WATER QUALITY AND PLANT SPECIES COMPOSITION WITHIN CHEMUSUSU DAM, BARINGO COUNTY, KENYA

KIBET FAITH CHERONO (B. SC. ENVIRONMENTAL SCIENCE)

(Reg. No. N50/22295/2012)

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ENVIRONMENTAL SCIENCE
SCHOOL OF ENVIRONMENTAL STUDIES
KENYATTA UNIVERSITY
NAIROBI, KENYA

NOVEMBER, 2016

DECLARATION

DECLARATION BY CANDIDATE:

This thesis is my original research work and has not been submitted or presented for an award of a degree in any University.

Faith Cherono Kibet
(Reg. No. N50/ 22295/ 2012)

Date: 24/11/2016

DECLARATION BY SUPERVISORS:

We confirm that the work reported in this thesis was carried out by the candidate under our supervision.

Prof. Shyam Manohar
Department of Environmental Science
Kenyatta University, Nairobi, (Kenya)

Date: 24th Nov. 2016

Dr. Esther Kitur
Department of Environmental Science
Kenyatta University, Nairobi, (Kenya)

Date: 24. 11. 2016

DEDICATION

To my daughter Miss Hadassah and beloved parents Mr & Mrs Johana Komen.

ACKNOWLEDGEMENT

First, I acknowledge the Almighty God through whom all things become. I also acknowledge my dedicated supervisors Prof. Shyam Manohar and Dr. Esther Kitur for their valuable academic guidance, criticisms, suggestions, corrections, encouragement and advice throughout this research work and throughout study duration.

Gratitude goes to Dr. Ezekiel Ndunda (Department of Environmental Sciences) for his guidance, Eng. Noah Chebii (Sub-county Water Officer, Eldama-Ravine) and his team for the support and insightful discussions, and Titus Tuitoek (Customer Relations Manager, Nairobi Water and Sewerage Company) for his resourcefulness. I wish to also thank Samuel Koech (Planning and Design Office), Walter Kiplagat (Sub-county Agricultural Officer), Stanley Kimetto (Agriculture Officer FTC, Eldama-Ravine) and Chris for their team work and support.

I am grateful to the Mines and Geology department, Nairobi as well as the Department of Plant Sciences, Kenyatta University for allowing me to use their facilities for water sample analysis and plant species identification, respectively. This thesis would not have been possible without genuine support of many actors both at institutional and individual capacities, all of whom I am unable to mention here. I however, wish to extend my profound gratitude and indebtedness to all.

I also thank my colleagues Linet, Ann and Carol who took their valuable time to objectively shape this work, thank you for the synergy. Last but not least, to my family especially my husband, Arch. David Lagat for his unwavering encouragement and support for which I am forever grateful.

God bless you all.

TABLE OF CONTENT

LIST OF FIGURES

Page No.

LIST OF TABLES

LIST OF PLATES

ACRONYMS AND ABBREVIATIONS

APHA	American Public Health Association
EEA	European Environment Agency
EU	European Union
FTC	Farmers Training College
FAO	Food and Agricultural Organization
ICOLD	International Commission on Large Dams
KEBS	Kenya Bureau of Standards
NAPE	National Association of Professional Environmentalists
NTU	Nephelometric Turbidity Units
SPSS	Statistical Package for Social Sciences
UNEP	United Nations Environment Programme
WHO	World Health Organization

ABSTRACT

Chemususu Dam, a newly constructed dam, receives water through forest surface run-off and Barain and Sawich rivers. The aim of the study was to assess the water quality and plant species composition of Chemususu Dam. The study was carried out in a period of six month (August 2014 to January 2015). Sampling was done during the day and physico-chemical parameters of water were obtained using standard laboratory methods. The data was subjected to statistical analysis using computer package SPSS version 21 and significance difference between means was obtained using paired t-test. Water samples for phytoplankton identification were collected and 4% formalin was added for preservation. Whole plant or shoot of macrophytes along the periphery of the dam were randomly collected at each sampling station and placed in polyethene bags. Mean temperature ranged from 17.02 °C in upstream River Sawich (C1) to 21.48 °C in dam (C3). Median pH was between 6.77 in dam to 6.89 in upstream River Barain (C2). The mean conductivity values ranged between 63.67 µS/cm in Barain river to 81.16 µS/cm in dam, mean turbidity ranged from 3.12 NTU in dam to 94.82 NTU in Sawich river. Mean dissolved oxygen ranged from 4.2 mg/l in dam to 6.1 mg/l in Barain river; mean total dissolved solids ranged from 111.5 mg/l in downstream River Chemususu (C4) to 181.7 mg/l in Sawich river; mean nitrates levels ranged from 4.39 mg/l in Chemususu river to 5.26 mg/l in Sawich river; mean phosphates was between 3.34 mg/l in Sawich river to 4.5 mg/l in Barain river; mean sulphate was between 3.3 mg/l in Chemususu river to 7.2 mg/l in Sawich river; mean carbonates was between 4.17 mg/l in Barain river to 8.6 mg/l in dam and mean chloride ranged from 2.17 mg/l in Chemususu river to 2.73 mg/l in dam. Statistical difference was recorded between turbidity of inflowing rivers; C1 and C2 (P= 0.007, T=4.4), inflowing rivers and dam; C1 and C3 (P= 0.003, T= 5.5), C2 and C3 (P= 0.001, T=6.6), and between inflowing rivers and out flowing river; C1 and C4 (P= 0.003, T=5.5), and C2 and C4 (P= 0.001, T=6.8) and phosphate levels between upstream rivers C1 and C2 (P= 0.025, T=-3.16). Levels of nitrates, sulphates, total dissolved solids, pH and chlorides are within acceptable levels according to KEBS and WHO standards. However, phosphate levels were above the required 2.2 mg/l and turbidity of upstream rivers was higher than 5 NTU. Plant species were identified and confirmed using taxonomic keys. Three species of angiosperms and 19 phytoplanktons were recorded during the study period. Based on our results, it is concluded that the water quality of the dam is safe to be used for domestic purposes and agricultural activities if chemical concentrations do not increase. Regular monitoring of water quality is necessary to audit and assess to ensure sustainability of the dam.

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Dams are constructed for many purposes which include water supply, flood control, irrigation, navigation, control of sediments, and hydropower generation (ICOLD, 2007). The expanding world population and economic growth has increased the need to build dams for storing large amounts of water to meet the demand. Constructed dams are used either as single purpose or multipurpose. Although 71.7% are single-purpose dams, and there is a growing number of multipurpose dams. The single-purpose dams are as follows; 48.6% for irrigation, 17.4% for hydropower, 12.7% for water supply, 10.0% for flood control, 5.3% for recreation, 0.6% for navigation and fish farming and 5.4% others (ICOLD, 2007).

The main problem faced by most dams is pollution from both solid and liquid waste from agricultural, urban and industrial sites (Tirado *et al.,* 2008). Atmospheric sources as a result of direct wet and dry deposition to the water surface also determine pollutants in water bodies (European Environmental Agency, 1999). Deforestation, cultivation along slopes, river's edges, and use of agrochemicals in the upper catchment areas also contribute to increased runoff which erodes lots of sediments and nutrient loads into river and reservoir systems (Tirado *et al.*, 2008). These activities lead to the deterioration of water quality and aquatic habitats of numerous aquatic species (Huckett, 2010). In many tropical countries, several water-borne diseases are also associated with water reservoirs with the most common one being schistosomiasis, a parasitic disease affecting over 200 million people worldwide (Uyigue, 2006; Araoye, 2002).

Reservoirs and lakes ecosystems are affected by eutrophication making them unsuitable for human use as they cause serious problems for public water supply and also impact on the lake ecosystem. In most cases, phosphorus is the principal cause of eutrophication. Leaching of nitrate is becoming an important

cause in determining acidification. Sedimentation is also a significant problem with long-term impacts due to its reduction of reservoir capacity and its indirect effect on water quality (EEA, 1999).

Aquatic plants species composition relies on the interaction of biological, physical and chemical characteristic of water. Therefore, perturbation of these features has an effect on the assemblage of hydrophytes hence affecting water quality and aquatic organisms such as fish (Nasser, 2013). Their composition vary continuously in accordance to environmental variables such as light, temperature, intensity of turbulent mixing, benthic feeders, altitude, seasons and time of day (Grabowska, 2012). Nutrient enrichment affects hydrophytes productivity and composition, and alters the ecosystems function and structure.

In a eutrophic lake or reservoir, there is an increase in development of cynobacteria which strongly aggravate water quality within the dam and out flowing river because of the potential threat from toxins to aquatic environment, human health and life (Grabowska, 2012). Therefore, the information obtained from phytoplankton communities significantly contribute to assessing eutrophication levels in aquatic habitats (Nasser, 2013).

Kenya is a relatively dry country with uneven distribution of water resource. To curb this challenge, there has been an increase in the development of reservoirs to meet the increasing water demand. Water resources have been mismanaged through increasing degradation of their catchments, growing pollution and weak water allocation practices (Government of Kenya, 2006). Chemususu Dam, *(Plate 1)* is located within a highly agricultural area.

Plate 1: Satellite image of Lembus- kwen County ward showing location of Chemususu Dam

1.2 Problem Statement/ Justification

The construction of Chemususu Dam started in 2010 and was completed in 2012. The dam is anticipated to ensure sustainable and adequate water storage capacity of approximately 10.94 million m^3 and enhance uninterrupted water supply of about 35,000 m^3/day to parts of Baringo and Nakuru Counties. No research has been done to assess the water quality and plant species composition of Chemususu Dam which is maintained by both forest surface run-off and rivers within the 64 Km^2 catchment area. Baseline data on the state of the dam at its early stage is required for future assessment and monitoring. The catchment area of the dam is a highly productive agricultural land, with cultivation being carried out up to the banks of streams draining into the dam. These rivers are also the main source of water for drinking, watering livestock and laundry.

Increasing human population and agricultural activities are the main causes of soil erosion and water pollution. This is further exacerbated by steep slopes within the area, high rainfall (1,200mm annually), deforestation, overgrazing

and poor adoption of soil conservation strategies which contributes to significant impacts on the dam's water quality and its plant species.

Sustainable use of reservoirs is seriously threatened by their declining water quality and storage capacity due to sediments load as a result of poor agricultural practises and land management causing substantial soil erosion and ultimate decline in reservoir capacity. Therefore, proper catchment management strategies should be adopted to enhance the lifespan of water reservoirs and quality (Young *et al.*, 2003).

Degradation is the cause of poor water quality and less water availability. During construction of Chemususu Dam, several acres of forest cover initially earmarked for reservoir clearance were not cleared due to resistance by neighbouring communities who intended to protect their local heritage. However, upon the completion of the erected embankment, several acres of forest cover have submerged, leading to decomposition of organic matter, all these factors effect on water quality and plant species composition. Therefore, the present study was conducted to analyse water quality and to find out the plant species composition within Chemususu Dam.

1.3 Research Questions

1. What are the levels of physico-chemical parameters of water in dam, upstream and downstream rivers?
2. How does the level of physico-chemical parameters of water vary within the dam, upstream and downstream of Chemususu Dam?
3. What is the composition of aquatic plant species in the dam?

1.4 General and Specific Objectives

The main objective was to assess the water quality and to find out the plant species composition of Chemususu Dam, Baringo County, Kenya. The Specific objectives are as follows:

1. To determine physico-chemical parameters of water within Chemususu Dam and rivers upstream and downstream of the dam.
2. To compare the levels of physico-chemical parameters of water from dam, upstream and downstream rivers.
3. To determine the plant species composition within Chemususu Dam.

1.5 Research Hypotheses

H_0: The levels of the physico-chemical parameters within the dam, upstream and downstream rivers are not significant.

H_0: There is no significant variation on the physico-chemical characteristics of water within the dam, upstream and downstream rivers.

H_0: The aquatic plant species composition does not significantly vary with seasons under natural conditions.

1.6 Significance of the Study

The results of this study will be useful as baseline data and to compare the water quality standards according to KEBS and WHO. Information obtained from this research will also be vital in advising the human population living around the catchment area on the appropriate farm practises to increase sustainability of the dam. The results are also of importance to the ministry of water and irrigation and the County Government of Baringo in making informed choice in providing tangible solutions to controlling pollution of water in Chemususu Dam and other related water resources.

1.7 Scope and assumptions of the study

The study was carried out on the inlets of two upstream rivers (Sawich and Barain) 100m and 40m from the dam respectively, Chemususu Dam and the downstream river, 100m from the spillway. Sampling was done for six month and may have not covered the changes occurring over a long period of time. Study was undertaken on the assumption that the points selected on upstream rivers were a representative of what gets into the dam and the sites within the dam represented the whole reservoir.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter covers the reasons for construction of dams, state of dams globally, in Africa and Kenya, contributing factors to water quality in dams, and watershed and its management for water quality have been considered. A review on the physico-chemical parameters and aquatic plants has also been carried out.

2.2 Global State and Reasons for Dam Construction.

Water is one of the most important components of the ecosystem, and all living organisms on the earth require water for their survival, growth and development. There is approximately 70% of water on earth but due to increasing human population, industrialization and use of fertilizers, it is highly polluted with different contaminants (Patil *et al.,* 2012). Therefore, it is necessary that the quality of drinking water should be accessed at regular intervals because contaminated drinking water causes serious health problems and provide habitats for diverse vectors of water borne diseases.

According to (Melakua *et al.,* 2007), the natural condition of the physical and chemical characteristics of rivers are affected by several factors including geology, climate, topography and inputs through rain and groundwater. Surface water pollution with heavy metals is also of concern due to its harm on health and its translocation to food chain. A study on Nairobi Dam showed high levels of Lead, Copper, Cadmium and Nickel in water which is utilised by residence of Kibera slums living adjacent to the dam for domestic and commercial purposes. Major sources of heavy metals in Nairobi dam were car garages, raw sewage, agriculture, industries, construction work and garbage (Ndeda & Manohar, 2014 b)

Anthropogenic factors highly agricultural runoff in catchments, domestic and industrial waste from urban areas influences river systems. Natural water

resources are significantly impacted by damming of rivers. These impoundments turn rivers into lakes influencing physical, chemical, hydrology and biological characteristic including increased stratification, residence time, reduction in turbulence, increase in autochthonous primary production and decreased turbidity. These changes eventually affect the kind of biota existing in the dam and downstream rivers (Thornton *et al.,* 1990).

Dams have been constructed for several reasons including hydropower generation, water supply, flood control, irrigation, navigation and recreation. However, sedimentation and pollution of water are the main challenges on their sustainability. Principally, all sediment (gravel, sand and mud) transported to a reservoir by a river is derived from erosion (Dinar *et al.,* 2001; Skinner *et al.,* 2009). Eroded soil from farms frequently contains large quantities of fertilizers and pesticides that contaminate water resources. Agrochemicals must be removed from public water supplies to make water safe for human consumption (Napier, 2000).

2.3 Contributing Factors to Water Quality in Dams

Rivers are characterized by unidirectional currents with high average flow velocity which varies as a result of the drainage pattern and climatic situation. There is continuous vertical mixing due to the prevailing turbulence and prevailing currents (Chapman, 1992). In reservoirs and lakes, currents are multi-directional with low and average current velocity on the surface. They also experience alternating periods of vertical mixing and stratification which is determined by the depth of water body and climatic condition.

Reservoirs are created by construction of a dam across rivers/streams resulting in impoundment of water behind the dam wall or can be formed naturally when a river diverts to a depression causing accumulation of water. Reservoirs exhibit both riverine and lacustrine characteristics (Chapman, 1992; Thornton *et al.*, 1990) and they range from large impoundments such as Lake Nasser 5,200 km^2 to small dams. According to Thornton *et al.,* (1990), reservoirs

receive water and nutrient inputs from rivers, and their hydrodynamics and basin morphology influence the biological, physical, and chemical characteristics. The riverine effects are dissipated by changes in depth of basins and width along the axis of the reservoir. The quantity and concentration of materials retained in water is also affected by the amount of residence time which varies depending on the basin morphology with a deep and broad basin having a longer residence time compared to shallow and narrow basin.

Studies have shown that there is a change in water quality of dams during the early stages of their formation as observed by Leentvaar, (1975) in Lake Brokopondo which submerged a large portion of rainforest resulting in low levels of dissolved oxygen and acidity resulting in death and reduction in number of fish and other aquatic organisms that were in the river before damming. The chemical aspect of an aquatic environment varies according to climate, local geology, and soil cover (Chapman, 1992). However, several anthropogenic activities have indirect and undesirable effect on aquatic environments and these include uncontrolled and excessive use of fertilizers, pesticides, urbanisation, abstraction of water, deforestation, release of chemical substances from industries, discharge of wastes and leaching of liquids from solid waste dump sites.

Eutrophication of reservoirs leads to algal growth and toxic substances which induce deterioration of the river system, especially downstream. Since dams interrupt the natural continuity of a river, fragmentation of the river ecosystem occurs, with specific ecological consequences (EEA, 2009). Much of the sediments carried into reservoirs become trapped and settles to the bottom. Sedimentation reduces the lifespan of the reservoir and water released is also depleted in quality due to reduced sediment and organic material that would otherwise contribute to the fertility of floodplains and estuaries downstream. This nutrient depletion also leads to a reduction in biodiversity of downstream aquatic habitat.

According to Streeter & Hargrove (2008), sedimentation is a natural phenomenon however, human activities such as cultivation, grazing, deforestation and mining, within a watershed often disturb the equilibrium between materials delivered to a stream. Reservoir sedimentation is a major problem in many parts of the world, causing drastic reductions in storage capacity, and high economic costs for sediment removal (Darghouth *et al.*, 2008; Othman *et al.*, 2013).

