

**WATER POLLUTION IN A RIPARIAN COMMUNITY: THE CASE OF RIVER
ATHI IN MAKUENI COUNTY, KENYA**

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Degree of Master of Science in Environmental Management of South Eastern Kenya
University**

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DECLARATION

I understand that plagiarism is an offence and I therefore declare that this thesis is my original work and has not been presented to any other University for any other award.

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DEDICATION

I dedicate this research to the Government of Makueni County and H.E Prof. Kivutha Kibwana, Governor Makueni County for endless effort to have Makueni people access adequate, safe and clean water.

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God bless you all.

ABSTRACT

The aim of this study was to determine the effects of water pollution on riparian community along River Athi in Makueni County. Specific objectives included; documenting the causes of pollution of the River Athi in Kathonzweni Sub County, to establish the health effects resulting from the pollution of the River Athi and finally to assess and document interventions put in place by the government and residents in the study area to control the pollution of the River Athi. Data was collected using a sample size of 51 households in five villages living along the River Athi who are within 5 kilometre distance from the river. Structured questionnaires, observation, and interviews were the data collection methods employed and the collected data was analysed using SPSS windows and presented using tables. The study results show that up-stream pollution from industries and sewage was the commonest reported river polluter at Iiani (93.3%), Kikome (62.5%), Mumbeeni (60%), Kyase (50%) and Kwanyaa villages (33.3%) Chi square(X^2) =1.7186), respectively. Results on the uses of river water within the five selected villages revealed there were seven water uses including watering crops, washing, drinking, fishing, cooking, bathing, and brick making. Across the five villages, malaria was the commonest illness reported in Iiani village (46.7%), Kyase and Kikome villages (37.5%), Kwanyaa village (22.2%) and Mumbeeni village (20%) ($X^2=0.0035$). According to the results, contact with river water was the common cause of most illnesses with Kwanyaa village (55.6%) having the highest percentage of illness.. This was because most of the piped water was supplied without treatment to the village. The study further shows that the residents' measures to control pollution were three and included observation of 30m riparian reserve by farmers and developers, not disposing refuse and pesticide cans in the river and the residents not washing near the river. The results of this study can provide a basis for designing water policies aimed at rural livelihood water quality and water security improvement within Makueni County.

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LIST OF ABBREVIATIONS AND ACRONYMS

BOD	Biological Oxygen Demand
CBO	Community Based Organization
Cd	Cadmium
CIDP	County Integrated Development Plan
COD	Chemical Oxygen Demand
Cr	Chromium
EC	Electrical conductivity
DDT	Dichlorodiphenyltrichloroethane
DF	Degree of freedom
DO	Dissolved oxygen
LDCs	Less Developed Countries
MPN	Most Probable Number
N	Nitrogen
NEMA	National Environmental Management Authority
NGO	Non-Governmental organization
Ni	Nickel
NTU	Turbidity Units
TDS	Total dissolved solids
TSS	Total suspended solids
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nation Environmental Programs
P	Phosphorous
Pb	Lead
PPM	Parts Per Million
P.V	Photo voltaic
WASREB	Water Service Regulatory Board
W.H.O	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Worldwide, pollution of rivers and streams has become one of the most crucial environmental problems of the 20th Century. Although some kind of water pollution can occur through natural processes, it is mostly as a result of human activities (Patty, 2006). All biological organisms depend on water to carry out complex biochemical processes which aid in the sustenance of life on earth. Over 70% of the earth's surface materials consists of water and apart from the air man breathes, water is one of the most important elements to man. Though water covers about 70% of the earth's surface, of which 2.53% is fresh water the remaining is salt water. Much of the fresh water is held in the icecaps, hence not available (UNESCO, 2003). According to the World Water Council (2005), there is only 3% of fresh water in the world, with only 0.3 % found in rivers and lakes, the rest is frozen. This scenario thus, suggests that man has a relatively low amount of fresh water resources with which he can carry out his activities. Unfortunately, man's influence has begun to degrade the fresh water resource available for his development. UNESCO (2003) estimates that, 2 million tons of waste are disposed off per day within receiving waters, including industrial wastes, chemicals, human waste and agricultural wastes such as fertilizers, pesticides and pesticide residues.

Rivers are potential sources for fresh water and some flow through major cities and towns of the world. UNESCO (2003) indicates that 48% of the world's population lives in towns and cities and by 2030, this figure is likely to rise to about 60%. Over the last years, in many African countries a considerable population growth has taken place, accompanied by a steep increase in urbanization, industrial and agricultural land use (Kithia, 2007). This has entailed a tremendous increase in discharge of a wide diversity of pollutants to receiving water bodies and has caused undesirable effects on the different components of the aquatic environment and on fisheries (Fakayode, 2005). According to

Fakayode (2005), there is growing appreciation that nationally, regionally, and globally, the management and utilization of natural resources need to be improved and that the amount of waste and pollution generated by human activity need to be reduced on a large scale.

Industries are the major sources of pollution in all environments. Based on the type of industry, various levels of pollutants can be discharged into the environment directly or indirectly through public sewer lines. Wastewater from industries includes: employees' sanitary waste, process wastes from manufacturing, wash waters and relatively uncontaminated water from heating and cooling operations (Glyn, 1996). High levels of pollutants in river water systems causes an increase in Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), toxic metals such as cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb) and faecal coli form and hence make such water unsuitable for drinking, irrigation and aquatic life. Industrial wastewaters range from those with high Biochemical Oxygen Demand (BOD) such as human sewage, pulp and paper industries, slaughter houses, tanneries and chemical waste from chemical industry. Others include waste from plating shops and textiles, which may contain toxic and require on-site physiochemical pre-treatment before discharge into municipal sewage system (Emongor, *et al.*, 2005). Pollution of fresh water systems in Africa, in contrast to the situation in developed countries of the world, is often the result of extreme poverty and economic and social under-development.

Hardoy *et al.*, (2001), indicate that "River pollution from city based industries and untreated sewage can lead to serious health problems in settlements downstream". Many rivers in Kenya lose their quality after they have passed through cities due to a number of human and industrial activities that contribute to their pollution. Settlements downstream that depend heavily on river water for domestic activities are forced to look for more

expensive alternatives where such communities are not fitted with pipe borne water. Concentration of pathogens in the water pose enormous health risk to people using river water for drinking, bathing, irrigation of crops eaten raw, fishing, and recreational activities (Niyogi *et al.*, 2005; Liu, *et al.*, 2006; Hellweger, 2008). The Nairobi River for instance, traverses Nairobi, a city with population over 3 million, and flows along a number of informal settlements such as Mathare, Korogocho, and Dandora which together with Nairobi City sewage treatment plants empty untreated or semi treated waste into the river, before emptying its water into River Athi. The combined waters of Nairobi and Athi rivers are extensively used by an estimated 4 million people, for drinking, and agricultural irrigation in the downstream counties of Machakos and Makueni (Kithiia, 2007).

