid waste collected from dump sites?(Time period)
Pankrono				
Moshie Zongo (Old Tafo)				
Buokrom				
New Tafo				
Dichemso				
Aboabo				
Asokwa				
Atonsu				

9. Does the KMA provide sanitation/waste management services for housing units located close to the Aboabo River?

a. Yes ( ) b. No ( )

10. If yes, what kinds of services are provided? If no, why?

……
……
……

Is your institution aware that some residents in the Aboabo river basin use the river and its banks as a dumping ground for refuse and sewage?

a. Yes ( ) b. No ( )

11. What induces people living in the river basin to pollute the Aboabo River?

12. Does the pollution of the Aboabo River have any consequences for communities downstream?

a. Yes ( ) b. No ( )

13. If yes, what are these consequences?

……
……

14. What constraints does the KMA face in managing solid waste in Kumasi?

……
……

15. What constraints does the KMA face in managing liquid waste in Kumasi?

……
……
……

16. What is your institution doing to solve the problem of the pollution of:

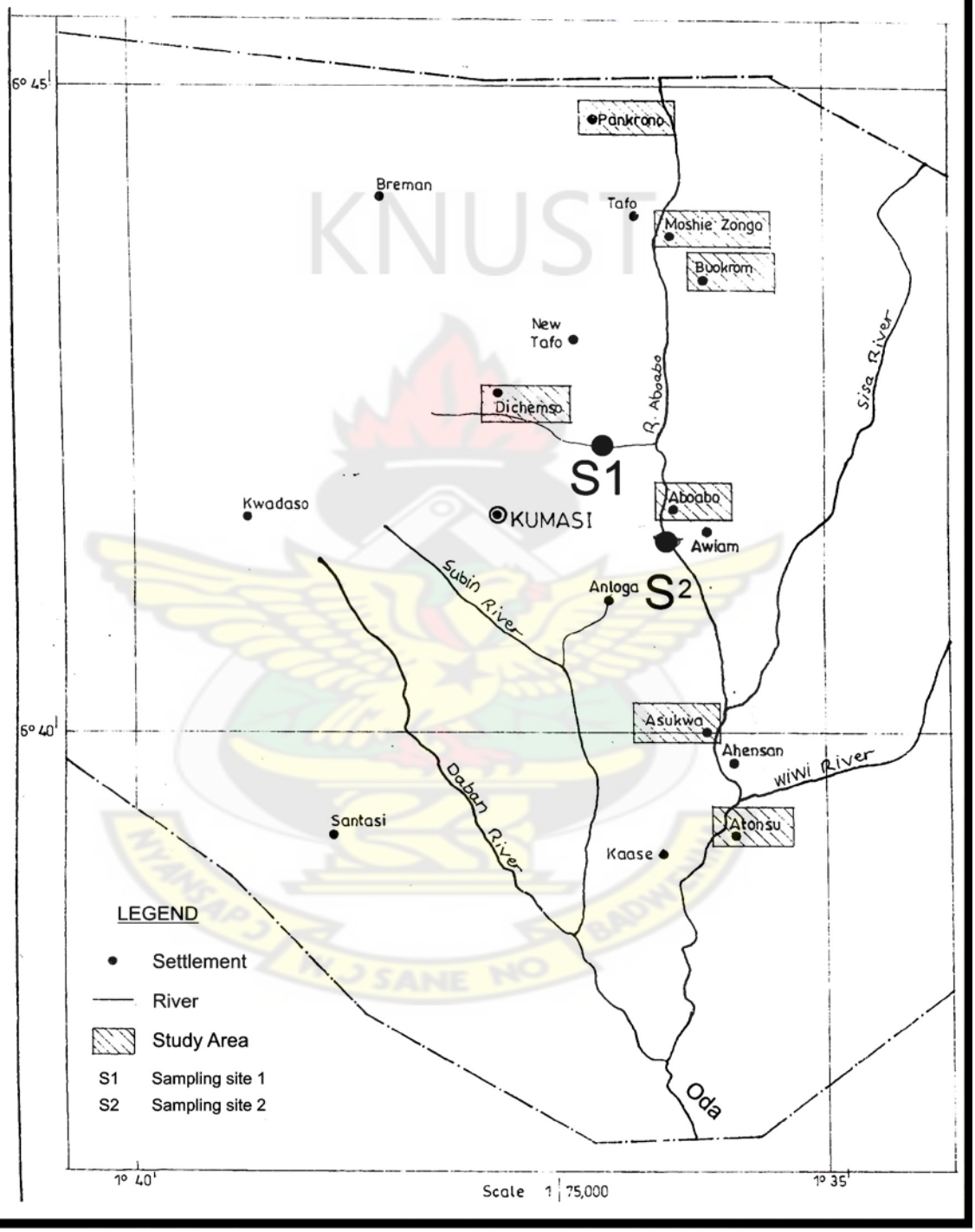
a. The Aboabo river to be specific?