2.4 State of Dams in Africa and Impact of Anthropogenic Activities on their Efficiency

Dam construction in Africa is an ancient activity. The Sadd el-Kafara Dam, dates from between 2950 and 2750 BC and is thought to have provided a secure water supply for men and animals engaged in quarrying stone to build monuments for the pharaohs (Warren, 2010). In 1960s, large man-made lakes were created in tropical Africa for power generation and water distribution. These include Lake Kariba on the Zambezi river which began to fill in 1958; Lake Nasser 5,200 km^2 on the river Nile, Lake Volta in Ghana, Lake Kainji in Nigeria, and Lake Cahora Bassa in Moçambique. West Africa has more than 150 of the 1300 large dams spread throughout the continent (ICOLD, 1998). In Africa, dams are being used for the regulation of natural water flows variable according to seasons and between years to meet the demand for industry, navigation, drinking, irrigation, leisure, tourism, fishing and fish farming (Skinner *et al.*, 2009).

However, studies have shown changes in water quality and aquatic species in dams compared to rivers draining to these reservoirs. Early studies on Lake Kariba showed a transitory increase in concentration of plant nutrient especially nitrate, de-oxygenation with sulphide production in hypolimnetic water and the displacement of a rich bush fauna due to the spread of water-fern *Salvinia molesta* over a considerable part of the lake surface (Talling, 2006). In Tanzania, some reservoirs are in danger of losing their storage capacity, due to the high rate of sedimentation (Mihayo, 2004). In 1970s twenty-one small-

scale dams were constructed on seasonal rivers in the Tabora region for irrigation and municipal supply. However, all except seven suffer from serious sedimentation (FAO, 2005). Miundu Dam on the Ngerengere river has also suffered high rate of bilharzia infection and mercury run-off from the gold mines near the dam has polluted the water. The dam is also being rapidly silted due to deforestation in surrounding areas.

2.5 Types of Dams and their Uses in Kenya

Kenya is classified as a water scarce country with only $647M^3$ of renewable freshwater per capita and is characterized by its spatial and temporal variability and extremes of floods and drought (GOK, 2005). Challenges related to water resources management include climate variability and increasing demand for water as a result of development and population pressure.

Dams in Kenya were initially constructed for generation of hydropower and they include Masinga which was commissioned in 1988, Kindaruma in 1981, Kamburu in 1974, Kiambere in 1987, Gitaru in 1999 and Turkwel Gorge Dam, in 1991. The National Water Conservation and Pipeline Corporation continues to construct several dams to increase water supply for the growing population. Several dam sites have been identified for construction of dams and some have been completed or are under construction. They include Badasa in Marsabit County, Umaa in Kitui County, Maruba in Machakos County and Chemususu in Baringo County, which forms the basis of this study. Water Resources Management Authority (WRMA) is charged with the responsibility of managing water resources and catchment areas in Kenya (Gachie, 2013).

Dams that have been constructed in the country to provide a continuous annual supply of water for domestic, commercial and agricultural purposes include; Ndakaini, Sasumua, Ruiru, Ngewa, Kianjjibbe, and Comte dams (Kitur, 2009) among others. In order to manage water resources, it is important to preserve the sustainability of both the natural water and infrastructure resources such as dams and pipelines, which can be achieved by adopting reservoir life cycle

management approach. This allows the country to maximize the benefits from its existing and upcoming dams (GOK, 2005).

2.6 Watershed and its Management for Water Quality in Dams

Proper management of dams will extend the life span of reservoirs by maintaining the water storage capacity, reducing the amount of nutrients entering reservoirs, slowing the eutrophication process and reducing taste and odour problems and associated treatment expenses (Streeter & Hargrove, 2008). Silt deposition resulting from river bank erosion, deforestation, poor land use practices and livestock activities at watering points among other anthropogenic activities contribute to water quality degradation.

Conservation measures that can be implemented at catchment level may broadly be categorized as measures which protect non-degraded areas and reversal measures of degradation. Implementing Best Management Practices (BMPs) that minimize soil exposure and soil particle detachment can reduce soil loss. They include crop rotations, cover crops, conservation tillage, terraces and buffers along stream banks (Young *et al.,* 2003). Each farm enterprise is unique, and encouraging widespread adoption of appropriate BMPs needs to be carried out.

Forested riparian buffers are crucial for maintaining water quality and ecological health in streams that flow through agricultural areas. They protect water quality by reducing bank erosion, filtering out excess nutrients and sediments which drain off adjacent farms. Riparian forests are usually cleared in order to farm the rich floodplain soil, destroying and compromising their viewed as having the most significant impact, in the form of nonpoint source pollution. Protecting water quality and ecological integrity in agricultural watersheds to a greater extent, depends on landowners' decisions about how they manage their land. Conservation practices, such as maintaining riparian buffers, adding grass filter strips along drainage systems and no-till farming,

can minimize the agricultural impacts on nearby water bodies (Young *et al.*, 2003).

2.7 Physico-Chemical Parameters and their Impact on Water Quality

2.7.1 Temperature

Temperature is a measurement of the average thermal energy of a substance. This energy can be transferred between substances as flow of heat. Water temperature can be altered by heat transfer from sunlight, air and thermal pollution (Ayoade *et al.*, 2006). Temperature is an important factor when assessing water quality since it influences several parameters and can alter the physical and chemical properties of a water body.

The metabolic rates and biological activities of aquatic organisms are affected by temperature hence influencing their habitats leading to cool and warm water organisms. Tropical plants exhibit dormancy and restricted growth in water temp below 21 ^{0}C. Temperature also affects photosynthesis and respiration of plants. Photosynthesis of algae will increase with rise in temperature and different species have different peak temperatures for optimum photosynthetic level (Wetzel, 2001). It enhances solubility and toxicity of certain compounds, especially of heavy metals such as lead and cadmium and also influence tolerance limit of organisms.

Temperature of springs is constant and is influenced by temperature of the drainage area. However, as water moves downstream, its temperature approximates the mean air temperature hence the increase during summer and decrease in winter (Lampert & Sommer, 1993). The size of the stream also determines the amount of change in temperature. Streams that pass through lake become warm in summer as the cold water sinks and is replaced by warm epilimnetic water in the outlet stream.

According to Kitur (2009), temperature of water in dam is determined by altitude of the area. Ruiru reservoir which is located in a highland region has

low temperature compared to Ngewa reservoir which is located in lowland area. High temperature in lowlands is as a result of low inflows and limited outflow which enhanced the progressive increase in temperature of water.

Surface water acquire higher temperature through radiant heat of the sun and this was reflected in Bakun reservoir which showed a decrease in temperature with depth (Lee *et al.,* 2012) and Turkwel Gorge reservoir (Kotut, 1998). Temperature increases since solar radiation cause heating up of water molecules. On the other hand, Miheso, (2008) observed that Ngong forest Dam with highest surrounding vegetation cover had low temperature compared to Rasecourse and Karen Dams. In Owen Dam (Oyhakilome *et al.,* 2012), the variations in temperature were due to time and period of sample collection.

2.7.2 pH

pH is affected by photosynthesis and respiration depending on the equilibrium of carbonate-bicarbonate and carbon dioxide (Lampert & Sommer, 1993). When aquatic plants photosynthesise during the day, carbon dioxide is removed from the medium causing an increase in pH while at night, pH declines since respiration (decomposition) of aquatic organisms release CO_2. Similarly, there is an increase in pH levels of warm waters as a result of conversion of carbon dioxide to organic carbon by photosynthesis. This rate may surpass the rate of the discharge of carbon dioxide from organic carbon by respiration (Araoye, 2009).

Studies have shown limited variation in pH values in reservoirs. Motoine River Dams as reported by Miheso (2008), showed a slightly basic state but within the required limits of between 6.5 to 8.5 according to KEBS. The variations within the dams were attributed to animal urine and the respiration of submerged plant ensured neutralization. The difference in pH values of Ruiru, Ngewa, Comte, Kianjjibe and Uhuru reservoirs were attributed to time of sample collection and weather conditions which determined the rate of photosynthesis and respiration.

Mantovo reservoir had median pH values of 8.13 which was attributed to presence of carbonate rocks in the reservoir's drainage basin and the overgrowth of cynobacteria and other primary producers which increased carbon dioxide when they died and are decomposed (Stamenkovic *et al.,* 2009). In Bakun reservoir, low pH values between 5.17 to 5.92 were recorded compared to the inflowing river. The low levels were ascribed to the presence of high levels of carbonaceous matter undergoing decay and releasing acidic products (Lee *et al.,* 2012).

2.7.3 Conductivity

Conductivity is the measure of the ability of an electric current to pass through water. The presence of inorganic dissolved solids such as phosphates, sulphates, nitrates, magnesium, calcium, aluminium, iron and chloride ions in water affect the conductivity levels of water. Temperature also influences conductivity due to its effect on viscosity and mobility of ions.

The amount of dissolved solids in rainwater and geology of an area through which water flows contribute to conductivity of stream or river due to the release of dissolved solids from soils and rocks which water flows over or through (Kitur, 2009 ; Miheso, 2008). Stream passing through urban areas may have high levels of conductivity due to faulty sewer systems autochthonous with pollutants such as nitrates, chlorides, phosphates and heavy metals.

Studies have shown variation in levels of conductivity as shown in the following studies: 160 µS/cm to 200 µS/cm in the Turkwel Gorge Reservoir (Kotut, 1998), 42 µS/cm to 60 µS/cm in Ruiru reservoir, 72 µS/cm to 95 µS/cm in Uhuru reservoir, 94 µS/cm to 166 µS/cm in Comte reservoir, 154 µS/cm to 310 µS/cm at Ngewa reservoir and 232 µS/cm to 356 µS/cm at Kainjjjibe reservoir (Kitur, 2009). Low levels of conductivity occurred during rainy seasons and are attributed to dilution by rainfall whereas its increase during dry seasons is due to evaporation (Kitur, 2009). Water residence time also contributes to change in conductivity with high levels being recorded at

Kianjjibe reservoir in lowland region whose water were being retained for irrigation. Conductivity of Motoine river dams were attributed to the geology of the area and the clay soils in the area which lead to increase in conductivity (Miheso, 2008).

2.7.4 Dissolved oxygen

Dissolved oxygen is essential for biological and chemical reaction as well as a respiratory gas for aquatic organisms. It is also an important indicator of ecological status, water quality, health and productivity of a reservoir (Araoye, 2009; Chapman, 1992). The concentration of dissolved oxygen is determined by photosynthesis, diffusion, aeration, decomposition and respiration (Lampert & Sommer, 1993). The main source of dissolved oxygen in water is photosynthesis since diffusion from air is slow unless under strong turbulence and mixing (Araoye, 2009). The amount of oxygen released and rate of photosynthesis is determined by the abundance of plants and type of species (Araoye, 2009). However, solubility of oxygen decreases with increase in temperature.

In stratified lakes, the epilimnion is warm since it is exposed to solar radiation, and is in contact with the atmosphere and photosynthesis takes place in this layer. Temperature in deeper layer is dependent on the temperature exchange, usually determined by water clarity and depth of mixing (Lampert & Sommer, 1993). Dissolved oxygen in the epilimnion remains high due to the contact with air required for aeration and by-products of photosynthesis. In metalimnion, if light penetrates beyond the thermocline and photosynthesis occurs in these strata, it will have high levels of dissolved oxygen. However, in eutrophic water, the respiration of organisms can deplete dissolved oxygen levels. In the hypolimnion, bacteria and fungi use dissolved oxygen to decompose organic material from dead algae and other organisms that sink to the bottom leading to low dissolved oxygen levels. The concentration in deep water depends on circulation patterns and the depth since oxygen supply is estimated from volume of hypolimnion multiplied by the oxygen concentration

immediately after circulation, quantity of decomposable matter and water temperature (Lampert & Sommer, 1993).

Studies have shown trends in dissolved oxygen of newly established dams. Chapman, (1992) states that de-oxygenation is experienced at first inundation of tropical reservoirs due to the high oxygen demand of the decaying submerged carbonaceous materials until a more stable aquatic regime is achieved (Stamenkovic *et al.,* 2009). According to Lee *et al.*, (2012), there was a reduction in levels of dissolved oxygen with increase in depth in Bakun reservoir and Lake Brokopondo (Leentvaar, 1975). Depletion of oxygen was due to decomposition of submerged vegetation which were not removed during impoundment and the location of these reservoirs in tropical areas also accelerated decomposition resulting in de-oxygenation.

The concentration of oxygen may also be reduced in surfaces water owing to lower saturation limits in warm water and low transparency (Stamenkovic *et al.,* 2009). Oxygen in rivers varies from source to downstream with the spring recording low levels since it is from underground. As it flows rapidly, the deficit is overcome by the atmospheric exchange. Presence of organic matter from livestock (Anyona *et al.,* 2014) and their erosion from farmlands cause reduction in dissolved oxygen levels. This is replaced by photosynthesis of rooted plants and attached algae causing fluctuation in dissolved oxygen levels with highest concentrations during the day (Sunkad, 2013; Deshmukh & Urkude, 2014; Lampert & Sommer, 1993).

In Mantovo reservoir, Dissolved Oxygen values were between 1.2 mg/l and 5.7 mg/l in the upper surface, while in the deepest parts of the lake they varied between 0.9 mg/l and 3.4 mg/l. The low levels of dissolved oxygen were due to the high levels of organic matter in the reservoir since the soil and vegetation were not removed during the infilling of the reservoir. Considerable influence was also exerted by the Kriva Lakavica River, which carried high content of sediments, silt, nutrients and suspended matter into the Mantovo Reservoir (Stamenkovic *et al.,* 2009). Low levels of dissolved oxygen in dams have also

been reported in Bakun reservoir (Lee *et al.,* 2012) and Lake Brokopondo (Leentvaar, 1975). On the other hand, Kitur, (2009) recorded high levels of dissolved oxygen with mean values of between 6.3 mg/l in Ngewa to 9.0 mg/l in Kianjjibbe reservoirs.

2.7.5 Turbidity

Turbidity is a measure of suspended material in water comprising of organic and inorganic materials such as sediment, algae, and other contaminants (Thornton *et al.*, 1990). In humid areas, suspended solids are often less than in arid regions though its level can raise with increase in stream flow. Fast flowing water erodes banks and washes off loose soil. When the water slows down, suspended solids settle down and can reduce the life capacity of dams (Chapman, 1992).

Pesticides and bacteria get attached to suspended particles making them to be easily transported ending up in water bodies consequently causing pollution. High turbidity prevents light penetration, hence decrease in productivity (Lee *et al.*, 2012). Viruses and protozoa also get attached to particulates, and removal of turbidity by filtration will significantly reduce microbial contamination in treated water (WHO, 2011).

Studies on causes of turbidity in Bakun reservoir and Motoine river dams showed that turbidity was predominantly due to suspended solids from the eroded soil transported through surface runoff due to deforestation in upstream watershed (Lee *et al.,* 2012; Miheso, 2008). Watering of animal in rivers also contribute to increase in loose soil which gets eroded (Mutisya, 2004). Owen Dam had values greater than recommended 5NTU for drinking water with high values being recorded during the rainy season (Oyhakilome *et al.,* 2012). On the other hand, Miheso, (2008) recorded values of between 25.15 NTU to 51.75 NTU due to the elevated agricultural activities within the vicinity of dams.

2.7.6 Total Dissolved Solids

Total dissolved solids represent the total concentration of dissolved substances in water. It is made up of inorganic salts and organic matter. Common inorganic salts that can be found in water include potassium, calcium, sodium and magnesium cations which are positively charged and carbonates, nitrates, bicarbonates, chlorides and sulphates anions which are negatively charged.

2.7.7 Nitrates

Nitrates are naturally found in small amounts in water due to its presence in igneous rock. However, increase in their levels is as a result of anthropogenic sources such as runoff containing nitrate based fertilizers, improperly treated wastewater, faulty septic systems and from decaying organic matter area with high number of confined animals (Ansar & Khad, 2005). Metabolic waste, excretory products and decaying organic matter further add organic nitrogen which are mainly oxidized by nitrifying bacteria releasing nitrates as by-product thus contributing to increase in nitrate levels in water bodies (WHO, 2011; Deshmukh & Urkude, 2014). Excess amounts of nitrate in a water body cause eutrophication which is detrimental due to its impact on the levels of dissolved oxygen (Yanamadala, 2005). Nitrates also regulate productivity of phytoplankton and an excess in surface water is taken as a warning for algal bloom.

Changes in the level of nitrate in water are caused by different factors including uptake by phytoplankton and denitrification by bacteria which contributes to the reduction in its level (Melakua *et al.,* 2007; WHO, 2011). Such behaviour explains the discrete concentration peaks with minimal carry-over to the immediate downstream sampling sites.

Nitrate toxicity in humans is due to its reduction to nitrite which oxidises haemoglobin (Hb) to methaemoglobinaemia (metHb) which is not able to transport oxygen to body tissues. Presence of nitrate in drinking water at concentrations greater than 50 mg l^{-1}could cause methaemoglobinaemia in

babies aged less than six months (WHO, 1998; Panneerselvam *et al.,* 2013). This occurs more in such infants due to deficiency of metHb reductase and presence of high levels of foetal Hb which gets oxidised easily to metHb. Other susceptible groups are pregnant women and people with deficient metHb (Craun *et al.,* 1981). Nitrate in the alimentary canals of humans may also react with amines to form carcinogenic nitrosamines, which could contribute to the development of gastric cancer.

2.7.8 Phosphates

Phosphate is often present in low quantities in most rivers and presence of high levels is often as a result of anthropogenic activities (Pontivs, 1990). Phosphates arise from run-off from farms, municipal sewage in which most phosphate will be as a result of domestic detergent and silage effluents containing organic phosphate (Melakua *et al.,* 2007). An increase in accumulated phosphate in soil can result from intensive fertilization of farms and grazing fields (Ansar & Khad, 2005). This accumulation has a major impact on the transportation of phosphates in surface run-off. Long-term excessive manure or slurry application can result in the saturation of soils with nutrients, especially phosphates which eventually gets eroded to water bodies.