Numerous studies have indicated that the river water is highly polluted with heavy metals and other pathogenic pollutants emanating from industrial and agricultural activities in the river basin (Kithiia, 2007; Abednego, *et al.*, 2013). The study sought to find out how both organic and inorganic matter introduced to the river impact on the river pollution. It also sought to establish the community's awareness on pollution and institutional conditions which influence river pollution to make recommendations for efficient pollution control and creation of public awareness.

1.2 Statement of the problem

Most rivers around the globe and in Africa receive effluent discharged from the city sewage treatment plants, before emptying its water into rivers down-stream. River Athi is the second longest river in Kenya and the waters are useful for irrigation, drinking and fishing. The river and its tributaries flow through major towns, national parks, industrial, agricultural and residential areas. Wastewater generated by inhabitants of cities contaminates rivers traversing them (Abraham, 2010). For example Nairobi River a major tributary of River Athi flow through Nairobi City and it is heavily impacted by pollution input from industrial and domestic waste. The combined waters of Nairobi

River and River Athi are extensively used by an estimated 4 million people, for drinking, and agricultural irrigation downstream.

The indestructible nature and long term toxic effects of heavy metals including lead (Pb), nickel (Ni), manganese (Mn), zinc (Zn), cadmium (Cd) and chromium (Cr) to man as a result of consumption of organisms obtained from polluted rivers has raised scientific and environmental concerns (Muiruri *et al.*, 2013). Weathering of soils and rocks and a variety of other anthropogenic activities are also other factors, which contribute to the presence of heavy metals in water hence creating a societal health risk people using water from the rivers. Past studies have dealt with water pollution in river Athi, indicating that as per the WHO domestic and irrigation water use guidelines, the water is not portable, hence posing health risks to communities, who use the river water as their primary source (Kithiia, 2007; Abednego *al.*, 2013).

River Athi basin covers an area of 941.79 km² with household population of 15,004 and a human population of 79,890 according to Kenya Census Report of 2009. A total of over 30,861 people live along the river line stretch of 51.06 kilometres. This is half the total district population who live within the 5 kilometres distance from the river line. This population is believed to access the River Athi water as their main source of domestic water. The effects of River Athi are felt downstream more so by the population in Kathonzwi Sub County. The people in this area are more vulnerable to the effect of water pollution as this is their only source of water. The question of what causes the pollution of the River Athi and its effect on the health of residents living along the river in Kathonzwi need to be studied and established as a first step towards addressing the challenges of point source and non-point sources of avenues for river pollution, water scarcity and localized monitoring of water quality and enabling policy on clean water supplies.

1.3 Objectives of the Study

1.3.1 General objective

The main objective of the study was to establish the causes and the associated health effects of River Athi water pollution and identify the government and residents' interventions to control the river pollution in Kathonzwani Sub County.

1.3.2 Specific objectives

1. To identify the main water uses and the causes of River Athi pollution downstream.
2. To assess the health related issues resulting from the pollution of the River Athi in Kathonzwani Sub County.
3. To determine the interventions put in place by the government and residents in the study area to control River Athi pollution.

1.4 Study Questions

1. What are the causes of River Athi pollution in Kathonzwani Sub County?
2. What are the health related issues resulting from River Athi water pollution in Kathonzwani Sub County?
3. What are the governments and residents' interventions of controlling River Athi water pollution in Kathonzwani Sub County?

1.5 Justification of study

This study is important because the outcome of the research will be useful to the government especially in policy formulation for water pollution control in Makueni County and creation of awareness to the affected community on the dangers of using the polluted water so as to put in place measures to control and avoid effects of the water pollution. The community will also benefit from the research on better utilization of the river water through involvement of County government, NEMA and local government structures. Researchers and Health workers will also benefit from the findings of the research. The study will also contribute to literature on effects of water pollution, the

remedies in water sources conservation, improved water and sanitation measures and high quality water supplies for health riparian communities. Besides policy formulation, the study is also important in evidence based awareness creation on water pollution, the dangers on the health of the communities and river management among the riparian communities.

1.6 Assumption of the study

The study is based on the following assumptions:

1. That the sources of water pollution are caused by industrial, domestic and agricultural practices upstream.
2. That the area has intervention mechanisms to deal with water pollution
3. That River Athi is the only main source of water in the study area.
4. That the water borne related illnesses arise from using polluted River Athi water.

1.7 Scope of study

The study site is Kathonzweni Sub-County which borders Kibwezi-West in the South East and Mbooni Sub-County in the upper part of Makueni County. River Athi traverses the county from a west to East flow forming the Makueni-Kitui counties boundary in the East. The area is sparsely populated with 125 people per Density km². Acacia trees dominate the undulating terrain of the study area (G.O.K, 2013). The study only considered households located within 5 kilometres distance from the River Athi water where the targeted households' draw the water for their domestic use. The following villages bordering the river were selected for the study: Mumbeeni, Iiani, Kyase, and Kikome. Kwanyaa village which lies further from the river was selected as a control point for the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

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

2.2 Water Pollution

Water sustains life. An adequate supply of fresh water is needed for domestic as well as industrial processes. Water bodies have become both the sources for fresh water and receptacles for domestic and industrial wastes leading to “water pollution”. Water pollution affects water quality. The quality of freshwater at any point on a landscape reflects the combined effects of many processes along water pathways and both quantity and quality of water are affected by human activity on all spatial scales (Peters and Meybeck, 2000).

Water quality is affected by changes in nutrients, sedimentation, temperature, pH, heavy metals, non-metallic toxins, persistent organics and pesticides, and biological factors, among many other factors (Carr and Neary, 2008). Continued inputs of contaminants will ultimately exceed an ecosystem’s resilience, leading to dramatic, non-linear changes that may be impossible to reverse (MA, 2005). For example, the extinction of all 24 species of fish endemic to the Aral Sea resulted from dramatic increases in salinity as inflows of freshwater dropped. The water we drink has essential ingredients for our

wellbeing and a healthy life. Unfortunately polluted water and air are common throughout the world (European Public Health Alliance, 2009).