……
……

b. Rivers in Kumasi in general?

APPENDIX IV

DRAINAGE MAP OF KUMASI SHOWING SAMPLING STATIONS



SOURCE: Department of Geography, KNUST 2009

APPENDIX V

CALCULATION OF SAMPLE SIZES FOR SELECTED COMMUNITIES

Community	Calculation	*Sample Size	Sample Selected
Selected Communities Upstream			
Pankrono	17/100 * 396	67.32	67
Moshie Zongo	17/100* 396	67.32	67
Buokrom	6/100 * 396	23.76	24
Selected Communities midstream			
Dichemso	10/100 * 396	39.6	40
Aboabo	17/100 *396	67.32	67
Selected Communities downstream			
Asokwa	8/100 * 396	31.68	32
Atonsu	25/100 *396	99	99
Total			**396**

Source: Authors calculations; GSS 2008.

*****All sample sizes were rounded up to the nearest whole number.

APPENDIX VI
SPSS OUTPUT FOR CORRELATION AND REGRESSION

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	Frequency of playing in river water(a)	.	Enter

a All requested variables entered.
b Dependent Variable: Attendance at medical facility for water borne diseases

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.516(a)	.266	.264	.87449

a Predictors: (Constant), Frequency of playing in river water
b Dependent Variable: Attendance at medical facility for water borne diseases

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	88.889	1	88.889	116.235	.000(a)
	Residual	244.714	320	.765		
	Total	333.602	321			

a Predictors: (Constant), Frequency of playing in river water
b Dependent Variable: Attendance at medical facility for water borne diseases

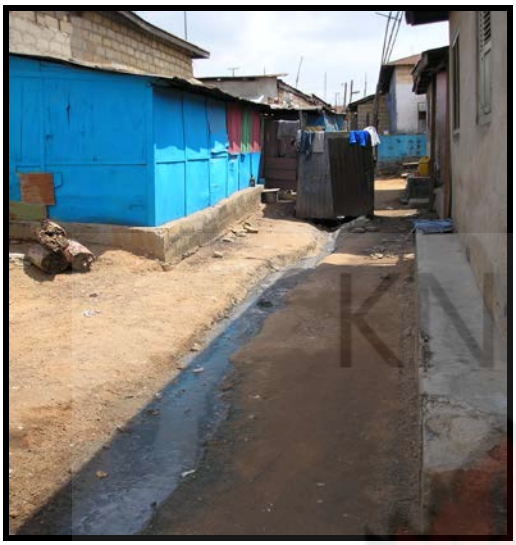
Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound	B	Std. Error
1	(Constant)	.541	.130		4.168	.000	.286	.797
	Frequency of playing in river water	.630	.058	.516	10.781	.000	.515	.745

a Dependent Variable: Attendance at medical facility for water borne diseases

APPENDIX VII
POLLUTION OF THE ABOABO RIVER-PHOTO GALLERY

A. **B.**



Pictures (a) and (b) show poor drainage within sections of the Aboabo river basin.

C. **D.**

Picture (C) shows the channeling of sewage into the Aboabo River at Atonsu.

Picture (D) shows the channeling of domestic waste water into the street at New Tafo.

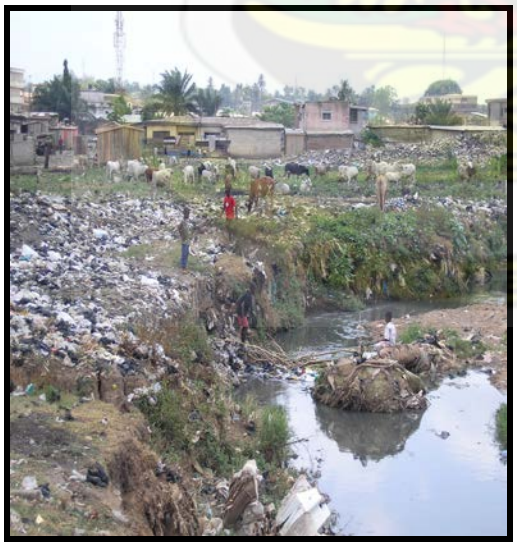
E.

F.

Picture (E) shows a man dumping saw dust at the edge of the Aboabo River at Anloga.

Picture (F) shows a washing bay that is situated on the banks of the Aboabo River. Water from the car washing bay drains directly untreated into the Aboabo River

G.



H.

Picture (G) shows children playing in the Aboabo River whilst picture (H) shows a young female defecating at the banks of the Aboabo river.