Build-up of phosphates contributes to dilapidation of surface water as a result of accelerated eutrophication (Shabalala *et al.,* 2005). During eutrophication, excessive growth of hydrophytes is experienced. Consequences of eutrophication for humans are bad taste and odour in public water supplies and production of cyanobacterial toxins (European Commission, 2002; Deshmukh & Urkude, 2014) which can threaten animal and human health, infilling or clogging of irrigation canals with aquatic weeds, loss of recreation use due to weed infestations and noxious odours, and economic losses due to the disappearance of species targeted in commercial and sport fisheries (UNEP, 2008; Jimoh *et al.,* 2003).

Some cynobacteria species produce cynotoxins which are toxic secondary metabolites. There are different categories of these cynotoxins; hepatotoxins affecting the liver, dermatoxins affecting skin and neurotoxins affecting nervous system (USEPA, 2012). High levels of cyanotoxins present in drinking water and recreational water may cause a wide range of symptoms in humans including headaches, fever, blisters, muscle and joint pain, diarrhoea, allergic reactions, stomach cramps, mouth ulcers and vomiting. These effects can occur within minutes to days after exposure. In severe cases, liver failure seizures, respiratory arrest and rarely death may occur (USEPA, 2012).

Study of Mae Kuang Udomtara Dam reservoir in Chiang Mai found proliferation of the blue-green alga *Microcystisa eruginosa*, which secretes the potent liver toxin microcystin. The explosive growth of these algae is related to nutrient enrichment, particularly phosphates (Tirado *et al.*, 2008).

2.7.9 Sulphates

Various mineral salts found in soil contain sulphates. They form salts with a variety of elements including magnesium, sodium, barium, calcium and potassium. Sulphate is commonly found in most water supplies since it is leached from the soil and is an aesthetic parameter. Other sources of sulphate are waste from industries using sulphate such as pulp, tanneries, textile, mining and smelting. Decaying animal and plant matter, chemical products including ammonium sulphate fertilizers and treatment of water with aluminium sulphate (alum) also introduces sulphate into a water supply (WHO, 2004).

Anthropogenic activities such as combustion of fossil fuels also emit sulphur oxides to the atmosphere, some of which is converted to sulphate (WHO, 2004). Sulphate-reducing bacteria are often encountered in water supplies and these bacteria produce hydrogen sulphide causing an unpleasant taste and odour. Sulphate salts and hydrogen sulphide increase the corrosive properties of water. High concentrations of sulphate may interfere with the efficiency of chlorination in some water supplies. High levels of sulphate in water cause

laxative effect on people using it for the first time and tend to impact on the taste. However, its effects tend to vary with persons depending on the time taken to be accustomed.

2.7.10 Chloride

Chlorides are present in both fresh and salt water and are widely distributed in nature as salts of sodium, calcium and potassium. High amounts of chloride in water cause a salty taste whose threshold is dependent on the associated cation (WHO, 2003). In clean surface water, chloride levels may sometimes be less than 2 mg/l. However, chlorides may considerably be increased when chlorine is used during water treatment process.

There are several other causes of chloride in water and they include water softeners, animal feed additives, pesticides, concentration and dissolution of salts resulting from irrigation with deep groundwater and fertilizers since potassium in most fertilizers is in form of potassium chloride (Mullany *et al.,* 2009). In public water supply, chloride levels are limited to 250 mg/l. Chlorides impact a salty taste to water and this occurs when chlorides associated with sodium are present and are more than 250 mg/l.

2.7.11 Carbonates

Hardness and alkalinity of water are influenced by the presence of carbonates and bicarbonates. Carbon dioxide arises from the atmosphere and biological respiration. The relative amount of carbonates, bicarbonates and carbonic acid are related to pH. Bicarbonate is found as the dominant anion in most surface waters as a result of weathering of rocks combined with the pH range of surface waters between 6-8.2. Carbonate is uncommon in natural surface waters because they rarely exceed pH of 9.0.

2.8 Plant species composition and their impacts on water bodies

Phytoplanktons are natural inhabitants of all water bodies and play a major role in the ecosystem as primary producers (Madsen & Wersal, 2012). They inhabit

the upper euphotic layer of water and form the most important factor in producing organic matter. They are microscopic, unicellular and multicellular organisms which form colonies visible with naked eyes as minute green particles. They are usually dispersed in water causing considerable turbidity if density increases (Madsen & Wersal, 2012). Microscopic analysis of water sample collected from lakes, streams and other water bodies determines the diversity of algal species and indicates warning signs of deteriorating condition (APHA, 1999).

Hydrophytes play a significant role in an aquatic ecosystem and they are classified into four categories namely (i) free floating, (ii) attached-floating (iii) submerged and (iv) emergent species. These types are important in food chain, provide microhabitats useful for protection against predators and laying eggs, substrates for aquatic organisms including invertebrates, algae and bacteria and also contribute to nutrient cycling (Cristina *et al.,* 2014). In an aquatic system polluted with heavy metals, hydrophytes uptake them, and extract large concentrations of heavy metals into their roots and translocate metals to surface biomass (Ndeda & Manohar, 2014 a).

2.8.1 Causes of changes in plant species composition in water bodies

Productivity of phytoplanktons and macrophytes are determined by the interaction of chemical, biological and physical characteristic of water. The environmental variables such as light, temperature, intensity of turbulent, benthic feeders, altitude, seasons and time of day also affects their composition (Grabowska, 2012). Nutrient load contributes to nutrient enrichment which affects the productivity and composition leading to change in function and structure of the ecosystems. The type of nutrients entering the reservoir reflects on the watershed characteristic including land use, morphology, and soil types.

Levels of nutrients in a natural lake or dam are reflected in the biomass and abundance of phytoplankton. In Lake Ogelube, the low levels of euglenophyceae indicated low pollution by organic materials, whereas the predominance of desmids signified oligotrophic conditions (Regina *et al.,*

2012). In many tropical countries, eutrophication is taking place as a result of nutrient inflows from human activities in watersheds. Increase in primary productivity has been observed in several lakes as well as dams, such as Lake Victoria and Hartbeespoort Dam in which levels of primary productivity has risen compared to previous study reports due to high nutrient inflows.

According to Regina *et al.,* (2012), water temperature determines the type of phytoplanktons existing in the water body. Result of temperature controlled experiments in phytoplankton cultured in water samples of Lake Chivero, showed that as water temperature increase, algal succession follows a progression from Bacilliarophyceae to Chlorophyceae to Cynophyceae. During summer/dry season, the growth of Cynophyceae members dominated in comparison to Chlorophyceae.

Freshwater micro plankton comprise of species with short life cycles, strongly affected by seasonal fluctuation of abiotic factors. Each algal species has a specific niche based on its physiological requirements and the constraints of the environment. It has also been noticed that phytoplankton succession depends particularly on light, temperature, nutrient availability and mortality factors through parasitism and by zooplankton (Nasser, 2013 a&b).

The habitat and environmental conditions over time determine the existing community of macrophytes in a given area. Urban reservoirs with increasing eutrophication of water bodies often results in high number of macrophytes (Sidinei *et al.,* 1999). The formation of aquatic plants especially in reservoirs is influenced by the existence of shallow surroundings and high levels of nutrients. However, the nutrient level and the size affect the level of composition and extent of occurrence of macrophytes. High levels of aquatic weeds can be problematic by hindering navigation, recreational activities impede drainage and cause chocking of irrigation channels, rivers and dams (Araujo *et al.,* 2012).

Literature review summary

The physico-chemical parameters of water are important in determining the quality of water since their levels are constantly changing due to increase in anthropogenic activities. The most significant step in solving water pollution problems is the knowledge of the status of water quality of water resources through regular monitoring of the selected water quality parameters. The knowledge on the impacts of anthropogenic activities contributes to creation of awareness and prevention of further degradation. There is need to monitor water quality of this newly constructed dam since its main purpose is to provide water for human consumption. Very little information is available on dams located in agricultural areas but scattered data are available on hydropower dams in Kenya.

Plant species composition studies in dams have been conducted to determine the potential for fish yields and productivity. Some species of phytoplanktons pose a potential threat to water quality due to discharge of toxins to water body and are harmful to human health and life. Water quality also affects the composition of micro and macro hydrophytes. Therefore, the present research work has been conducted as baseline data for future monitoring and auditing to compare the water quality, composition of species, their succession and zonation of Chemususu Dam.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Area

Chemususu Dam is the study area and lies between latitude 0°05' 16.34" N and longitude 35°37' 59.00" E at an altitude of 2480 meters above the sea level. The dam is surrounded by Lembus forest and approximately covers 95 hectares. It is located 17.5 km west of Eldama-Ravine town and 245 km North West of Nairobi the capital city of Kenya (*Fig. 3.1).*

Chemususu Dam *(Plate 2)* is in Lembus Kwen county assembly ward, Koibatek sub-county in Baringo County, bordered by Turkana and Samburu Counties to the North, Laikipia County to the East, Nakuru and Kericho Counties to the South, Uasin Gishu County to the South West, Elgeyo Marakwet County to the West and West Pokot County to the North West.

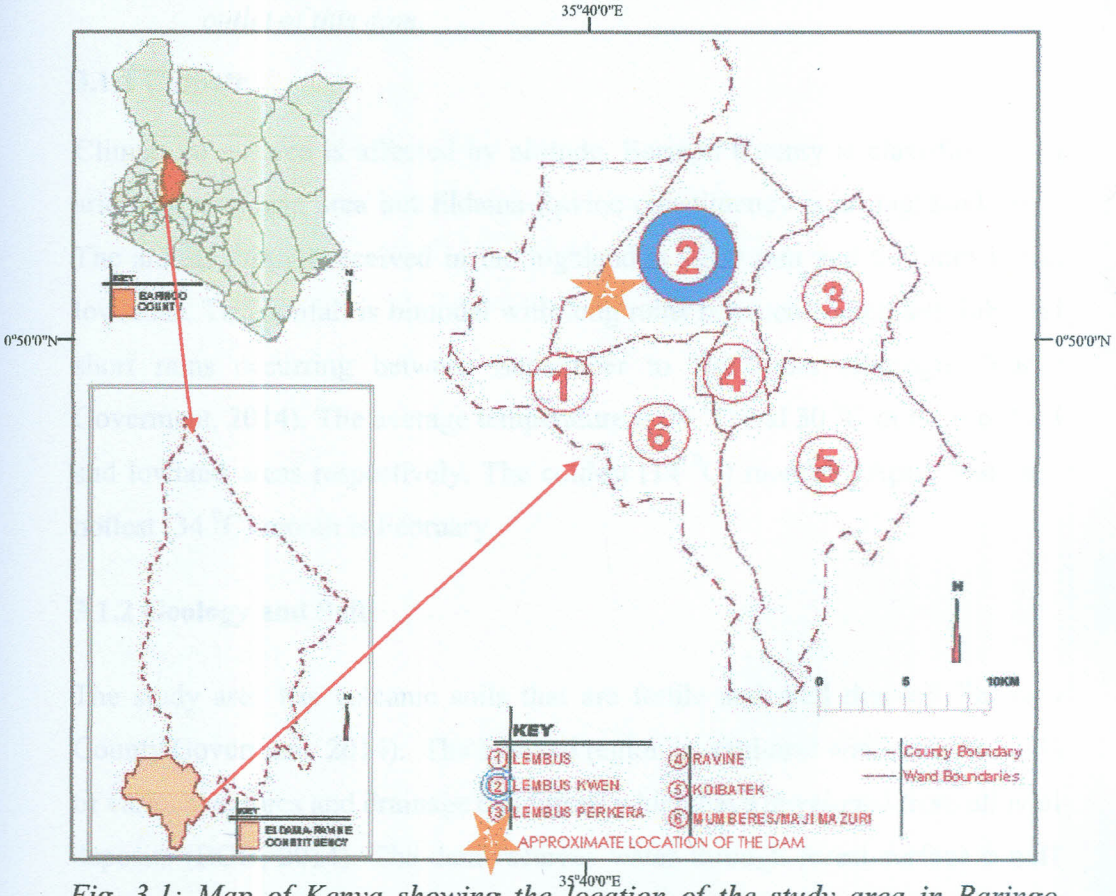


Fig. 3.1: Map of Kenya showing the location of the study area in Baringo County, Eldama-Ravine Constituency, Lembus Kwen Ward (Source: Baringo county plan, 2014)

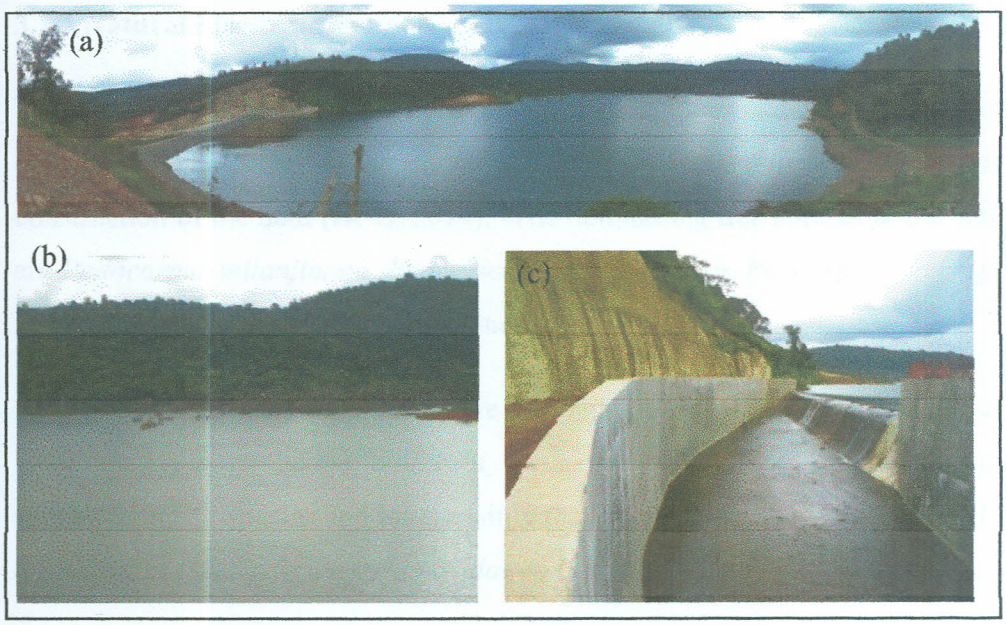


Plate 2: (a) Shows the picture of the study area; Chemususu Dam (b) submerged vegetation due to construction of dam and (c) Manmade outlet of this dam.

3.1.1 Climate

Climate of an area is affected by altitude. Baringo County is classified as an arid and semi-arid area but Eldama-Ravine constituency is an highland zone. The annual rainfall received in the highland is 1200 mm and 600 mm in the lowlands. The rainfall is bimodal with long rains between March and July and short rains occurring between September to November (Baringo County Goverment, 2014). The average temperature is 24 ^{0}C and 30 ^{0}C in the highland and lowland areas respectively. The coldest (14 ^{0}C) month is April while the hottest (34 ^{0}C) month is February.

3.1.2 Geology and Soils

The study area has volcanic soils that are fertile and well drained (Baringo County Goverment, 2014). The lowland region is semi-arid with complex soils of various textures and drainage conditions which have developed from alluvial deposits (BCG, 2014). The dam receives water through forest surface runoff and from rivers Sawich and Barain which originate from Morkisis and Tugumoi hills respectively.

3.1.3 Natural Flora and Fauna

The natural flora in the area comprises of both indigenous and exotic trees. The dam area had several indigenous trees which were deforested during the construction of the dam (BCG, 2014). The dominating tree species in the area are *Podocarpus milanjianus, Juniperus procera, Olea sp, Ficus sp, Prunus sp, Dombeya sp, Varonica auriculifera,* and *Euclea sp.*

The common fauna in the forest are baboons, *Colobus guereza* (columbus monkey), *Lepus sp* (hares), buffaloes, *Sylvicapra grimmia* (common duikers), several butterfly species and birds mainly the Ploceidae *sp* (weavers), *Hirundo atrocaerules* (swallows) and *Passaridae sp* (sparrows).

3.1.4 Socio-economic Activities

The main socio-economic activity is agriculture (mixed farming) which contributes 80% of the generated income. The cultivated crops in the area are potatoes *(Solanum tuberrosum)*, maize *(Zea mays)*, beans *(Phaseolus sp)*, cabbages *(Brassica oleracea var. capitata)*, spinach *(Spinacia oleracea)*, indigenous vegetables, onions *(Allium sp)*, green peas *(Pisum sativum)*, carrots *(Daucus carota subsp. sativus)* and fruits including passion *(Passiflora edulis)*, bananas (*Musa sp*), oranges *(Citrus sinensis)*, lemon (*Citrus limon*), avocadoes (*Persea americana*), and pears *(Pyrus sp).* Animal reared in the area consist of dairy, poultry and bee keeping. Other economic activities in the area include quarrying and charcoal burning which are practised in small scale (BCG, 2014).

3.1.5 Population

The population size of Baringo County is 555,561 consisting of 279, 081 males and 276,480 females. The County has an inter-census growth rate of 3.3% which is above the national average of 3% and is projected to increase to 723,411 in 2017 (GOK, 2010). Lembus Kwen ward has a population of 20, 207 with an area of 178.01 km^2 (BCG, 2014).

3.2 Study design

The study design is descriptive survey. Laboratory procedures were used to obtain data on the levels of physico-chemical parameters. Phytoplanktons were observed with the help of a compound microscope and taxonomic keys were used to confirm the macrophytes and phytoplanktons.

3.2.1 Selection of the study site

The dam was purposely selected since it is new and baseline information is required for future auditing and assessment. This is the first study to be conducted to determine the state of the physico-chemical parameters and plant species composition after infilling.