According to European Public Health Alliance, (2009) about one sixth of the world's population, accounting for approximately 1.1 billion people do not have access to safe water and 2.4 billion lack basic sanitation. Pollution may be as a result of discharge of industrial effluents, sewage effluents and agriculture or households wastes (European Public Health Alliance, 2009; (Ashraf *et al.*, 2010). Water pollution affects the health and quality of soils and vegetation (Carter, 1985). Some water pollution effects are recognized immediately, whereas others do not show up for months or years (Ashraf *et al.*, 2010). Estimation indicates that more than fifty countries of the world with an area of twenty million hectares are treated with polluted or partially treated polluted water (Hussain, *et al.*, 2001; Khan, 2010) and this poor quality water causes health hazard and death of human being, aquatic life and also disturbs the production of different crops (Ashraf *et al.*, 2010; Scipeeps, 2009).

The effects of water pollution are said to be the leading cause of death for humans across the globe, moreover, water pollution affects our oceans, lakes, rivers, and drinking water, making it a widespread and global concern (Scipeeps, 2009). Drinking water containing a fluoride content ranging from 5.26 to 26.32 milligrams per litre is considered to be beyond human consumption as this is too high as compared to the World Health Organization's recommended standard of 0.6 to 1.7 milligram per litre (Rizvi, 2000). Ashraf *et al.*, (2010), argues that Pakistani cities are facing tribulations of urban congestion, deteriorating air and water quality and waste management while the rural areas are witnessing rapid deforestation, biodiversity and habitat loss, crop failure, desertification, land degradation, lack of clean drinking water, noise pollution and poor sanitation (Government of Pakistan, 2009).

2.3 Sources of water pollution

According to (Abednego *et al.*, 2013) river water pollution is broadly categorized into point and non-point sources. Point sources discharge pollution from specific sources such as drain pipes, ditches, or sewer outfalls. Non-point sources or diffuse sources on the other hand have no specific location where they discharge into a principal body of water. Non-point sources of pollution pose a major challenge to environmental management due to the diverse sources of pollution and multiple and often complicated pathways of pollutant transport. Nitrogen (N) and Phosphorus (P) inputs from agricultural fields and urban lawns, allochthones input greatly increase the N and P pollution in agricultural and urban watersheds (Zhu, 2008); (Hayakawa, 2006). (Vega *et al.*, 1998) pointed out that surface runoff can be considered a diffuse source due to the fact that it is seasonal and affected by climate.

Substances can enter the environment through intentional, measured releases (pesticide applications); as regulated or unregulated industrial and agricultural by-products; through accidental spills or leaks during the manufacturing and storage of these chemicals; or as household waste (Carr and Neary, 2008). In agricultural settings, over-spraying and long range transport can cause these substances to be found long distances from the initial point of application. About 700 new chemicals are introduced into commerce each year in the United States alone and worldwide, pesticide application is estimated to be approximately 2 million metric tonnes (Stephenson, 2009).

Despite their widespread use, the prevalence, transport, and fate of many of chemicals remain largely unknown because until recently, testing techniques were unable to detect contaminants at the low concentrations at which they are present in the environment (Carr and Neary, 2008). Synthetic chemicals known as endocrine disruptors are a good example of emerging contaminants where the threats and consequences for water quality, human health, and the environment are still not fully understood. Research is needed to

address uncertainties of emerging chemical contaminants, there is also the threat of emerging pathogens – those that are appearing in human populations for the first time, or have occurred before but are increasing in incidence or are expanding into areas where they have not been reported (WHO, 2003). Not only do water-related diseases remain a leading cause of global morbidity and mortality, but several studies have confirmed that the variety of disease is expanding and the incidence of many water-related microbial diseases is increasing (WHO, 2003). In recent years, 175 species of infectious agents from 96 different genera have been classified as emerging pathogens (WHO, 2003). The emergence of new pathogens or the increase in their incidence also threatens water quality.

2.4 Sources of river pollution

Anthropogenic factors play a major role in contributing to the pollution of rivers (UNEP, 2008). According to UNEP, (2006) anthropogenic factors such as agricultural development, population growth, urbanization and industrialization as well as market policy failures are the root causes of water pollution. Improper management of solid waste is one of the main causes of environmental pollution (Kimani, 2007). The increasing trends in water quality degradation in River Athi and its supplying tributaries in the city of Nairobi are largely due to changes in land-use systems (rapid urban infrastructure development). Industrial activities from manufacturing and related industries as well as rapid, population (rural–urban migration) growth impact on water quality in the rivers. The expansion of agricultural activities and increased release of waste water contributes to significant amounts of water pollutants into River Athi (Kithia, 2007).

This situation is of major concern to national water policy makers and environmentalists and the Kenyan government in general. The presence of heavy metals such as Cd and Ni in sediments is a clear indication that the agricultural discharge as well as from spill of leaded petrol from transportation lorries, garages in the towns continue to discharge pollutants to the rivers (Kosgey *et al.*, 2015). The situation confounds the riparian

communities with the associated health risks and spread of waterborne diseases, reduced availability of portable water, loss of sustainable livelihoods and biodiversity.

2.4.1 The role of agriculture in water pollution

Diverse human-produced organic chemicals can enter surface and groundwater through human activities, including pesticide use and industrial processes, and as breakdown products of other chemicals (Carr and Neary, 2008). Many of these pollutants, including pesticides and other non-metallic toxins, are used globally, persist in the environment, and can be transported long ranges to regions where they have never been produced (UNEP, 2009). Dichlorodiphenyltrichloroethane (DDT), a pesticide that has been banned in many countries but is still used for malaria control in countries throughout Africa, Asia, and Latin America (Jaga and Dhamani 2003) remains persistent in the environment and is resistant to complete degradation by microorganisms (WHO, 2004).

High polychlorinated biphenyls (PCB) levels found in Hudson River fish led to bans on fishing, and decades of remediation efforts that continue to this day (EPA, 2009). Other emerging contaminants include endocrine disruptors, pharmaceuticals, and personal care products that may not be removed by existing waste water treatment operations and end up entering fresh water systems. Apart from fertilizer application, sewage disposal from urban areas contribute significantly to nitrogen loadings in river systems leading to eutrophication (Hayakawa *et al.*, 2006). It may also enter through agricultural intensification and commercialisation leading to widespread river pollution.

2.4.2 The role of urbanization and industrialization in water pollution.

Population growth and urbanization have significant roles in contributing to water pollution. An increase in population growth leads to an increase in the demand for housing and an increase in the generation of wastes. A study of the Nworie and Otamiri

rivers in Nigeria showed a strong relationship between nitrate concentration in water and urbanization (Ibe and Njemanze, 2008). As urbanization increased, nitrate concentration of the rivers increased. The increase in nitrate concentration was attributed to surface water flow from farm lands, recreational areas, industrial effluents and the indiscriminate disposal of solid waste into the rivers. Potential sources of these nitrates were identified as being the use of soaps, detergents and agricultural fertilizers (Ibe and Njemanze, 2008).