3.2.2 Selection of the Sampling points

Water samples were collected from six sampling points *(Table 3.1& fig 3.2)*. Sawich and Barain rivers were purposely selected because they are the main rivers flowing into the dam. Sampling points were randomly selected at approximately 100m to the inlet in Sawich river (C1) and 40m (C2) in Barain river in accessible areas closest to the dam inlets to get a representative sample of the water getting into the dam.

Table 3.1: Sampling Stations, Location and GPS coordinates

Location	Sampling station	GPS coordinates
Inlet (River Sawich)	C1	0°6.012'N 35°36.285'E
Inlet (River Barain)	C2	0°6.024'N 35°37.082'E
Chemususu Dam	D1	0°5.639'N 35°37.159'E
	D2 — C3	0°5.402'N 35°37.805'E
	D3	0°5.335'N 35°37.982'E
Out flow (River Chemususu)	C4	0°5.273'N 35°38.138'E

Within the dam, two points were randomly selected along the accessible periphery. Sampling point D1 was between the two inlets in the Northward side while D2 was far from the inlets towards the Eastern side. Sampling point D3 was along the dam wall on the Southern part and this point was far from influence of inlets, animals and bank erosion. Accessibility of the dam was made difficult by its location within Lembus forest, steep slopes along some boundaries and lack of a safe means which made it difficult to sample water at the centre of the dam and other edges. For out flowing water, one point was selected 100m from the spill way so as to reduce any dilution from forest runoff and farmlands *(Fig. 3.2).*

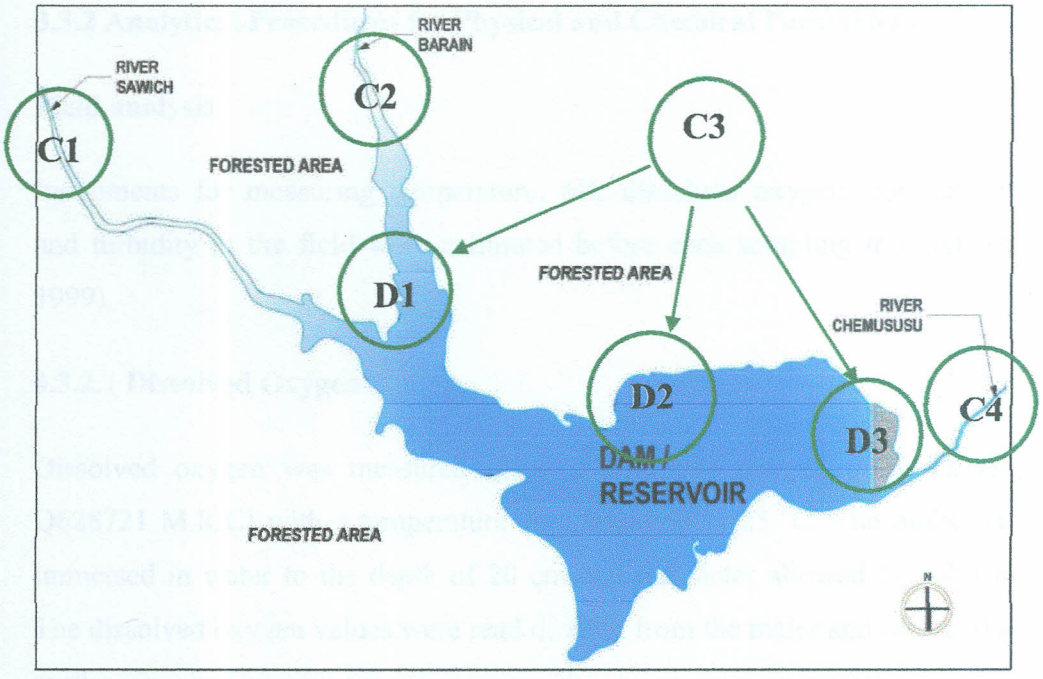


Fig. 3.2: Shows sampling stations for dam, upstream and downstream rivers during sampling period August 2014 to January 2015.

3.3 Data Collection

3.3.1 Water Sampling Procedure and Storage

Physico-chemical parameters analysed to monitor the water quality were pH, temperature, turbidity, dissolved oxygen, conductivity, total dissolved solids, nitrates, phosphates, sulphates, carbonates and chlorides.

Water was sampled once per month for six months (August 2014 to January 2015). The water sample holding bottles were thoroughly washed and rinsed with distilled water in the laboratory. In the field, all the bottles were rinsed with sample water from each sampling station before the actual sample collection. Water from the rivers was collected midstream while in the dam at 2m from the edge. Water samples were collected 20 cm below the water surface using a water scooper and transferred to two 500 ml plastic bottles at each sampling station and firmly corked. Water samples for chemical analysis were fixed using 0.2M H_2SO_4 then firmly corked. They were kept in an ice box ready to be transported to the laboratory for analysis.

3.3.2 Analytical Procedures for Physical and Chemical Parameters

Field analysis

Instruments for measuring temperature, pH, dissolved oxygen, conductivity and turbidity in the field were calibrated before each sampling trip (APHA, 1999).

3.3.2.1 Dissolved Oxygen

Dissolved oxygen was measured using a dissolved oxygen probe (model Q628721 M.R.C) with a temperature compensation at 25 ^{0}C. The probe was immersed in water to the depth of 20 cm and the meter allowed to stabilise. The dissolved oxygen values were read directly from the meter and recorded in mg/l.

3.3.2.2 Temperature

Temperature was measured using a centigrade temperature sensor of the dissolved oxygen probe. The probe was immersed in water to a depth of 20 cm and the readings were allowed to stabilize and later recorded.

3.3.2.3 pH

pH was measured using a pH meter (model Q640629 HANNA). The pH meter probe was immersed in water and allowed to stabilize before taking the reading.

3.3.2.4 Conductivity

Electrical conductivity was measured with a conductivity meter probe (HI 9033 HANNA) with a temperature compensation at 25 ^{0}C. The probe was lowered into the water and allowed to stabilize before conductivity was recorded in µS/cm.

3.3.2.5 Turbidity

Turbidity meter model number (2100P HACH) was used to measure turbidity. The sample cell was filled with water to the marked line and capped. It was wiped and inserted in the instrument cell compartment so the orientation mark aligns with the orientation mark in front of the cell compartment, then the lid was closed. The range was selected by pressing range key and turbidity was read and recorded in Nephelometric Turbidity Units (NTU).

Laboratory Analysis

3.3.2.6 Total Dissolved Solids (TDS)

TDS were measured gravimetrically. An empty and dry evaporating dish was weighed using a weighing balance Sartorius (model AZ124). A well mixed 100 ml water samples were filtered through 47 mm 541 Whatman diameter filter paper and placed in the evaporating dish. The dish was placed in a hot plate and evaporated to almost dryness. It was then placed in an oven at 105 ^{0}C and allowed to evaporate until constant mass was obtained. The dish was removed and placed in a desiccator to cool. The dish was weighed and the weight of TDS was calculated (APHA, 1999).

3.3.2.7 Nitrates (NO_3^-)

Nitrates concentration were determined using 50 ml of each water sample which was well mixed, measured and put into 100 ml beakers. Then 1ml of concentrated hydrochloric acid was added to the samples. Nitrate stock solution was prepared by dissolving 0.712 g of potassium nitrate salt in distilled water and then diluted to 1000 ml mark. A series of nitrate working standards of 1 mg/l, 5 mg/l and 10 mg/l were prepared and used to calibrate the UV/VIS spectrophotometer T80+ machine at 220 nanometers (nm). The concentration of nitrates in mg/l was determined by running the samples in the calibrated UV/VIS spectrophotometer (APHA, 1999).

3.3.2.8 Phosphates (PO_4^{3-})

Water samples were digested using sulphuric acid-nitric acid method (APHA, 1999). Portion of 100 ml of sample water was measured and put into 250 ml beakers. A volume of 5 ml of concentrated nitric acid and 1ml of concentrated sulphuric acid was added. Samples were then heated on hot plate and evaporated to a volume of about 2 ml and allowed to cool before adding 20 ml of distilled water. The pH of the samples were then regulated using sodium hydroxide solution and concentrated hydrochloric acid into ratio 1:1 using phenophthaline as indicator (faint pink colour). The samples were then topped up to the 100 ml mark.

Phosphorous stock solution was prepared by dissolving analar grade 0.2192g of di-ammonium hydrogen phosphate in distilled water in 1000 ml volumetric flask and the volume adjusted to the mark. Standard solutions of 1 mg/l, 5 mg/l and 10 mg/l were then prepared from stock solution. A volume of 10 ml of the digested samples and standards were pipetted into separate 100 ml beakers and 25 ml of distilled water and 10 ml of molyb divanadate buffer were added to each sample. Molyb divanadate solution was prepared by dissolving 0.2197 g of ammonium metavanadate in 400 ml of 1:1 nitric acid and 50 g of ammonium molybdate in 400 ml of distilled water, solution was then mixed and volume adjusted to 1 litre with distilled water.

The samples and standards were allowed to stand at least for ten minutes before calibrating the UV/VIS spectrophotometer T80+ at 430 nm using standard solutions. The concentration of phosphorous were determined by running the samples on the calibrated UV/VIS spectrophotometer and recorded in mg/l (APHA, 1999).

3.3.2.9 Sulphates (SO_4^{2-})

Sulphate standards of 5 mg/l, 10 mg/l, 20 mg/l and 40 mg/l were prepared using sulphate stock solution then 10 ml of sulphate buffer and a spoonful of barium chloride were added to each sulphate standard and stirred for 60 sec at a constant speed. The UV/VIS spectrometer T80+ was calibrated at a wavelength of 420 nm using the prepared standards. The water samples were shaken thoroughly and 50 ml was measured and transferred into different beakers. The samples were treated by adding 10 ml sulphate buffer and barium chloride and stirred for 60 sec at constant speed. The sulphate concentration in mg/l was obtained by running the samples on the calibrated UV/VIS spectrophotometer (APHA, 1999).

3.3.2.10 Chlorides (Cl^-)

Samples were thoroughly shaken and 50 ml was measured and placed in beakers. 1 ml of potassium dichromate solution (indicator) was added to each sample and titrated with silver nitrate (0.014N $AgNO_3$) until the colour changed to orange and the titre reading of the sample was taken (APHA, 1999).

$$Cl^- \text{ mg/l} = \frac{(A-B) \times N \times 35.45}{\text{ml water sample}}$$

Where: A= Titre of sample, B= Titre of blank, N= Normality of $AgNO_3$ (0.0141N)

3.3.2.11 Carbonates (CO_3)

The samples were thoroughly shaken and 50 ml of each sample was measured and placed in different beakers. It was titrated with 0.02 N sulphuric acid to a pH of 4.5 and the titre reading was taken. Carbonates were calculated as:

$$CaCO_3 \text{ mg/l} = \frac{\text{Titre x } 1000}{\text{Volume (50)}}$$ (APHA, 1999)

3.4 Sample collection and identification of plant species

Macrophytes were collected from three sampling stations D1, D2 and D3 of the dam. To keep track of macrophytes along the dam, field notes corresponding to each plant was recorded including date, location, flower colour, plant size and habitat information (Elzinga *et al.,* 2001). Whole plant or shoots of macrophytes were randomly collected along the periphery of the dam from each sampling point and were placed in a clear polythene bags for identification.

Water samples for phytoplankton identification were scoped 20 cm below the surface of water using a 2 litre water sampler, passed through plankton net and transferred into 50 ml plastic containers. The samples were preserved using 4% formalin (APHA, 1999) and then transported to Kenyatta University Plant Sciences Department Laboratory. The water samples for phytoplankton identification were mixed and a drop was placed in the slide for observation using an Optica compound microscope at x10 magnification. Phytoplankton species were confirmed using taxonomic keys (Needham & Needham, (1972); Bronmark & Hansson, 2005; Guiry, 2012).

3.5 Data Analysis

The data obtained on the levels of physico-chemical parameters was subjected to statistical analysis using computer package SPSS version 21. Paired t-test was used to test the hypothesis. The data was also presented in form of graphs and tables.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Physical parameters of water quality of Chemususu Dam, upstream river inlets and downstream river

The physical parameters measured during the study period were temperature, pH, turbidity, conductivity, dissolved oxygen and total dissolved solids of inflowing rivers Sawich (C1) and Barain (C2), Chemususu Dam (C3) and out flowing river (C4).

4.1.1 Temperature

Temperature recorded during the study showed modest variations *(Fig 4.1)*. Temperature of C1 (River Sawich) ranged from 14.2 °C to 20.5 °C; in C2 (River Barain) it ranged between 14.1 °C to 20.6 °C; 20.2 °C to 23.5 °C in C3 (dam) and 19.1 °C to 22.1 °C in C4 (River Chemususu). The mean temperatures ranged from 17.02±1.10 °C in station C1 to 21.48±0.61 °C in C3 *(Table 4.1)*. The highest temperature of 23.5 °C was recorded in C3 in January.

Table 4.1: Mean values of physical parameters and Median recorded in Chemususu Dam, inlet and outlet of rivers during the study period (August 2014 to January 2015)

Parameter	C1	C2	C3(D1,D2,D3)	C4
Temperature (°C)	17.02±1.10	17.05±1.15	21.48± 0.61	20.48±0.50
pH	6.88±0.24	6.89±0.22	6.77±0.12	6.87±0.16
Turbidity (mg/l)	94.82±16.78	44.28±6.34	3.12±0.17	4.15±0.63
Conductivity (µS/cm)	67.48 ±4.10	63.67 ± 4.60	81.16±4.13	79.2± 3.66
Dissolved Oxygen (mg/l)	6.09±0.33	6.1±0.12	4.2±0.76	4.73±0.76
Total Dissolved Solids (mg/l)	181.7±31.53	131.5±30.34	115.22±5.41	111.5±4.99

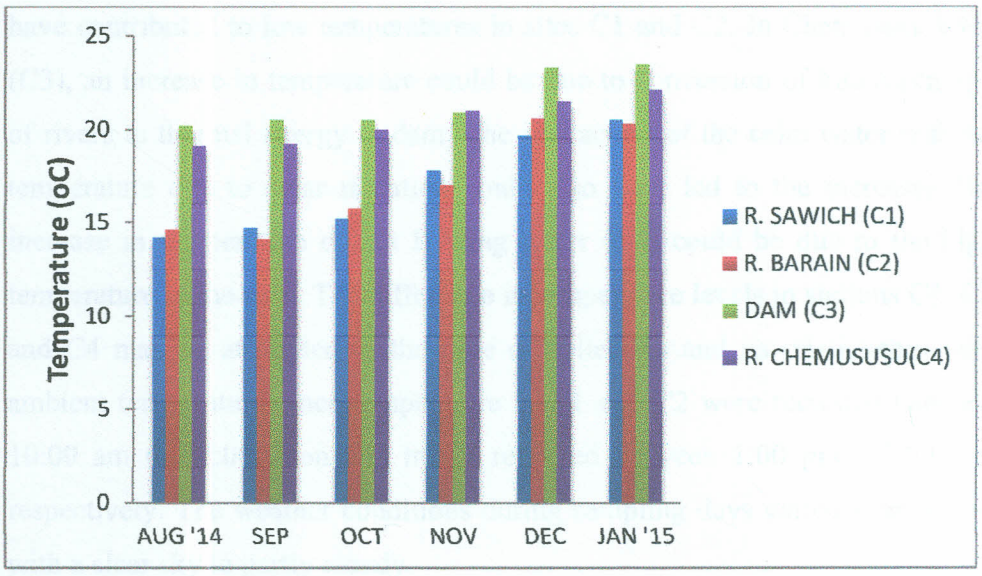


Fig 4.1: Monthly values of temperature (^{0}C) in upstream rivers (C1&C2), dam (C3) and downstream river (C4) during the study period (August 2014-January 2015) within the study area.

Using paired t-test, the mean temperature recorded was significantly different between temperature in upstream rivers and the dam with C1 and C3 (P=0.001, T= -7.889); C2 and C3 (P= 0.001, T= -7.613). There was also a significant difference between the temperature of upstream rivers and out flowing river with C1 and C4 (P= 0.002, T= -5.665), and between C2 and C4 (P= 0.004, T= -5.013).

A variation in water temperature is influenced by meteorological aspects such as humidity, solar radiation and rainfall (Subehi & Fakhrudin, 2010). Surface water temperatures have also been found to follow the ambient air temperature (Kitur, 2009; Subehi & Fakhrudin, 2010 and Deshmukh & Urkude, 2014). Inflows from tributaries and the surrounding environments such as vegetation cover also affect the temperature of water in dam (Miheso, 2008; Lee *et al.*, 2012 and Kitur, 2009).

The significant differences in temperature can be attributed to ambient temperature conditions. The location of the dam is in an highland region at an altitude of 2,480 meters above sea level. The inlet Rivers also originate from higher altitude areas and in some sections they flow under forest which could

have contributed to low temperatures in sites C1 and C2. In Chemususu Dam (C3), an increase in temperature could be due to conversion of kinetic energy of rivers to thermal energy in dam. The interaction of the calm water with air temperature due to solar radiation could also have led to the increase. The increase in temperature of out flowing water (C4) could be due to the high temperature in the dam. The difference in temperature levels in stations C1, C2 and C4 may be attributed to the time of collection and its relationship with ambient temperature since temperature in C1 and C2 were recorded between 10:00 am to 12:00 noon and in C4 recorded between 1:00 pm - 3:00 pm, respectively. The weather conditions during sampling days varied from sunny with a clear sky to partly cloudy.

4.1.2 pH

The pH values were within the normal range during the study period *(Fig 4.2)*. These values ranged from 6.2 to 7.71 in C1, 6.4 to 7.54 in C2, 6.47 to 7.34 in C3 and 6.54 to 7.67 in C4. Median pH values of 6.88±0.24, 6.89±0.22, 6.77±0.12 and 6.87±0.16 were recorded in C1, C2, C3 and C4 respectively *(Table 4.1)*. The highest pH value of 7.71 was recorded in C1. Paired t-test showed no significant difference in pH between the sites ($P > 0.05$).

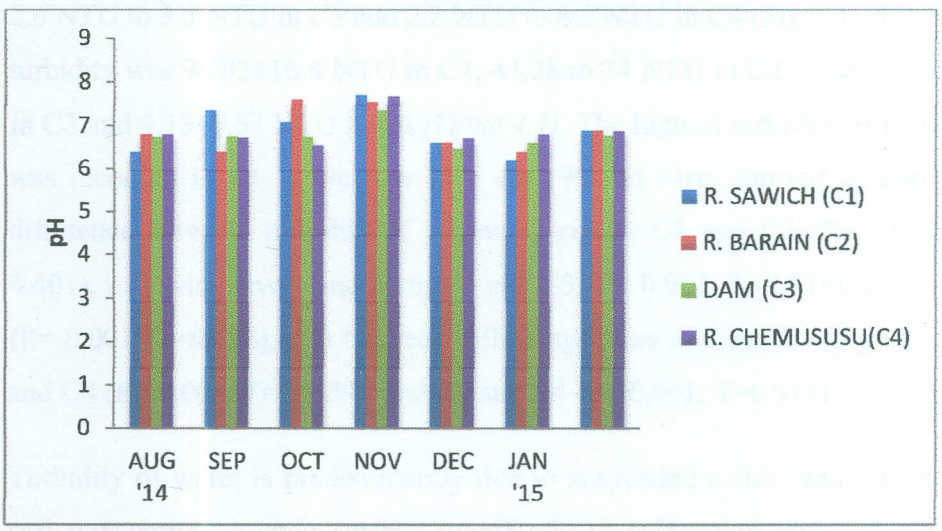


Fig 4.2: Monthly values of pH in upstream rivers (C1&C2), dam (C3) and downstream river (C4) during the study period (from August 2014-January 2015) within the study area.

pH is affected by photosynthesis, respiration and decomposition of organic matter. pH depends on the equilibrium of carbonate-bicarbonate and carbon dioxide (Stamenkovic *et al.*, 2009; Bozemo, 2013). The rate of photosynthetic activities affects the assimilation of carbon dioxide and bicarbonates that are responsible for changes in pH (Lampert & Sommer, 1993; Kitur, 2009 and Stamenkovic *et al.,* 2009). pH of impounded water is affected by the submerged carbonaceous materials that are undergoing decay and release acidic products (Lee *et al.*, 2012; Araoye, 2009).

pH levels within the dam (*Fig.4.2*) may be due to deposition of organic matter into water due to surface runoff from forest and farmlands as well as the submerged vegetation during infilling of the dam. The partial decomposition by bacteria and fungi of this organic matter produce various organic acids that are capable of lowering the pH. The pH level of water in the study area was within the recommended drinking water standards of 6.5-8.5 according to KEBS and WHO (*Appendix 1*).

4.1.3 Turbidity

Turbidity exhibited wide variation during the study period (*Fig 4.3*). Within station C1, it was between 42 NTU to 134 NTU; 23.5 NTU to 57.5 NTU in C2, 2.6 NTU to 3.5 NTU in C3 and 2.8 NTU to 6.2 NTU in C4 (Fig.4.3). The mean turbidity was 94.82±16.8 NTU in C1, 44.28±6.34 NTU in C2, 3.12±0.17 NTU in C3 and 4.15±0.63 NTU in C4 *(Table 4.1).* The highest turbidity of 134 NTU was recorded in C1 in October (*Fig 4.3*). Paired t-test showed a significant difference between turbidity of inflowing rivers; C1 and C2 (P= 0.007, T= 4.401), inflowing rivers and dam; C1 and C3 (P= 0.003, T=5.518), C2 and C3 (P= 0.001, T=6.626), and between inflowing rivers and out flowing river; C1 and C4 (P= 0.003, T= 5.489), and C2 and C4 (P= 0.001, T=6.814).

Turbidity of water is predominantly due to suspended solids from the eroded soil transported through surface runoff due to cultivation and deforestation (Lee *et al.*, 2012, Miheso, 2008, Bozemo, 2013). Increased use of river water

for domestic and animal drinking also contribute to increase in loose soil which is eroded to rivers (Mutisya, 2004; Oyhakilome *et al.*, 2013).

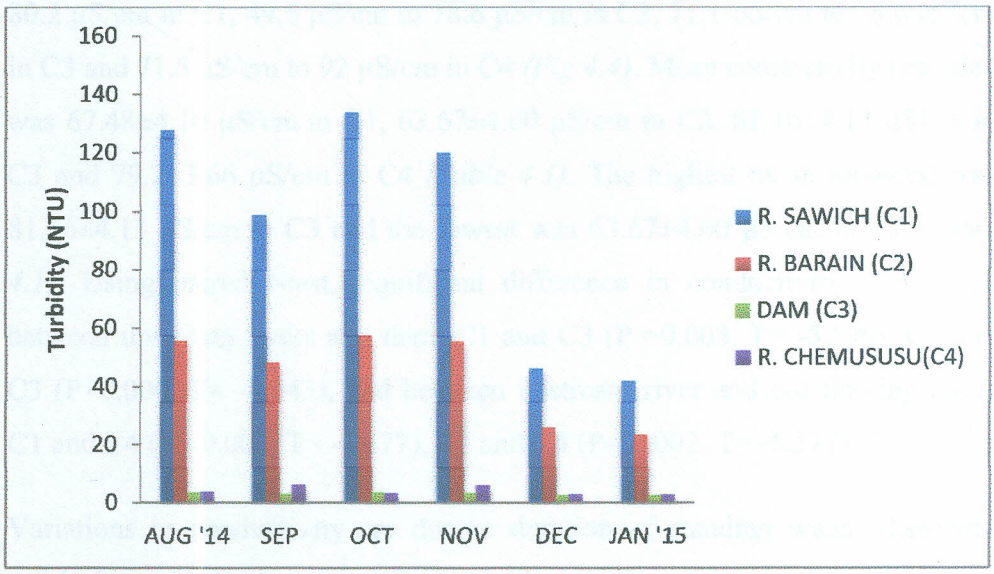


Fig. 4.3: Monthly values of turbidity in upstream rivers (C1&C2), dam (C3) and downstream river (C4) during the study period (from August 2014-January 2015) within the study area.

High levels of turbidity in C1 *(Fig.4.3)* could be due to surface runoff of suspended organic matter and loose soil from agricultural farms since the catchment area is dominated by farmlands. Watering of livestock along the rivers and their movements on hilly topography with poor vegetation cover, may result in loose soil surface and increased soil erosion. Increased river turbulence could also cause loosening of soil along the edges of the river.

The low levels of turbidity in C3 could be attributed to the slow movement of water which allows for the settling of suspended particles and silt *(Fig.4.3)*. The forest surrounding the dam could also have contributed to reduced shoreline erosion by binding the soil. Sampling station C4 also recorded low levels of turbidity compared to C1 and C2 which could be due to low turbulence since most suspended solids are settled in the dam. Turbidity level in Chemususu Dam (C3) and out flowing river (C4) were within the recommended levels according to drinking water standards of 5 NTU and 4 NTU according to (KEBS, 2007) and (WHO, 2011) respectively *(Appendix 1)*.

4.1.4 Conductivity

Levels of conductivity exhibited a wide variation ranging from 54.60 µS/cm to 80.2 µS/cm in C1, 49.5 µS/cm to 78.6 µS/cm in C2, 71.1 µS/cm to 96.6 µS/cm in C3 and 71.5 µS/cm to 92 µS/cm in C4 *(Fig 4.4)*. Mean conductivity recorded was 67.48±4.10 µS/cm in C1, 63.67±4.60 µS/cm in C2, 81.16±4.13 µS/cm in C3 and 79.2±3.66 µS/cm in C4 *(Table 4.1)*. The highest mean recorded was 81.16±4.13 µS/cm in C3 and the lowest was 63.67±4.60 µS/cm in C2 *(Table 4.1)*. Using paired t-test, significant difference in conductivity was found between upstream rivers and dam; C1 and C3 (P =0.003, T= -5.596), C2 and C3 (P=0.000, T= -8.443), and between upstream river and out flowing river; C1 and C4 (P= 0.005, T= -4.677), C2 and C4 (P= 0.002, T= -6.277).

Variations in conductivity are due to duration of standing water, dissolved solids from catchment area, dilution with rainfall and ion exchange between sediments and water in dam (Kitur, 2009). Internal loadings of vegetation and soil also contribute to changes in conductivity levels (Lee *et al.*, 2012). The geology of the catchment area also contributes to conductivity (Anyona *et al.*, 2014). Clay soils contain minerals that readily dissolve in contact with water (Miheso, 2008).

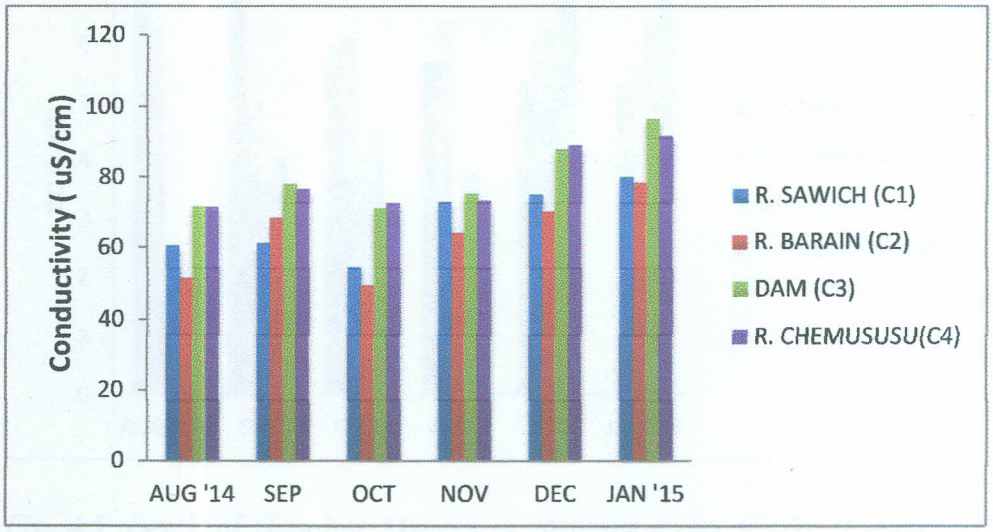


Fig. 4.4: Monthly conductivity levels in upstream rivers (C1&C2), dam (C3) and downstream river (C4) during the study period (from August 2014-January 2015) within the study area.

The conductivity levels in inflowing rivers C1 and C2 was lower than in dam. This could be attributed to the water flow and the short time the water has in contact with the bedrock. The high levels of conductivity in C3 could be as a result of residence time which leads to ion exchange between sediments and water. The submerged vegetation and soil could also have led to the increase in conductivity. In the out flowing river (C4) conductivity levels were higher compared to inflowing rivers C1 and C2 and this may be attributed to the conductivity of the dam.

4.1.5 Dissolved oxygen

Dissolved oxygen levels measured during the study period showed wide variations *(Fig 4.5)*. In C1 the levels in mg/l ranged from 5.3 to 7.34; 5.7 to 6.4 in C2; 1.7 to 6.46 in C3 and 2.2 to 6.9 in C4 was recorded during the study period. Mean DO recorded were 6.09±0.33 in C1, 6.1±0.12 in C2, 4.2±0.76 in C3 and 4.73±0.76 in C4 *(Table 4.1)*. The highest level was recorded in C2. Using paired t-test, there was significant difference in dissolved oxygen between sites C1 and C3 (P= 0.03, T= -2.949).

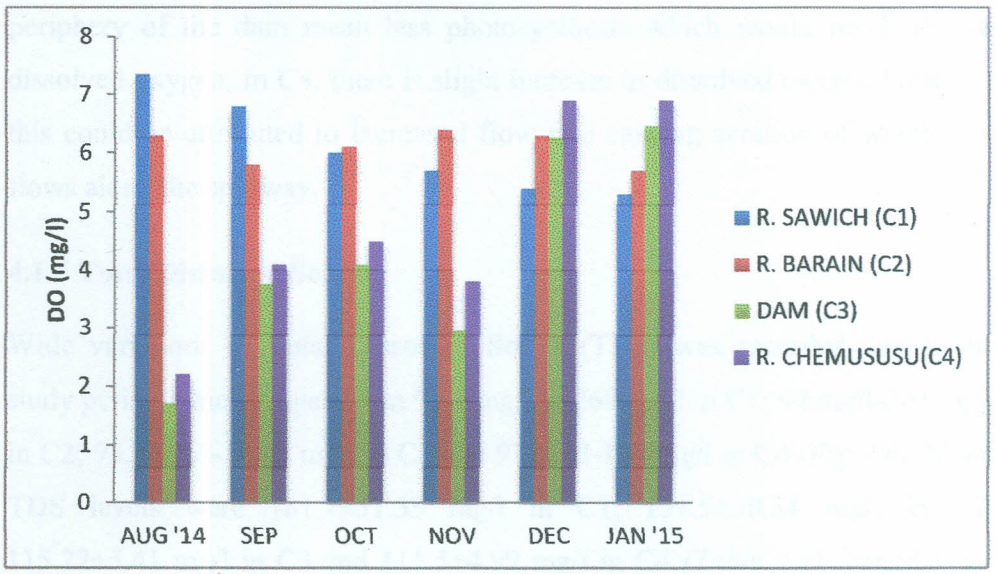


Fig. 4.5: Levels of Dissolved Oxygen in upstream rivers (C1&C2), dam (C3) and downstream river (C4) during the study period (from August 2014-January 2015) within the study area.

Dissolved oxygen levels are influenced by photosynthesis, aeration, decomposition and respiration (Araoye, 2009). Dissolved oxygen levels in reservoir are influenced by the high demand of oxygen by decaying submerged carbonaceous material (Stamenkovic *et al.,* 2009; Chapman, 1992). The rate of photosynthesis by aquatic plants and atmospheric exchange due to turbulence caused by wind which influence levels of dissolved oxygen in water (Lampert & Sommer, 1993). The abundance of plants, type of species, and temperature determines the amount of oxygen released (Araoye, 2009). Discharge of organic matter from farmlands leads to decrease in dissolved oxygen (Sunkad, 2013; Anyona *et al.,* 2014; Deshmukh & Urkude, 2014).

In flowing rivers C1 and C2 recorded high levels of DO and this could be as a result of water flow which increases aeration. However, C3 recorded low DO levels during the entire study period *(Fig.4.5).* This could be attributed to reduced flow rate which reduces turbulence which results in aeration. In addition, the low dissolved oxygen may be as a result of decomposition of submerged vegetation which were not deforested during construction of the dam (*Plate 2 and 10* in the appendices). Low levels of macrophytes along the periphery of the dam mean less photosynthesis which would result in low dissolved oxygen. In C4, there is slight increase in dissolved oxygen level and this could be attributed to increased flow rate causing aeration of water as it flows along the spillway.

4.1.6 Total Dissolved Solids

Wide variations of Total Dissolved Solids (TDS) was recorded during the study period which ranged from 97.2 mg/l to 268 mg/l in C1; 44 mg/l-201 mg/l in C2; 93.3 mg/l-133.3 mg/l in C3 and 97 mg/l-127 mg/l in C4 *(Fig 4.6).* Mean TDS levels were 181.7±31.53 mg/l in C1, 131.5±30.34 mg/l in C2, 115.22±5.41 mg/l in C3 and 111.5±4.99 mg/l in C4 *(Table 4.1).* Paired t-test results showed no significant difference in TDS between the different sites ($P>0.05$).

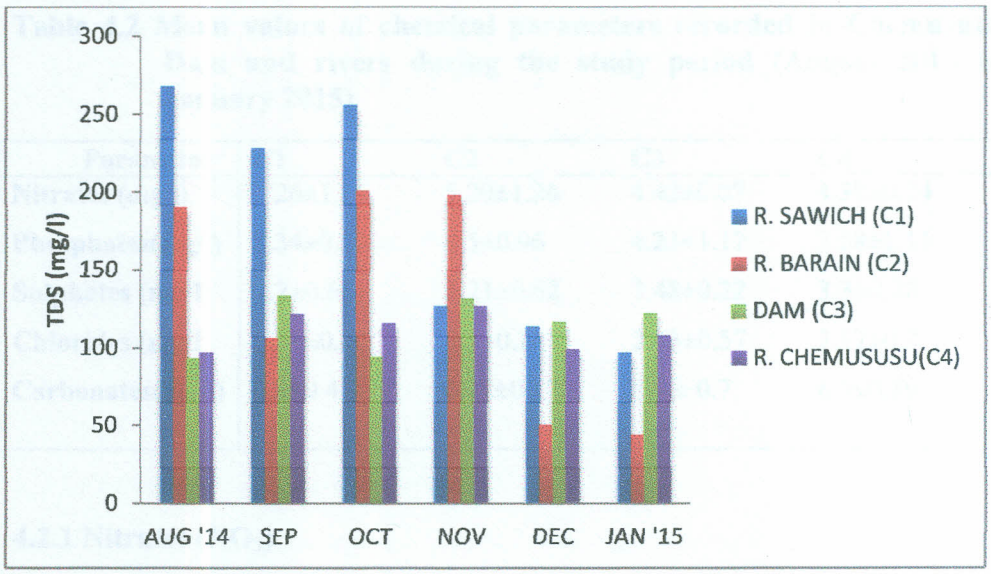


Fig. 4.6: Monthly values for TDS in upstream rivers (C1&C2), dam (C3) and downstream river (C4) during the study period (from August 2014-January 2015) within the study area.

TDS in reservoirs mainly originates from the dissolved ions released from sediments and nutrients from the mineralization of organic materials from submerged vegetation. High values of total dissolved solids beyond the permissible limits influence the taste, hardness and corrosive property of water (Sunkad, 2013).