Industrial activities are a significant and growing cause of poor water quality. Industry and energy production use accounts for nearly 20% of total global water withdrawals (UNEP, 2009), and this water is typically returned to its source in a degraded condition. Industrial waste water can contain a number of different pollutants, including: Microbiological contaminants, chemicals from industrial activities, metals, and nutrients such as phosphorus and nitrogen. Worldwide, it is estimated that industry is responsible for dumping 300-400 million tons of heavy metals, solvents, toxic sludge, and other waste into waters each year (UNEP, 2009).

In many developed nations, significant progress has been made in reducing direct discharges of pollutants into water bodies, primarily through increased treatment of industrial waste water before it is discharged. An Organization for Economic Co-operation and Development (OECD) report documented that in member countries in the past several decades, “industrial discharges of heavy metals and persistent chemicals have been reduced by 70-to-90 percent or more in most cases” (OECD, 2006). In developing countries, on the other hand, more than 70% of industrial wastes are not treated before being discharged into water (UNEP, 2009). Despite this progress, developed nations continue to discharge more industrial pollution into water bodies on a per-capita basis than less developed nations. For example, chlorinated solvents were found in 30% of groundwater supplies in 15 Japanese cities, sometimes traveling as much

as 10 km from the source of pollution (UNEP, 1996). Industrial water pollution is a major source of damage to ecosystems and human health throughout the world. Many industrial contaminants also have grave consequences for human health when consumed as part of drinking water.

In less developed countries, many rivers and streams are heavily polluted due to anthropogenic activities (Jonnalagadda and Mhere, 2001). Similarly a study to look at the effect of anthropogenic activity on water quality of the Odzi River concluded that water quality in the upper reaches of the Odzi River was medium to good. After collecting and analysing water samples, the results showed that water quality dwindled due to seepage from abandoned mine dumps and discharges from farm lands (Jonnalagadda and Mhere, 2001). In the year 2005, a study of the impact assessment of industrial effluent on the Alaro River in Nigeria was carried out. It was realized water quality of the Alaro River was adversely affected and impaired by the discharge of industrial effluents.

Furthermore, levels of parameters downstream were significantly elevated and the quality of effluent did not meet requirements to be discharged into surface water (Fakayode, 2005). Owen, (1994) also maintain that human activities such as mining could cause the release of heavy metals such as lead, mercury, tin and cobalt into rivers. When water from a river which is contaminated with heavy metals is consumed in large amount, it could be very lethal to human. Upstream industrial pollution is believed to be major to the River Athi that is a major source of water for Makueni County and is polluted by industries in Nairobi city, Thika town and Athi River town. Dust from the roads and carbon dioxide and monoxides from the vehicles find their way into the water resources.

2.4.3 Institutional and policy failures in the control of water pollution

In many areas in less developed countries, toilets, latrines or proper drains are non-existent or have broken down. Wastes are disposed of near or in the same river, lakes or wells used for drinking and food preparation (Fakayode, 2005). The laws prohibiting the

indiscriminate dumping of refuse or pollution of rivers in Ghana in particular exist but the enforcement of these laws proves difficult. Omane (2002) asserts that water pollution still persists perhaps due to the fact that these laws were varied and each narrowed towards particular purposes other than pollution prevention. In addition, these laws were fragmented under so many governmental departments and they were too many, too weak. In the case of Kumasi, (Obuobie *et al.*, 2006) indicated that many people attribute the increasing water pollution in the Kumasi metropolis to the failure of city authorities to collect, treat and dispose of waste water efficiently. In addition, government institutions like hospitals and learning institutions contribute to water pollution, making the prosecution of individuals, private and public institutions a farce.

In Kenya, Environmental Management and Co-ordination Act (EMCA) 1999 which created NEMA and Water Act, 2002, revised in 2012 and 2016 Cap 372 has a framework for integrated water resources management, use, development, conservation, protection and control of water resources within each catchment area. Parliament through legislation unveiled institutional policy reforms in water Act 2002 to help the country in management of its natural resources. The previous water management systems were sectorial, technical driven and centralised which proved to be inadequate. However the water sector reforms oriented changes have challenges in governance issues and stakeholder inclusion which has not been adequately ingrained in planning and implementation of development projects. Despite the existing community inclusion policies and water pollution control measures, the institutions involved such as NEMA do not effectively monitor and enforce laws on proper water development management (NEMA, 2004).

2.5 Effects of river pollution

According to (Prabuet *al.*, 2008), the primary effect of river pollution is the reduction in the quality of water in the river. In the least developed countries of in Africa, South America and Asia, 95% of all sewage is discharged untreated into rivers, lakes or the

ocean. In India for example, it is estimated that two-thirds of the surface waters are contaminated to an extent of being considered dangerous to human health. For example Yamuna River in New Delhi had 7,500 coliform bacteria per 100 ml before entering the city. This gives an indication of how heavily rivers draining the cities are polluted with organic wastes. The coliform count increased to 24 million cells per 100 ml as the river picked 20 million litres of industrial effluents every day from New Delhi (Prabu *et al.*, 2008). Similarly study of the Huluka River in Ethiopia revealed a worsening trend of pollution from the upstream to the downstream end of the river with ten times higher values of BOD and COD reported downstream and ions concentration also showing an increasing trend (Prabu *et al.*, 2008). Users of polluted or degraded water resources could suffer negative effects downstream (Peters and Meybeck, 2000).

2.5.1 Effects on water quality

Similarly, there is evidence that River Athi is highly polluted with microbiological quality of the surface water being high above the compliance level of national standards and the WHO guidelines for drinking water and agricultural use. The situation implicitly renders the water from the river as not potable, which poses a health risk to communities that rely on the rivers as primary sources of domestic and subsistence irrigation use (Abednego *et al.*, 2013). Polluted drinking water or water polluted by chemicals is a source of waterborne diseases and cause other health risks (WHO, 2004).

2.5.2 Features of water quality

The principal features of water quality concepts in streams, rivers and lakes can be categorized into three main groups; Physical, Chemical and Biological (<http://www.cdphe.state.co.us/> (Accessed 11th January, 2015)).