The TDS at C1 and C2 could be due to ions of phosphates, nitrates and sulphates in runoffs from farmlands. A decrease in TDS levels in Sawich and Barain rivers in the months of November, December and January could be due to low rainfall hence low surface runoff. The low TDS in C3 could be due to uptake of nutrients by phytoplankton and existing hydrophytes. All the sampling stations were within the recommended TDS level of 1,000 mg/l and 500 mg/l according to KEBS (2007) and WHO (2011), respectively.

4.2 Chemical Parameters

The chemical parameters measured during the study period in the four sampling sites were nitrates, phosphates, sulphates, chlorides and carbonates (Table 4.2).

Table 4.2 Mean values of chemical parameters recorded in Chemususu Dam and rivers during the study period (August 2014 to January 2015)

Parameter	C1	C2	C3	C4
Nitrates (mg/l)	5.26±1.16	5.20±1.26	4.42±0.07	4.39±0.14
Phosphates(mg/l)	3.34±0.72	4.5±0.96	4.23±1.17	3.58±1.15
Sulphates (mg/l)	7.2±0.66	6.21±0.62	3.48±0.22	3.3±0.20
Chlorides (mg/l)	2.33±0.42	2.5±0.34	2.73±0.57	2.17±0.3
Carbonates(mg/l)	6.8±0.4	4.17±0.17	8.6 ± 0.7	8.5±0.89

4.2.1 Nitrates (NO_3)

A wide variation in nitrate levels was recorded during the study period and ranged from 2.12 mg/l to 8.71 mg/l in C1; 1.17 mg/l to 9.25 mg/l in C2; 4.24 mg/l to 4.60 mg/l in C3 and 4.01 mg/l to 4.84 mg/l in C4 *(Fig 4.7)*. The mean values for nitrates were 5.26±1.16 mg/l in C1, 5.20±1.26 mg/l in C2, 4.42±0.07 mg/l in C3 and 4.39±0.14 mg/l in C4 *(Table 4.2)*. Using paired t-test, the mean concentration of nitrates at different sites showed no significant difference between sites (P> 0.05). Low nitrate levels were recorded in C4 (*Table 4.2*).

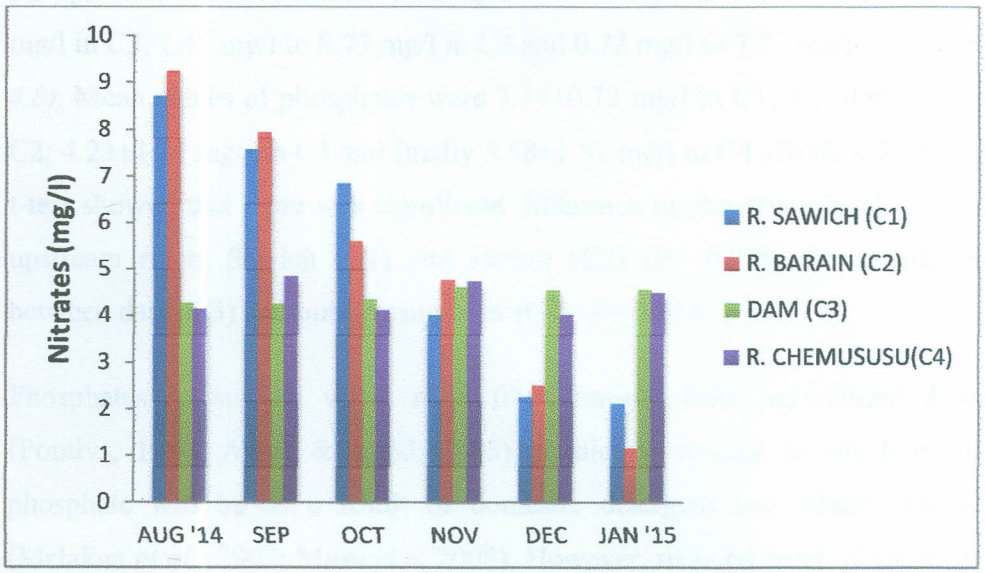


Fig.4.7: Levels of Nitrates in upstream rivers (C1&C2), dam(C3) and downstream river (C4) during the study period (from August 2014-January 2015) within the study area.

Changes in the levels of nitrate in water are caused by phytoplankton uptake and denitrification by bacteria (Melakua *et al.,* 2007; WHO, 2011). Discharge of sewerage (Sunkad, 2013), and agricultural activities through excess application of inorganic fertilizers and manure are also sources of nitrates in water (WHO, 2011). Metabolic waste, excretory products and decaying organic matter oxidized by nitrifying bacteria contribute to increase in nitrate levels in water bodies (Deshmukh & Urkude, 2014).

The high mean concentration recorded at C1 (5.26±1.16 mg/l) may be due to use of fertilizers which get leached and eroded to streams. It was also observed that high concentrations occurred during rainy months *(Appendix 2).* The low levels in C4 compared to inflowing rivers; C1 and C2 may be as a result of uptake by phytoplankton in the dam. In all the four study sites, the nitrate levels are within the required standards of 45 mg/l by WHO (2011) and 50 mg/l as stipulated by KEBS (2007).

4.2.2 Phosphates (PO_4)

There was a wide variation in phosphate concentration during the study period. Phosphate levels varied from 1.35 mg/l to 5.39 mg/l in C1; 1.69 mg/l to 7.78 mg/l in C2, 1.45 mg/l to 8.79 mg/l in C3 and 0.72 mg/l to 7.73 mg/l in C4 (*Fig. 4.8).* Mean values of phosphates were 3.34±0.72 mg/l in C1; 4.5±0.96 mg/l in C2; 4.23±1.17 mg/l in C3 and finally 3.58±1.51 mg/l in C4 *(Table 4.2).* Paired t-test showed that there was significant difference in phosphate levels of both upstream rivers Sawich (C1) and Barain (C2) (P= 0.025, T= -3.16), and between dam (C3) and out flowing river (C4) (P= 0.014, T= 3.718).

Phosphates in surface water arise from run-off from agricultural farms (Pontivs, 1990; Ansar & Khad, 2005), municipal sewage in which mostly phosphate will be as a result of domestic detergent and silage effluents (Melakua *et al.,* 2007; Mustapha, 2008). However, reduced level of phosphate in dam is as a result of uptake by phytoplankton and adsorption to particulate matter and subsequent sedimentation (Melakua *et al.,* 2007).

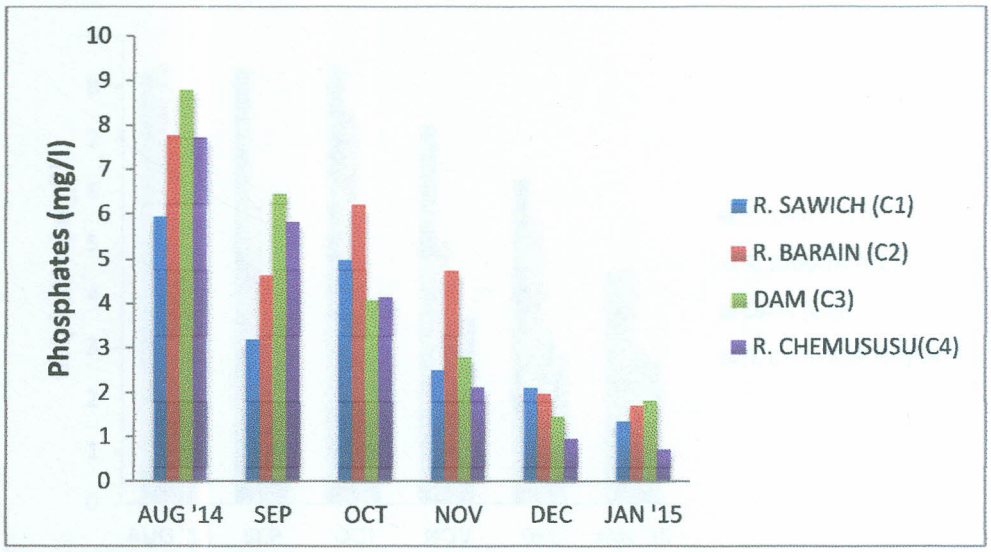


Fig.4.8: Level of Phosphate in the water of upstream rivers (C1&C2), dam (C3) and downstream river (C4) during the study period (August 2014-January 2015).

Use of fertilizers for farming could have contributed to phosphate in rivers and dam during rainy seasons (*Appendix 2*). The difference in upstream rivers could be attributed to the different areas from where the rivers originate and fertilizers applied to farms. Presence of swamp along Sawich River (C1) could also have contributed to low levels of phosphates as it acts as a sink. Washing of clothes in rivers may have also resulted to an increase in phosphates. Phosphate levels are higher than the recommended level of 2.2 mg/l by KEBS (2007).

4.2.3 Sulphates (SO_4)

Levels of sulphates showed a modest variation across the sampling sites (Fig 4.9). Sulphates ranged from 4.42 mg/l to 8.43 mg/l in C1, 4.51 mg/l to 8.51 mg/l in C2, 2.93 mg/l to 4.48 mg/l in C3 and 2.72 mg/l to 3.97 mg/l in C4 *(Fig. 4.9)*. Mean values were 7.2±0.66 mg/l in C1, 6.21±0.62 mg/l in C2, 3.48±0.22 mg/l in C3 and 3.3±0.20 mg/l in C4 (*Table 4.2*). The paired t-test results showed that there was significant difference in sulphates between upstream rivers and dam; C1 and C3 (P=0.001, T= 2.14), C2 and C3 (P=0.002, T= 6.79), and between upstream rivers and out flowing river; C1 and C4 (P=0.001, T=7.46) and between C2 and C4 (P=0.004, T=5.04).

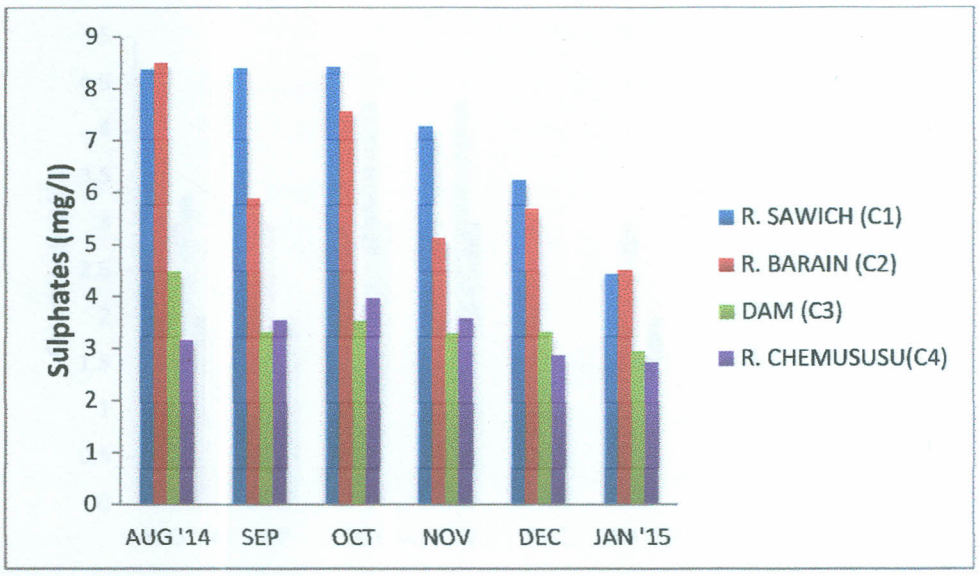


Fig. 4.9: Monthly levels of Sulphates within upstream rivers (C1&C2), dam (C3) and downstream river (C4) during the study period (August 2014-January 2015).

Sources of sulphate in water include leaching from soil, industrial discharge, decaying animal and plant matter, chemical products including ammonium sulphate fertilizers and treatment of water with aluminium sulphate (alum) also introduces sulphate into a water supply (WHO, 2004). Sulphate level in the study area was within the recommended limits of 400 mg/l and 500 mg/l according to KEBS (2007) and WHO (2011) respectively.

4.2.4 Chlorides (Cl^-)

Modest variations in chloride levels were observed during the entire study period ranging between 1 mg/l to 4 mg/l in C1, 1 mg/l to 3 mg/l in C2, 1.3 mg/l to 4.3 mg/l in C3 and 1 mg/l to 3 mg/l in C4 *(Fig. 4.10)*. The mean chloride level was 2.33±0.42 mg/l in C1, 2.50±0.34 mg/l in C2, 2.73±0.57 mg/l in C3 and 2.17±0.3 mg/l in C4 *(Table 4.2)*. Paired t-test results showed no significant difference in chloride levels between different sites ($P>0.05$).

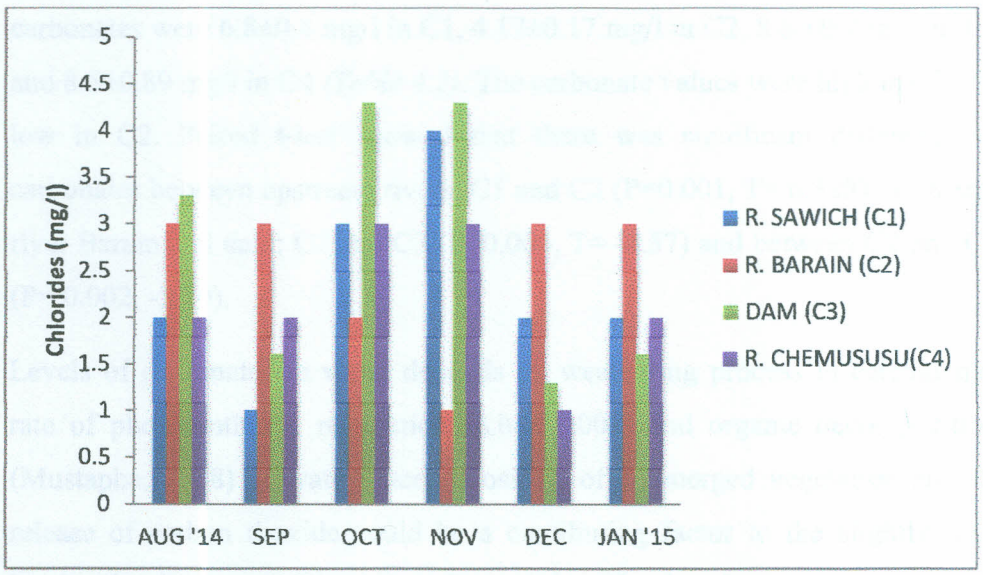


Fig.4.10: Monthly Chlorides values for upstream rivers (C1&C2), dam (C3) and downstream river (C4) of the study area (August 2014-January 2015).

An increased level of chloride in water is as a result of fertilizer, municipal and domestic sewage (Sunkad, 2013 and Stamenkovic *et al.,* 2009). Water softeners, animal feed additives, pesticides, concentration and dissolution of salts resulting from irrigation with deep groundwater also contribute to increase in chloride levels of surface water (Mullay *et al.,* 2009).

The low levels of chloride ions noticed during the study period may be an indicator of lower ion input from the catchment since it's a rural area with no urban centres and industries. Presence in Sawich river (C1) and Barain river (C2) may be attributed to livestock waste. The difference between chloride levels of C3 and C4 could be due to the ability of chlorides to react with other dissolve material in water forming compounds of chloride hence a reduction in out flowing river (C4). Chlorides were within the required levels of 250 mg/l according to KEBS (2007) and WHO (2011).

4.2.5 Carbonates (CO_3)

Water analysis showed that carbonates levels in upstream rivers ranged from 6 mg/l to 8 mg/l and 4 mg/l to 5 mg/l in C1 and C2 respectively; 5.3 mg/l to 11.7 mg/l in C3 and 5 mg/l to 11 mg/l in C4 *(Fig.4.11)*. The average values of

carbonates were 6.8±0.4 mg/l in C1, 4.17±0.17 mg/l in C2, 8.6 ±0.7 mg/l in C3 and 8.5±0.89 mg/l in C4 *(Table 4.2)*. The carbonate values were high in C3 and low in C2. Paired t-test showed that there was significant difference in carbonates between upstream rivers; C1 and C2 (P=0.001, T= 6.325); upstream river Barain and dam; C2 and C3 (P=0.006, T= -4.57) and between C2 and C4 (P= 0.002, -5.70).

Levels of carbonates in water depends on weathering process in catchments, rate of photosynthesis, respiration (Kitur, 2009) and organic decomposition (Mustapha, 2008) in water. Decomposition of submerged vegetation and its release of carbon dioxide could be a contibuting factor to the slightly high levels of carbonates in Chemususu Dam and outflowing river.

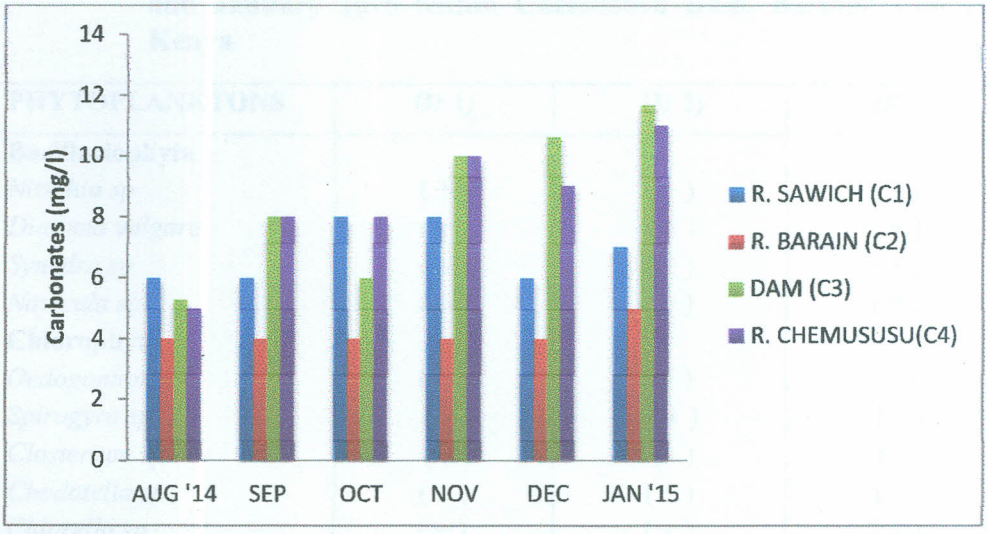


Fig.4.11: Monthly Carbonates values for upstream rivers (C1&C2), dam(C3) and downstream river (C4) during the study period (August 2014-January 2015).