2.5.2.1 Physical features

Solids form the most common matter carried along by flowing river water. These solids could be from organic or inorganic sources. Examples include refuse, tree barks, tree trunks, silt, and boulders. When evaluating water quality, suspended solids (SS) are measured in mg l⁻¹ (<http://water.usgs.gov/> (Accessed 4th January, 2016)). Colour, taste and odour are properties that are subjectively determined. They are caused by dissolved impurities either from natural sources or from the discharge of noxious substances like excreta, oil, and bathwater into the water course by man. Turbidity refers to the cloudiness of water due to fine suspended colloidal particles of clay or silt, waste effluents or micro-organisms and is measured in turbidity units (NTU) (Shaw, 1994). Electrical conductivity (EC) is a physical property of water which is dependent on the level of dissolved salts. It is measured in micro-Siemens per centimetre ($\mu\text{S cm}^{-1}$) and it gives a good estimate of the dissolved salt content of a river. Temperature is measured in Celsius degrees ($^{\circ}\text{C}$) and is a good measure for assessing the effects of temperature changes on living organisms (www.woonasquatucket.org/waterqualitydata2005.htm Accessed 13th May, 2015).

2.5.2.2 Chemical features

The chemical features worth studying in water quality analyses is very extensive since water is a universal solvent and many chemical compounds can be found in solution in naturally occurring water bodies (www.woonasquatucket.org/waterqualitydata2005.htm Accessed 4th January, 2016). As such, only a selection of the most significant would be discussed. PH measures the concentration of hydrogen ions (H^{+}) and it is an indicator of the degree of acidity or alkalinity of water. On the scale from 0 to 14 a pH of 7 indicates a neutral solution. Where pH is less than 7, the water is acidic and if pH is greater than 7, the water is alkaline. Dissolved Oxygen (DO) plays a key role in the assessment of water quality. Fish and other forms of aquatic life require dissolved oxygen for their sustenance. Dissolved oxygen affects the taste of water and high concentrations of

dissolved oxygen in domestic supplies are encouraged by aeration. Dissolved Oxygen is measured in mg/L (O₂).

According to water quality analysis data of 2005, nitrogen may be present in the form of organic compounds usually from domestic wastes. Examples of nitrogenous compounds include ammonia and ammonium salts. Nitrogen can also be in the form of nitrites or fully oxidized nitrates. Measures of nitrogen give an indication of the state of pollution by organic wastes. It is measured in mg/L (N). Chlorides are found in brackish water bodies contaminated by sea water or in ground water aquifers with high salt water content. The presence of chlorides (mg/LCl) in a river is an indication of sewage pollution from other chloride compounds (<http://www.nal.usda.gov/> (Accessed 15th December, 2015)).

2.5.2.3 Biological features

Some harmful diseases are transmitted by water-borne organisms. The common organism found in all human excreta is *Escherichia coli* (E.coli) and this gives an indication of sewage pollution or pollution from human sources. This is measured in Most Probable Number (MPN) per 100ml which is determined statistically from a number of water samples (www.waterqualitydata2005.htm, Accessed 4th March, 2016).

2.5.3 Effects on water quantity

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

2.5.4 Effects on human health

Human health to a large extent is dependent on access to clean portable water. Unfortunately, not everyone on the planet has access to this precious resource. Some persons have access to water but such water is polluted. Polluted water could be a carrier of many diseases and when it is ingested into the human system, it could have negative implications for human health. Persons who use polluted water are in danger of contracting water-borne, water-hygiene, and water-contact or water-habitat vector diseases such as typhoid, amoebic dysentery and diarrhoea (Hammer *et al.*, 2006).

Water-contact diseases are contracted when an individual's skin is in contact with pathogen infested water. An example is schistosomiasis (bilharzias) in which the eggs of the pathogen (*Schistosoma spp.*) present in the faeces or urine of an infected individual. Water-habitat vector diseases are transmitted by insect vectors that spend all or part of their lives in or near water. Examples include malaria and filariasis as well as onchocerciasis which have the mosquito and aquatic fly respectively as its vectors (Hammer *et al.*, 2006).

According to (UNDP, 2012) it is estimated that more than 1 billion people are denied the right to clean water and 2.6 billion people lack access to adequate sanitation. In Sub-Saharan Africa, it is estimated that 42% of the population lives without improved water (WHO, 2004). The absence of improved water sources puts people's health at risk and may force them to extract water from alternative, unsafe sources, exposing them to diseases such as diarrhoea, dysentery, cholera, typhoid and schistosomiasis (WHO, 2001). It is estimated that as many as 80% of all infectious diseases in the world are associated with insufficient and unsafe water (Smet, 2002). Furthermore in less developed countries (LDCs), it is estimated that 25 million people per year die from

contaminated water; three-fifth of whom are children and worldwide, every hour 1,000 children die from diarrhoea related diseases.

An adequate provision of good drinking water is therefore essential for the promotion of good health and sanitation. Where there is too little water for washing oneself, flushing toilets, properly cleaning food, utensils and clothes, the likelihood of contracting diseases such as diarrhoea could be very high. According to (Wolff, 1999), when significant improvements in the quality and quantity of water are made in less developed countries, there would be about 2 million fewer deaths from diarrhoea among children. In addition, research has shown that access to safe water reduces child death rates by more than 20% in Cameroon and Uganda whilst in Egypt and Peru, the presence of flush toilets in the house reduced the risk of infant death by more the 30% (UNDP, 2012).

2.5.5 Socio-economic implications

The pollution of rivers also, has socio-economic implications. Adequate water supply promotes good health and improves the prospects of new livelihood activities which are otherwise denied due to poor health which lead to poverty (UNESCO, 2006). Where water and sanitation investments are not made, the likelihood of contracting diseases such as diarrhoea, dysentery, cholera, typhoid and schistosomiasis is high which lead to loss of working days as well as productivity hence impacting negatively on the household incomes. Women are the most vulnerable to the effects of poor water quality and constitute almost 70% of the 1.3 billion people living in extreme poverty, often trapped in a cycle of ill health (WHO, 2001)

According to the (World Bank, 2008) labour is often the only asset that poor households have and that sickness and death can have intergenerational effects. Any improvements in environmental health can have long-term impacts on households' ability to move out of

poverty”. An improved water supply could therefore trigger a reduction in working hours and increase rest for women and children who hitherto, had to walk long distances or join long queues to fetch water of questionable quality. For poor rural women, the time saved could be used for household child care, collection of more water for hygiene or the engagement in productive activities such as trading to supplement household incomes. In addition, children could gain more time to attend school (Smet and Van Wijk, 2002).