4.2 Plant Species

4.3 Plant Species Composition

During the study period, a total of 19 phytoplankton species were identified within Chemususu Dam belonging to three divisions: Chlorophyta, Bacillariophyta, and Dinophyta *(Table 4.3)*. There were 2 sp; 4 sp and 13 sp belonging Dinophyta, Bacilariophyta and Chlorophyta respectively. It was observed that the frequency of species was less than five from the month of

August to October 2014 but the frequency increased from the month of November 2014 to January 2015 which recorded 14 species in D1 ; 13 species in D2 and 9 species in D3 *(Table 4.4).*

Phytoplankton composition depends on seasonal dynamics regulated by changes in nutrient availability, temperature, light, impact of rain, intensity of turbulent mixing, benthic feeders, altitude and seasons (Grabowska, 2012). According to Regina *et al.,* (2012), increase in water temperature influence algal succession progression from Bacillariophyceae to Chlorophyceae to Cynophyceae. Nasser, (2013 b) recorded a decrease in the number of phytoplankton species and their growth during rainy season.

Table 4.3: List of phytoplankton species composition between August 2014 and January 2015 within Chemususu Dam, Baringo County, Kenya

PHYTOPLANKTONS	(D 1)	(D 2)	(D3)
Bacillariophyta			
Nitzchia sp	(+)	(+)	(+)
Diatoma vulgare	(+)	(+)	(+)
Synedra sp	(+)	(+)	(+)
Navicula sp	(+)	(+)	(+)
Chlorophyta			
Oedogonium sp	(+)	(+)	(-)
Spirogyra sp	(+)	(+)	(+)
Closterium sp	(+)	(-)	(-)
Chodatella sp	(+)	(+)	(-)
Chlorella sp	(+)	(+)	(+)
Crucigenia sp	(+)	(+)	(-)
Pleurotaenium sp	(+)	(+)	(+)
Gonatozygon sp	(+)	(+)	(+)
Closterium aciculare	(+)	(+)	(-)
Pediastrum sp	(-)	(-)	(+)
Scenedesmus sp	(-)	(+)	(+)
Cosmarium sp	(-)	(+)	(-)
Geminella sp	(-)	(+)	(+)
Dinophyta			
Ceratium sp	(+)	(-)	(+)
Peridinium sp	(+)	(+)	(+)

KEY: (-) Absent (+) Present

During the study, it was observed that in the rainy periods the phytoplankton species were low in numbers during August, September and October *(Table 4.4)*. This could be attributed to the disturbances by rainfall and may be the low levels of dissolved oxygen whose averages were 3.4 mg/l, 2.9 mg/l and 3.2 mg/l for sampling stations D1, D2 and D3, respectively. An increase in the number of species from November to January could be due to increase in temperature and slightly high dissolved oxygen levels (Nasser, 2013b).

Table 4.4: Plant Species composition between August 2014 and January 2015 in Chemususu Dam, Kenya

Sampling station D1	Sampling station D2	Sampling station D3
18th August 2014		
• *Navicula sp*	• *Ceratium sp* • *Navicula sp*	• *Ceratium sp* • *Navicula sp*
13th September 2014		
• *Navicula sp* • *Synedra sp* • *Ceratium sp*	• *Ceratium sp* • *Navicula sp*	• *Spirogyra sp* • *Ceratium sp* • *Navicula sp*
18th October 2014		
• *Navicula sp* • *Synedra sp* • *Ceratium sp* • *Chodatella sp* • *Chlorella sp*	• *Spirogyra sp* • *Scenedesmus sp* • *Navicula sp* • *Nitzchia sp*	• *Navicula sp* • *Synedra sp* • *Spirogyra sp*
15th Nov 2014		
• *Closterium sp* • *Spirogyra sp* • *Peridinium sp* • *Pediastrum sp* • *Navicula sp* • *Synedra sp*	• *Peridinium sp* • *Closterium aciculare* • *Crucigenia sp* • *Spirogyra sp* • *Scenedesmus sp* • *Navicula sp*	• *Peridinium sp* • *Spirogyra sp* • *Gonatozygon sp* • *Scenedesmus sp* • *Navicula sp*
16th December 2014		
• *Crucigenia sp* • *Spirogyra sp* • *Pleuritaenium sp* • *Peridinium sp* • *Gonatozygon sp* • *Scenedesmus sp* • *Diatoma vulgare* • *Navicula sp*	• *Spirogyra sp* • *Oedogonium sp* • *Peridinium sp* • *Chlorella sp* • *Geminella sp* • *Cosmarium sp* • *Ceratium sp* • *Nitzschia sp* • *Synedra sp*	• *Chlorella sp* • *Geminella sp* • *Pediastrum sp* • *Peridinium sp* • *Spirogyra sp* • *Nitzchia sp* • *Navicula sp*

17th January 2015		
• *Spirogyra sp* • *Chodatella sp* • *Gonatozygon sp* • *Closterium aciculare* • *Scenedesmus sp* • *Pediastrum sp* • *Crucigenia tetrapedia* • *Closterium sp* • *Ceratium sp* • *Pleuritaenium sp* • *Diatoma vulgare* • *Navicula sp* • *Synedra sp* • *Nitzchia sp*	• *Closterium sp* • *Chlorella sp* • *Spirogyra sp* • *Cosmarium sp* • *Peridinium sp* • *Chodatella sp* • *Ceratium sp* • *Gonatozygon sp* • *Pleuritaenium sp* • *Geminella sp* • *Diatoma vulgare* • *Synedra sp* • *Navicula sp*	• *Pediastrum sp* • *Peridinium sp* • *Spirogyra sp* • *Gonatozygon sp* • *Ceratium sp* • *Navicula sp* • *Geminella sp* • *Nitzchia sp* • *Synedra sp*
Angiosperms		
• *Typha latifolia* • *Portulaca oleracea*	• *Typha latifolia* • *Portulaca oleracea* • *Aponogeton afroviolaceus*	Angiosperms were absent on this site due to constructed dam wall and rocky base/ platform.

There were three species of aquatic macrophytes along the periphery of Chemususu Dam. *Typha latifolia (Plate 3)* is emergent and present along sampling station D1 and D2. *Aponogeton afroviolaceus (Plate 4)* is attached submerged hydrophyte found in sampling point D2 and *Portulaca Oleracea (Plate 5)* was present in sampling station D1 and D2 respectively.

Plate 3: Typha latifolia along the South-East boundary of Chemususu Dam (also growing in sampling stations D1 and D2)

Plate 4: Aponogeton afroviolaceus attached aquatic weed along the South-East edge of Chemususu Dam (sampling station D2)

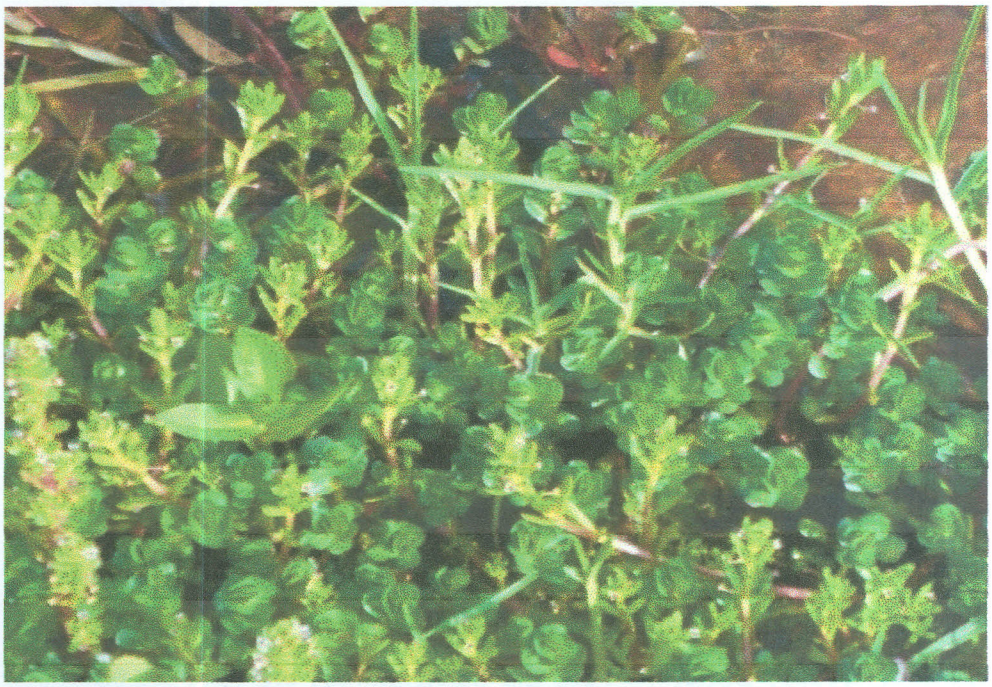


Plate 5: Portulaca oleracea along North-West and South-East edge of Chemususu (sampling station D2 & D3 respectively)

Typha latifolia is a dominant swamp plant which covered small sections along the periphery of the dam (*Plate 3*) except the dam wall. *Aponogeton afroviolaceus* (*Plate 4)* appeared in the second last month of sampling (December, 2014). It is a perennial plant that inhabits running and stagnant water. Its leaves can either be submerged or float depending on the depth of water. It grows close or in areas where sediment accumulates and withstands dry spells due to its dormant tubers (Grimsson *et al.,* 2014).*Portulaca oleracea,* is a low growing succulent plant which was found along the periphery of the dam. It grows along streams, flood plains and swamps.

The frequency of macrophytes is low within the dam due to its 1 year old establishment. It is expected that with time, there will be an increase in the number of species of angiosperms and algal flora.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

1. The results from the study showed that the levels of physico-chemical parameters vary from site to site; rivers (C1, C2 and C4) and dam (C3). The high levels of some of the parameters; nitrates, phosphates and turbidity in rivers are attributed to anthropogenic activities in the catchment area.
2. Levels of turbidity, conductivity, total dissolved solids, nitrates, sulphates, pH and chlorides in all the sites are within the required drinking water standards according to Kenya Bureau of Standards (2007) and WHO (2011). However, phosphate levels in all the sites are higher than the recommended 2.2 mg/l by KEBS (2007). Turbidity levels in Sawich and Barain rivers are also above the recommended levels of 5 NTU (KEBS, 2007) and 4 NTU (WHO, 2011).
3. There are 19 phytoplankton species belonging to Dinophyta (2), Bacilariophyta (4) and Chlorophyta (13) identified during the study period. There are three emergent species of microphytes; *Typha latifolia, Portulaca oleracea* and *Aponogeton afroviolaceus* present within the periphery of Chemususu Dam.

5.2 Recommendations

1. Regular monitoring of water quality parameters should be done to ensure that water is within the recommended limits.
2. Farmers should be trained about the quantity and duration to apply chemical fertilizer for optimum use by crops only because eroded agrochemicals will end up in the water body and surrounding environment.
3. The phosphate levels in water within the dam should be considered during treatment process in order to reduce the levels to the permissible concentration which is less than 2.2 mg/l.

4. Enforcement of environmental laws must be in practice to keep the water body clean and good for human consumption.

5.3 Areas for further research

It is necessary to study the abundance and diversity of phytoplankton within all months of the year so that updated information will help the future researchers to compare water quality and the actual changes in abundance and dominance of species since these are influenced by the physico-chemical parameters of water bodies with time.

One should also study sediment load in rivers and soil conservation measures to minimize the rate of siltation and eutrophication of Chemususu Dam.

REFERENCES

Ansar, A., & Khad, F. (2005). Eutrophication: An Ecological Vision. *The Botanical Review, 71*(4), 49-82.

Anyona, N. D., Abuom, O. P., Dida, O. G., Gelder, B. F., Onyuka, O., & Matano, A.-S. (2014, August). Effect of Anthropogenic Activities on Physicochemical Parameters and Benthic Macroinvertebrates of Mara River Tributaries, Kenya. *Journal of Environmental Science and Toxicology , 2*(5), 098-109.

APHA. (1999). *Standard Methods for the Examination of Water and Wastewater.* Washington DC: American Public Health Association.

Araoye, P. (2002). Man-made lakes, ecological studies and conservation needs in Nigeria. *Biological sciences, 50*(3/4), 857-864.

Araoye, P. A. (2009). The seasonal variation of pH and dissolved oxygen concentration in Asa lake, Ilorin, Nigeria. *International Journal of Physical Sciences, 4*(5), 271-274.

Araujo, T., Leonardo, R., Regina, P., & Maria, S. (2012). Floristic surveys of aquatic macrophytes in reservoirs in the Agreste zone of Pernambuco State, Brazil. *Brazilian Journal of Botany, 35*(4), 313-318.

Ayoade, A., Adebis, A. A., & Fagade, O. (2006). Dynamics of limnological features of two man-made lakes in relation to fish production. *African Journal of Biotechnology, 5*(10), 1013-1021.

Baringo County Goverment. (2014). *Baringo County Development Plan 2015/16.*

Bonzemo, S. W. (2013). *Assessment of water quality status of river kibisi, kenya using the ephemeroptera, plecoptera and trichoptera (ept) index.* Unpublished Msc Thesis, Kenyatta University, Nairobi.

Bronmark, C., & Hansson, L. A. (2005). *The biology of lakes and ponds.* New York: Oxford University Press.

Chapman, D. (1992). *Water Quality Assessments;A Guide to Use of Biota,Sediments and Water in Environmental Monitoring.* London: E&FN Spon.

Craun, G. F., Greathouse, D. G., & Gunderson, D. H. (1981). Methaemoglobin levels in young children consuming high nitrate well water in the United States. *Int. J. Epidemiology, 10*(4), 307-317.

Cristina, A. d., Cervi, A., Bona, C., & Padial, A. A. (2014). Aquatic macrophyte community varies in urban reservoirs with different degrees of eutrophication. *Acta Limnologica Brasiliensia, 26*(2), 129-142.

Darghouth, S., Ward, C., Gambarelli, G., Styger, E., & Roux, J. (2008). *Watershed Management Approaches, Policies, and Operations: Lessons for Scaling Up.* Washington, DC: The world Bank Group.

Deshmukh, C. K., & Urkude, R. N. (2014). Physico-chemical and microbial status of Malkhed lake at Chandur railway, District: Amaravati. *Journal of life sciences, 9*(2), 667-682.

Dinar, A., Shah, F., & Palmieri, A. (2001). Economics of reservoir sedimentation and sustainable management of dams. *Journal of Environmental Management*(61), 149–163.

Elzinga, L. C., Salzer, W. D., & Willoughby, W. J. (2001). *Measuring and Monitoring Plant Populations.* Denver: Bureau of Land Management.

European Commission. (2002). *Eutrophication and Health.* Luxembourg: European Communities.

European Environmental Agency. (1999). *Lakes and Resevoirs in the EEA area.* Copenhagen: European environment Agency.

European Environmental Agency. (2009). *Water resources across Europe-confronting water scarcity and drought.* Copenhagen: European Environment Agency.

FAO. (2005). *Aquastat.* Retrieved February 26, 2014, from FAO: www.fao.org/nr/water/aquastat/countries_regions/tanzania/index.stmq

Gachie, J. (2013). *SoftKenya.* Retrieved January 24, 2014, from SoftKenya.com: http://www.SoftKenya.com

Goverment of Kenya. (2006). *Water: A Shared Responsibility.* Nairobi: Government Printers.

Goverment of Kenya. (2010). *2009 Population and Housing Census Results.* Nairobi: Goverment printers.

Government of Kenya. (2005). *Kenya Water Report.* Nairobi: Government Printers.

Grabowska, M. (2012). The role of a eutrophic lowland reservoir in shaping the composition of river phytoplankton. *Ecohydrology and Hydrobiology, 12*(3), 231-242.

Grimsson, F. Z. (2014). Aponogeton pollen from the Cretaceous and Paleogene of North America and West Greenland: Implications for the origin and palaeobiogeography of the genus. *Journal of Science Direct, 200*, 161-187.

Guiry, M. (2012). *AlgaeBase.* Retrieved March 25, 2015, from http://www.algaebase.org

Huckett, S. P. (2010). *A Comparative Study to Identify Factors Affecting Adoption of Soil and Water Conservation Practises among Smallhold Farmers in the Njoro River Watershed of Kenya.* Unpublished PhD thesis, Utah State University.

ICOLD. (1998). *ICOLD world register of dams.* Paris: International Commission on Large Dams.

ICOLD. (2007). *Dams and the World's Water.* Paris: International Commission on Large Dams.

Jimoh, O., Ayodeji, M., & Mohammed, B. (2003). Effects of agrochemicals on surface waters and groundwaters in the Tunga-Kawo (Nigeria) irrigation scheme. *Hydrological Sciences Journal*(6), 1013-1023.

Kenya Bureau of Standards. (2007). *Drinking Water Specification: The Requirements for Drinking Water* (Third edition ed.). Nairobi, Kenya: Goverment Printers.

Kitur, E. L. (2009). *A Comparative Study on the Influence of Variations in Environmental Factors on the Phytoplankton Properties of Selected Reservoirs in Central Kenya.* Unpublished PhD Thesis, Kenyatta University, Nairobi.

Kotut, K. (1998). *Phytoplankton and nutrient dynamics at Turkwel Gorge Reservoir, a new man-made lake in northern Kenya.* Deparment of Plant and Microbial Sciences. Nairobi: Kenyatta University.