2.6 Water pollution in Kenya

Kenyan urban population which has been growing at a rate of 8% per annum is now more especially when 27% of the country’s total population is currently living in urban centres and cities (NEMA, 2004). In addition, generation of solid, liquid and gaseous wastes has been increasing at the same level as industrial development and the diversification of consumption patterns. According to NEMA (2004) the per capita waste generation range between 0.29 and 0.66 kg day⁻¹ within the urban areas of the country, and that of the municipal waste generated in the urban centres 21% emanated from industrial sources and 61% from residential areas.

The city of Nairobi is the heart of industrial production in Kenya and the commercial hub of the East African Community (EAC). It is drained by three tributaries of the Nairobi River, namely; Ngong, Nairobi and Mathare rivers. These rivers collect most of the wastes generated in the city and its waters are heavily polluted by solid, liquid and organic wastes (NEMA 2004; Muiruri *et al.*, 2013; Abednego *et al.*, 2013). The polluted water has a strong impact on human beings and other living organisms and the environment in general. Nairobi River has acted as a major depository of waste from both domestic and industrial sources. The riparian reserves of the three main rivers are marked with numerous informal settlements without adequate sewerage and sanitation services and hence discharge their raw sewage into the rivers; and most industries find it cheaper

to discharge their effluents into the rivers without any satisfactory treatment (Wolff, 1999).

2.7 Water pollution intervention in Kenya

Existing national legal tools for pollution control in Kenya form a three-tier system consisting of:- Statutory provisions dealing with water, air, wastes and toxic and hazardous substances; Two, the Common law rules relating to negligence and nuisance; and three the County Government laws and Acts.

All the above tools have developed slowly but haphazardly as a response to individual and critical cases of pollution largely based on discrete environmental media and specific pollutants. Statutory law remains the most significant legal framework for the control of pollution and for environmental management and protection in Kenya. The main legal instruments for control of water pollution are the (G.O.K, 2012). These instruments define actions and activities which are polluting and specific pollutants which are subject to control. Until now, this remains the most significant legal framework for the control of pollution and for environmental management and protection in Kenya. However, it has not been efficient enough in dealing with problems of pollution at the national level. Its main failure lies in lack of clean air and waste management Act; lack of generally applicable criteria and standards; overlap of tasks of the different legislations, and hence of the different organs; and lack of enforcement powers (www.nema.org.ke Accessed 11th November, 2015)

2.8 Conceptual framework on causes and intervention to river water pollution

River water pollution has affected the security of human health within the study area. This has been clearly given by the high number of individuals being affected by sicknesses emerging from polluted water which they are in contact with for their daily domestic water use needs and livelihoods. The damage and pollution the river water can

only be tackled through proper pollution control measures by both the residents and government; for example educating and creating awareness to the residents on the need to protect the river water, the government to enact regulations to control river pollution and enforce the laws by arresting the offenders and imposing sanctions on polluters. This brings about healing of the of river water hence human health security on use of water. Outer sphere shows intervention mechanism in position by state agencies and government, middle sphere shows (EMCA) policy in place for intervention and inner sphere gives the people culture, beliefs and way of life.

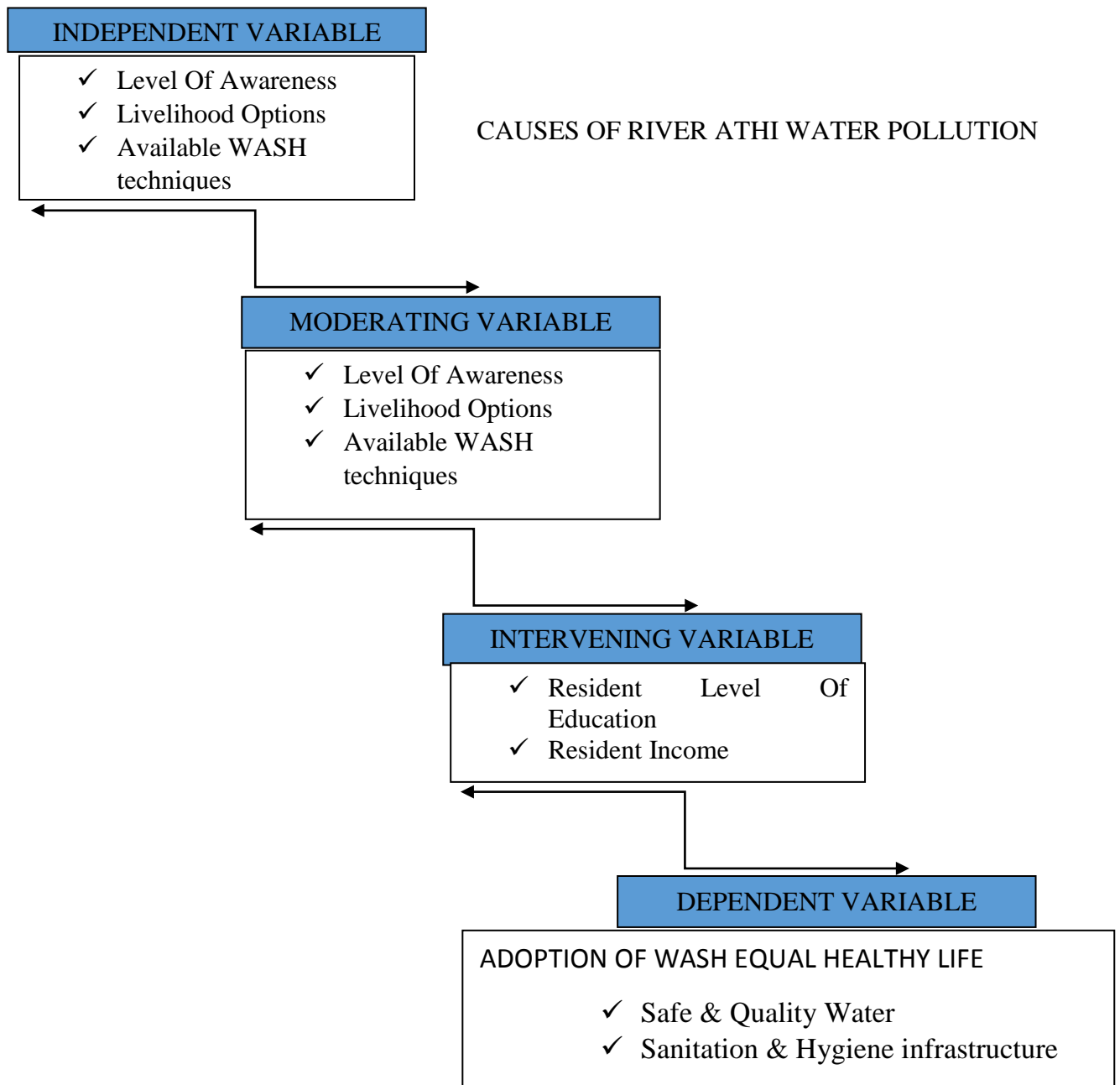


Figure 2.1: Conceptual framework

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

The chapter outlines study methods used in the research. It also defines population and size of the area of study and the design applied to get data from the field. The chapter also describes sample size used in data collection.