Lampert, W., & Sommer, U. (1993). *Limnoecology: The ecology of Lakes and Streams.* New york: Oxford University Press, Inc.

Lee, N., Yee, T. L., & Grinang, J. (2012, June). Physico-chemical Characteristics in the Filling Phase of Bakun Hydroelectric Reservoir, Sarawak, Malaysia. *International Journal of Applied Science and Technology, 2*(6), 92-101.

Leentvaar, P. (1975). *Hydrobiological observations in Surinam with special reference to the man-made Brokopondo Lake.* Amsterdam: Research Institute for Nature Management.

Madsen, D., & Wersal, m. R. (2012). *A Review of Aquatic Plant Monitoring and Assessment Methods.* Marietta: Aquatic Ecosystem Restoration Foundation.

Melakua, S., Wondimub, T., Damsa, R., & Moensa, L. (2007). Pollution status of Tinishu Akari river and its tributaries(Ethiopia) evaluated using Physico-Chemical parameters major ions and nutrients. *21*(1), 13-22.

Mihayo, J. (2004). *Water supply from wetlands in Tanzania.* Dar es Salaam: Ministry of Water, Energy and minerals.

Miheso, L. R. (2008). *Effects of Pollution of Motoine River Dams, Kenya.* Nairobi: Kenyatta University.

Mullany, R. J., Lorenz, L. D., & Arntson, D. A. (2009). *Chloride in ground water and surface water in areas underlain by the glacial acquifer system, Northern United States.* Virginia: US Geology survey.

Mustapha, K. M. (2008). Assessment of the Water Quality of Oyun Reservoir, Offa, Nigeria Using Selected Physico-Chemical Parameters. *Turkish Journal of Fisheries and Aquatic Sciences, 8*, 309-319.

Mutisya, D. K. (2004). *The Impact of Irrigated Agriculturen on Water Quality of Kongoni and Sirimon rivers, Ewaso Ng'iro North Basin.* Unpublished MSc thesis, Kenyatta University, Nairobi.

Napier, T. L. (2000, August). Use of soil and water protection practices among farmers in the North Central region of the United States. *Journal of the American Water Resources Association, 36*(4), 723–735.

Nasser, M. K. (2013 a). *Ecology and Biodiversity of Freshwater Microalgae in the Selected Areas of the Western Ghats.* Mahatma Gandhi University. unpublished.

Nasser, M. K. (2013 b). *Variability of Phytoplankton in Lentic Habitats, Ph.D Thesis.* Mahatma Gandhi University.

Ndeda, L., & Manohar, S. (2014 a). Bio concentration factor and Translocation Ability of Heavy Metals within differnt Habitats of Hydrophytes in Nairobi Dam, Kenya. *IORS Journal of Environmental Science, Toxicology and Food Technology, 8*(5), 42-45.

Ndeda, L. A., & Manohar, S. (2014 b). Determination of Heavy Metals in Nairobi Dam water, Kenya. *IORS Journal of Environmental Science, Toxicology and Food Technology, 8*(5), 68-73.

Needham, J., & Needham, P. (1972). *A freshwater guide to the study of freshwater biology* (5th edition ed.). London: Holden- Day.

Othman, F., Sadeghian, S. M., Ebrahimi, F., & Mohammad, H. (2013). A Study on Sedimentation in Sefidroud Dam by Using Depth Evaluation and Comparing the Results with USBR and FAO Methods. *2nd International Conference on Environment, Energy and Biotechnology*, 43-48.

Oyhakilome, G. I., Aiyesanmi, A. F., & Akharaiyi, F. C. (2012). Water Quality Assessment of the Owen Multipurpose Dam,Ondo state,Soth Western Nigeria. *Journal of Environmental Protection*, 14-25.

Panneerselvam, A., Arumugam, G., Elizabeth, S. H., Thirumagal, J., & Nasimun, N. (2013). Evaluation of water quality of Pulliyakanu Lake. *World JournalL of Pharmacy and Pharmaceutical Sciences with reference to physico- chemical aspects, 2*(5), 3641-3649.

Patil, P., Sawant, D., & Deshmukh, R. (2012). Physico-chemical parameters for testing of water. *International Journal of Environmental Sciences, 3*(3), 1194 - 1207.

Pontivs, F. W. (Ed.). (1990). *Water quality and treatment, A Handbook for Community Water Supplies,*. USA: McGraw-Hill, Inc.

Regina, M. N.-M., Frank, C. M., & Miles, R. L. (2012). Phytoplankton biomass and primary production dynamics in Lake Kariba. *Lakes & Reservoirs: Research and Management, 17*, 275–289.

Shabalala, N. A., Combrinck, L., & McCrindle, R. (2013). Effect of farming activities on seasonal variation of water quality of Bonsma Dam, KwaZulu-Natal 2013. *South African Journal of Science, 109*(7/8), 1-7.

Sidinei, M. T., Luis, B. M., Maria, S. C., Kita, K. K., & Camargo, A. F. (1999). Aquatic macrophytes of Itaipu reservoir, Brazil: survey of species and ecological considerations. *Brazilian Archives of Biological Technology, 42*(1), 15-22.

Skinner, J., Niasse, M., & Haas, L. (2009). *Sharing the benefits of large dams in West Africa.* London: International Institute for Environment and Development.

Stamenkovic, V. S., Smiljkov, S., Paunovic, M., & Hristovsk, S. (2009). The water quality of Mantovo reservoir. *Directory of open acess journals, 61*(3), 501-512.

Streeter, T., & Hargrove, W. (2008). *Sedimentation in Our Reservoirs: Causes and Solutions.* Kansas Water Office, Kansas state.

Subehi, L., & Fakhrudin, M. (2010, March). Preliminary study of the changes in water temperature at pond Cibuntu. *Journal of Ecology and the Natural Environment, 3*(3), 72-77.

Sunkad, B. (2013, April). Water quality of Malaprabha river with reference to physicochemical factors near Khanapur town of Belgaum district. *International Journal of Innovative Research in Science, Engineering and Technology, 2*(4).

Talling, J. (2006). Tropical African Inland Waters. *A brief history of the Scientific Study of Tropical African Inland Waters, 26*, 3-37.

Thornton, K. W., Kimmel, B. L., & Payne, F. E. (1990). *Reservoir Limnology; Ecological Perspective.* New York: John Wiley & Sons, Inc.

Tirado, R., Englande, A. J., Promakasikorn, L., & Novotny, V. (2008). *Recent studies in Thai reservoirs have found blooms of toxin-producing algae in the water.* London: Greenpeace Research.

UNEP. (2008). *Water Quality for Ecosystems and Human Health.* Toronto: United Nations Environment Programme Global Environment Monitoring System/Water Programme.

United States Environmental Protection Agency. (2012). *Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems.* United States Office of Water.

Uyigue, E. (2006). *Dams and Livelihood: The Problems of Parasitic Diseases in Communities Hosting Dams in Nigeria.* Lagos: Society for Water and Public Health Protection.

Warren, A. (2010). *The role of dams in creating a water secure world.* Wiltshire: Halcrow Group Ltd.

Wetzel, R. G. (2001). Limnology: Lake and River Ecosystems. San Diego, CA: Academic Press.

WHO. (1998). *Guidelines for Drinking Water Quality vol. 1, Recommendation.* Geneva: World Health Organization.

WHO. (2003). *Background document for development of WHO guidelines for drinking water.* Geneva: World Health Organization.

WHO. (2004). *Sulfate in Drinking-water.* Geneva: World Health Organization .

WHO. (2011). *Guideline for drinking- water quality* (Fourth edition ed.). Switzerland: World Health Organization.

Yanamadala, V. (2005). Calcium Carbonate Phosphate Binding Ion Exchange Filtration and Accelerated Denitrification Improve Public Health Standards and Combat Eutrophication in Aquatic Ecosystems. *Water Environment Research, 77*(7), 3003-3012.

Young, R. D., Erickson, D. L., & Ryan, R. L. (2003). Farmers' Motivations for Adopting Conservation Practices along Riparian Zones in a Mid-western Agricultural Watershed. *Journal of Environmental Planning and Management,, 46*(1), 19-37.

APPENDICES

Appendix 1: Drinking Water Standards according to KEBS and WHO

Parameter	KEBS (2007)	WHO (2011)
pH	6.5-8.5	6.5-8.5
Sulphates (mg/l)	400mg/l	500mg/l
Chlorides (mg/l)	250mg/l	250mg/l
Turbidity (NTU)	5NTU	4 NTU
Total Dissolved Solids (mg/l)	1000mg/l	500mg/l
Nitrate (mg/l)	50mg/l	45mg/l
Phosphates (mg/l)	2.2 mg/l	-

Appendix 2: Monthly rainfall data (January 2014 to January 2015) during the study period (Baringo FTC meteorological station)

Month	Precipitation (mm)
January 2014	20.5
February	25.2
March	22.7
April	42.8
May	82.9
June	73.6
July	7.6
August	108.7
September	44.2
October	167.9
November	83.7
December	88.1
January 2015	00.0

Appendix 3: Records of monthly water Temperature (°C) at sampling stations recorded within study duration (August 2014 to January 2015)

Dates of Sampling	C1	C2	C3(D1, D2,D3)	C4
15th August 2014	14.2	14.6	20.2	19.1
13th September 2014	14.7	14.1	20.5	19.2
18th October 2014	15.2	15.7	20.5	20
15th November 2014	17.8	17	20.9	21
16th December 2014	19.7	20.6	23.3	21.5
17th January 2015	20.5	20.3	23.5	22.1
Average	17.0	17.1	21.5	20.5

Appendix 4: pH of water at different sampling stations measured from August 2014 to January 2015

Dates of Sampling	C1	C2	C3(D1,D2,D D3)	C4
15th August 2014	6.4	6.8	6.73	6.8
13th September 2014	7.34	6.4	6.75	6.72
18th October 2014	7.08	7.6	6.74	6.54
15th November 2014	7.71	7.54	7.34	7.67
16th December 2014	6.6	6.6	6.47	6.7
17th January 2015	6.2	6.4	6.6	6.8
Median	6.9	6.9	6.8	6.9

Appendix 5: Level of Turbidity (NTU) of water measured at different study sites of dam and rivers (August 2014 to January 2015)

Dates of Sampling	C1	C2	C3(D1, D2, D3)	C4
15th August 2014	128	55.5	3.5	3.7
13th September 2014	98.8	57.5	3	6.2
18th October 2014	134	48.2	3.5	3.3
15th November 2014	120	55.2	3.4	6
16th December 2014	46.1	25.8	2.7	2.8
17th January 2015	42	23.5	2.6	2.9
Average	94.8	44.3	3.1	4.2

Appendix 6: Level of Conductivity (µS/cm) of water at different sampling stations from (August 2014 to January 2015)

Dates of Sampling	C1	C2	C3(D1, D2,D 3)	C4
15th August 2014	60.5	51.4	71.6	71.5
13th September 2014	61.3	68.3	78.13	76.7
18th October 2014	54.6	49.5	71.1	72.6
15th November 2014	73.1	64.1	75.5	73.4
16th December 2014	75.2	70.1	88	89
17th January 2015	80.2	78.6	96.6	92
Average	67.5	63.7	81.2	79.2

Appendix 7: Level of Dissolved Oxygen (mg/l) of water at different sampling stations from August 2014 to January 2015

Dates of Sampling	C1	C2	C3(D1, D2, D3)	C4
15th August 2014	7.34	6.3	1.7	2.2
13th September 2014	6.8	5.8	3.76	4.1
18th October 2014	6	6.1	4.1	4.5
15th November 2014	5.7	6.4	2.96	3.8
16th December 2014	5.4	6.3	6.26	6.9
17th January 2015	5.3	5.7	6.46	6.9
Average	6.1	6.1	4.2	4.7

Appendix 8: Level of Total Dissolved Solids (mg/l) of water at different sampling stations from August 2014 to January 2015

Dates of Sampling	C1	C2	C3(D1, D2, D3)	C4
15th August 2014	268	190	93.3	97
13th September 2014	228	106	133.3	122
18th October 2014	256	201	94	116
15th November 2014	127	198	131.7	127
16th December 2014	114	50	116.7	99
17th January 2015	97.2	44	122.3	108
Average	181.7	131.5	115.2	111.5

Appendix 9: Level of Nitrates (mg/l) of water at different sampling stations from August 2014 to January 2015

Dates of Sampling	C1	C2	C3(D1, D2, D3)	C4
15th August 2014	8.71	9.25	4.26	4.14
13th September 2014	7.58	7.94	4.24	4.84
18th October 2014	6.85	5.6	4.34	4.11
15th November 2014	4.01	4.75	4.6	4.73
16th December 2014	2.27	2.52	4.54	4.01
17th January 2015	2.12	1.17	4.55	4.48
Average	5.3	5.2	4.4	4.4

Appendix 10: Levels of Phosphates (mg/l) of water at different sampling stations from August 2014 to January 2015

Dates of Sampling	C1	C2	C3(D1, D2, D3)	C4
15th August 2014	5.93	7.78	8.79	7.73
13thSeptember 2014	3.18	4.62	6.45	5.82
18th October 2014	4.98	6.19	4.07	4.14
15th November 2014	2.51	4.72	2.79	2.12
16th December 2014	2.11	1.98	1.45	0.95
17th January 2015	1.35	1.69	1.82	0.72
Average	3.3	4.5	4.2	3.6

Appendix 11: Level of Sulphates (mg/l) of water at different sampling stations from August 2014 to January 2015

Dates of Sampling	C1	C2	C3(D1, D2, D3)	C4
15th August 2014	8.38	8.51	4.48	3.15
13th September 2014	8.41	5.89	3.32	3.55
18th October 2014	8.43	7.57	3.53	3.97
15th November 2014	7.29	5.12	3.29	3.58
16th December 2014	6.24	5.66	3.32	2.86
17th January 2015	4.42	4.51	2.93	2.72
Average	7.2	6.2	3.5	3.3

Appendix 12: Levels of Carbonates (mg/l) of water at different sampling stations from August 2014 to January 2015

Dates of Sampling	C1	C2	C3(D1, D2, D3)	C4
15th August 2014	6	4	5.3	5
13th September 2014	6	4	8	8
18th October 2014	8	4	6	8
15th November 2014	8	4	10	10
16th December 2014	6	4	10.6	9
17th January 2015	7	5	11.7	11
Average	6.8	4.2	8.6	8.5

Appendix 13: Levels of Chlorides (mg/l) of water at different sampling stations from August 2014 to January 2015

Dates of Sampling	C1	C2	C3(D1, D2, D3)	C4
15th August 2014	2	3	3.3	2
13th September 2014	1	3	1.6	2
18th October 2014	3	2	4.3	3
15th November 2014	4	1	4.3	3
16th December 2014	2	3	1.3	1
17th January 2015	2	3	1.6	2
Average	2.3	2.5	2.7	2.2

Appendix 14: Selected photos of the study area

Plate 6: Shows sampling station C1 (River Sawich), Baringo County, Kenya

Plate 7: Shows researcher at sampling station C2 (River Barain) taking note of the physical parameters of the river water

Plate 8: Shows sampling station C2 (River Barain) during a rainy period

Plate 9: Shows sampling station D1 (Chemususu Dam) and northern section of the dam in background

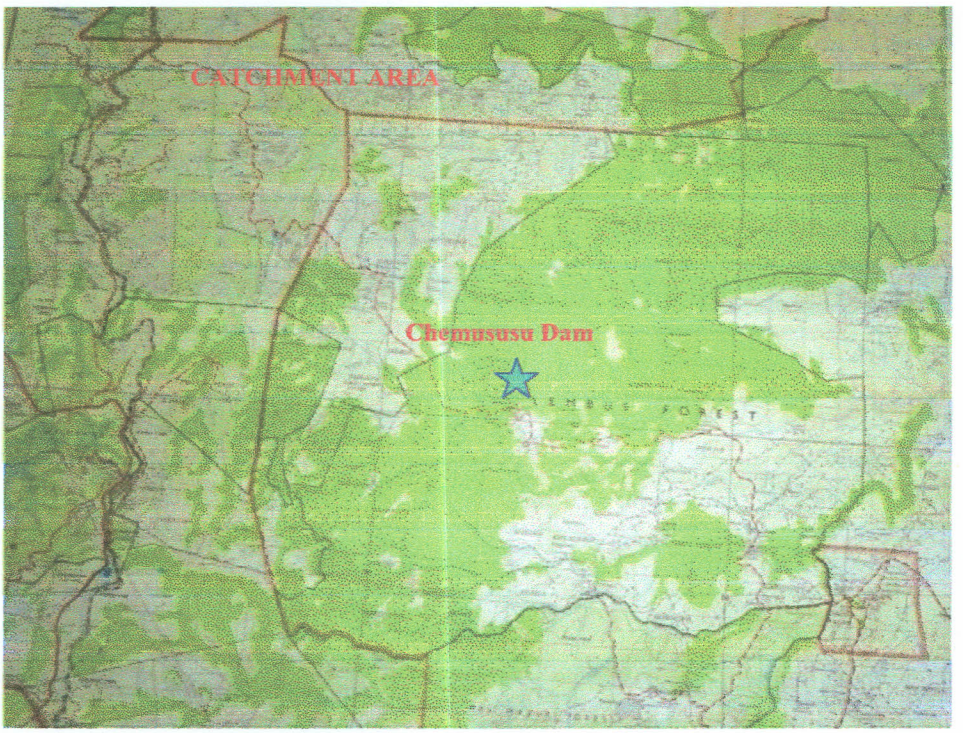
Plate 10: Shows a section of submerged trees and floating algae close to sampling station D1

Plate 11: Shows dam wall (sampling station D3) and Typha latifolia growing along the periphery of the reservoir

Plate 12: Overflow of water from Chemususu Dam, Kenya.

Plate 13: Out flowing water from Chemususu Dam creating River Chemususu (sampling station C4)

Appendix 15: Topographic Map



Topographic map showing approximate location of Chemususu Dam.