3.2 General Study area

The general study area falls within Makueni County, which covers an area of approximately 8,034.7 km² and borders Kajiado, to the West, Taita Taveta to the South, Kitui to the East and Machakos County to the North. The county lies between Latitude 1° 35' and 3 ° 00 South and Longitude 37°10' and 38° 30' East (G.O.K, 2013). The County lies in the arid and semi-arid zone in in the South-Eastern Kenya. The general terrain of the area consists of undulating plains, with various hills and small plateaus rising between 600-1900 metres above sea level. Mbooni and Kilungu hills in the upper part of the County have the highest elevation upto 1900 metres above sea level. The lower part of the County is comprised of low lying areas stretching to the southern parts in Tsavo rising to 600m above sea level, and to the volcanic Chyulu hills in the south west boarder of the county, (G.O.K, 2013). The County is served by river Athi which is the most important perennial river. The river has high potential for irrigation alongside other natural resources found in Makueni County like land, good soils and suitable climate for agriculture and livestock production and, horticulture (GOK, 2012).

3.2.1 Specific study area

The specific study area falls within Kathonzweni Sub County of Makueni County. The choice of the study site is informed by several considerations suitable in investigating the research problem. The study area falls along River Athi which cuts across Kathonzweni

Sub County making the boundary of Makueni and Kitui Counties respectively. The study area has increasingly lacked fresh water since River Athi which is the main source of water is mostly polluted by anthropogenic activities either upstream or within the study area. According to the views of the community, recently death rates have increased most probably due to the polluted water and vectors from the River. The study was specifically done in Mumbeeni village, Iiani village, Kyase village and Kikome village, all of which lie within 5 kilometres from the river. Kwanyaa village was chosen and used as a control point for the study. It lies beyond the 5Km radius, away from the river and most of its households had other main water sources apart from that of the River Athi.

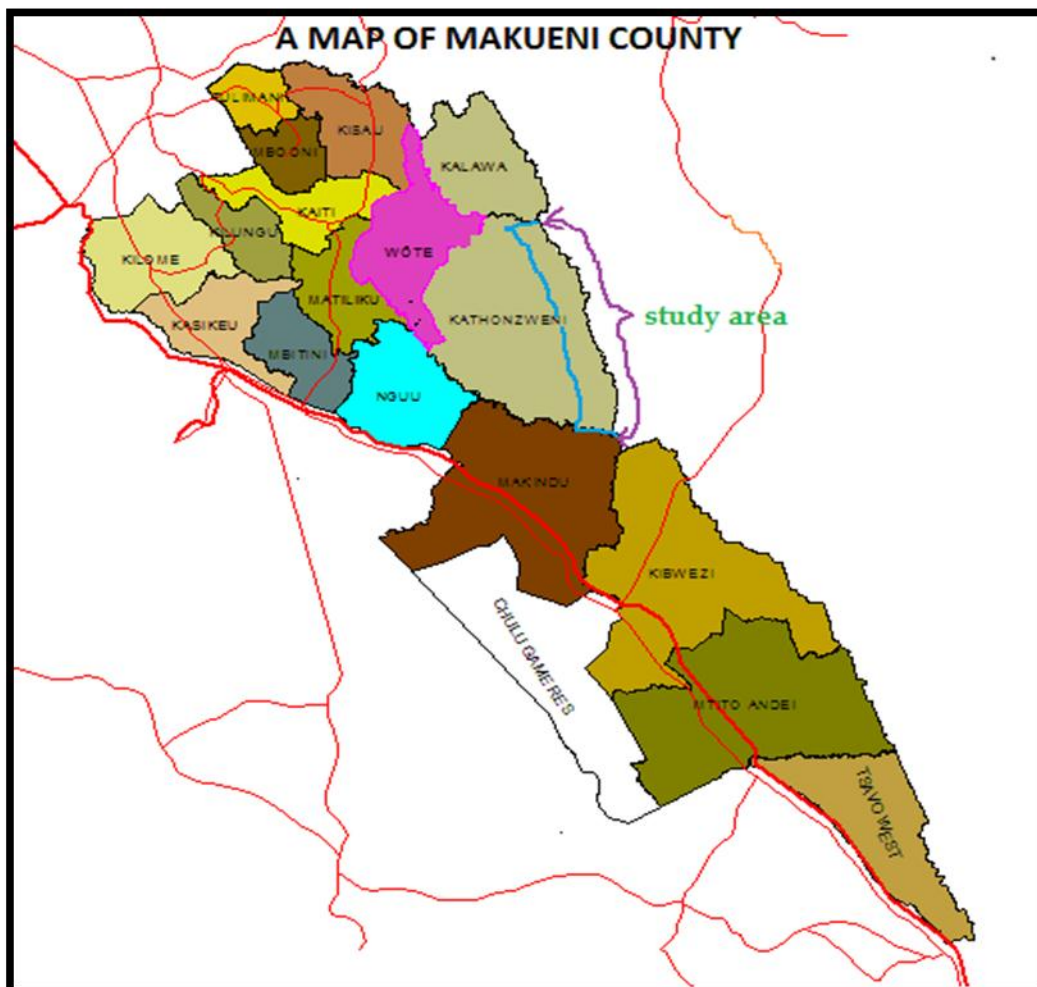


Figure 3.1: Map of Makueni County showing Kathonzweni Sub-County; The study area



Figure 3.2: Google Earth map of the study site showing sampling of study centres,
 Source: Kenya Bureau of statistics, 2010



Figure 3.3: Google map of spatial human activities in study area

3.2.2 Agro- Climatic conditions

The rainfall distribution in the area is bimodal and is received in two rain seasons. The short rain season normally begins in October and December and the long rain season begins in March and end in June. The upper hilly parts which include Mbooni and Kilungu hills receive an average of 800-1200mm of rainfall per annum. The low lying parts in the drier southern part of the County which consists of the specific study area (Kathonzweni), receive an average of 300-400mm per annum. The temperatures in the upper areas range between 24.6 °c to 35.5 °c recorded in the low lying areas. The mean monthly temperatures in the area; ranges between 18 °c to 25 °c. The months of February and October are the hottest and July being the coolest month. The terrain of Wote town is generally flat with the immediate site location adjacent to small rocky hills on the Eastern site overlooking a range of surrounding hills in the background (G.O.K, 2013).

3.2.3 Soils, land use and vegetation

The vegetation in this area is generally rangeland dominated by *Commiphora Spp* and Acacia species, bushes and grasses. The areas vegetation is a mix of indigenous plant species typical in semi-arid dry conditions with low rainfall regime. Due to anthropogenic activities including increased farming activities and grazing; most of this vegetation is degraded. The expansion of agriculture, livestock grazing, wanton destruction of trees for charcoal burning and human settlement, has led to unprecedented clearing of vegetation in the area and land degradation. However in spite of the ranging land degradation, indigenous tree plants species thrive in the area amidst low rainfall which impacts negatively on soils, vegetation and land use (G.O.K, 2013).

3.2.4 Geology

The geology of the area is located within the Mozambican belt, generally occupied by the basement complex system consisting mainly of metamorphic rocks, with soils ranging from sandy, black cotton soils (clay) in the river valleys to alluvial soils in some areas. Vast areas have soils ranging from sandy to clay soils while the rest of the areas are rocky and stony in nature. Sand deposits in the rivers are overly exploited for local and commercial use in building. The clay soils are used for brick making which is common along river banks in the area. (G.O.K, 2013)

3.2.5 Drainage and hydrology

The county receives limited and erratic rainfall leading to a situation where surface water sources are scarce. The major sources of water are seasonal rivers such as Thwake, Kaiti, Kikuu and Kambu, among others that flow only during rainy seasons. The only reliable perennial river is River Athi that flows along the border of Makueni and Kitui Counties. All of the seasonal rivers in the area drain into River Athi. Generally these rivers are characterised by very low flows (base flows) in dry season and high flows during rainy seasons. Most of the ephemeral streams generally become dry within one month after the

rainy season. The flows are usually fast and turbid due to high sediment concentration associated with high rates of soil erosion in the catchment areas, much of it washed into river Athi onwards to the Indian Ocean (Muriuki *et.al.*,2005; G.O.K, 2013).

3.2.6 Socio-economic conditions

Agro-pastoralism forms the main source of income for the rural communities in Makueni County. Agriculture at 80%, is foremost the main source of livelihoods, with wage employment accounting for 10% and rural and urban self-employment at 8% and 4% respectively. Livelihoods options in the count are limited such that majority of the residents lack meaningful sources of livelihoods. The vast majority of the unemployed people, almost and exclusively rely on agriculture for their livelihoods, much of it based on rain fed subsistence crop production. Most of the available livelihood options are weather dependent, hence not commercially viable, as they entirely depend on rain fed agriculture. Environmental degradation continues to occur due to people's over-reliance on rain-fed agriculture. In order to increase their livelihood outcomes they have increasingly adopted unsustainable livelihood strategies like charcoal burning and sand harvesting which continue to impact negatively on the environment (loss of biodiversity and encroachment to fragile ecosystem), and especially farming on river banks leading to soil erosion, water pollution and leading to drying of riverbeds (G.O.K, 2013).

3.2.7 Population distribution

A total of over 30,861 people live along the river line stretch of 51.06 kilometres. This is half the total district population who live within the 5 kilometres distance from the river line. This population is believed to access the River Athi water as their main source of domestic water. The effects of River Athi are felt downstream more so by the population in Kathonzweni Sub County (G.O.K, 2013).

Table 3.1: Population distribution in the specific study area in Kathonzwani Sub-county

Sub-Location	Male	Female	Total	Households	Area Km²	Population density
Ivinganzia	1353	1517	2870	553	34.85	82.35
Kanthuni	1407	1646	3053	557	43.34	70.44
Katithi	1364	1540	2904	576	38.93	74.59
Yekanga	1419	1483	2902	523	34.93	83.09
Yinthungu	1460	1629	3089	584	40.52	76.23
Kithuki	2750	2991	5741	1064	82.85	69.23
Mwania	1569	1670	3239	599	62.87	51.52
Total	11,322	12,476	23,798	4,456	338.29	70.35

Source: Census report 2009.

3.3 Data collection methods

Various methods were employed in data collection and analysis. These included use of questionnaires and key informant interviews. Questionnaires were administered to households in selected sites through random sampling. The questionnaire was used as a guide in household interviews so as to attain the set objectives. The questionnaires were not issued to the household members to avoid poor data entry instead interviews were made in each household head. To validate data collected using questionnaires, interviews were conducted on various key informants including, Water Service Providers, NEMA Officers and Public Health Officers. Only top managements were interviewed and at this

stage questionnaires were given to them because they have knowledge to fill the questionnaires. Secondary data from past studies was also used in this study.

As confirmation of secondary information from available literature that River Athi water is polluted, samples of the River water was collected and analysed from the Government chemist. The institution used Atomic Absorption Spectroscopy method where concentrations of gas phase atoms were measured through light produced by a hollow cathode lamp. This method qualitatively determined chemical elements using absorption of optical radiation by free atoms in gaseous state. The method was used especially to analyse metals in very low concentration typically in Parts Per Million (PPM)). The method was essential because it determined more elements in rapid sequence in one sample analysis. For the physical analysis, the Multiple-tube method was used. The method which is also known as “the most probable number (MPN) method” is based on indirect assessment of microbial density in the water sample by reference to statistical tables to determine most probable number of microorganism present in the original sample. The method was essential because River Athi water is turbid and the river water is highly used for drinking making the method more ideal

3.4 Sample size

The study sample size comprised of 51 households in the whole study area of 514 households. Households sampled in each village were determined by the sample size of 10% rule (Mugenda, 2003). The 51 sample size was distributed as; Mumbeeni village had 8 households, Iiani village had 13 households, Kyase village had 12 households, Kikome village had 9 households and Kwanyaa village had 9 households sampled.

Table 3.2: Village sampling sites and their sample size

Strata number	Village (Sampling Point)	Total households	Sample Size
1.	Mumbeeni	84	8
2.	Iiani	128	13
3.	Kyase	122	12
4.	Kikome	88	9
5.	Kwanyaa	92	9
Total		514	51

3.5 Survey design

The study employed a survey research design. According to Orodho (2005), Survey concerns describing, recording, analysing and reporting conditions that exist or have existed. The survey design was relevant to this study as the research reported on socio-economic characteristics of the respondents and study area and interventions put in place by the government and residents in the study area to control the pollution of the River Athi.

3.6 Sampling technique

The study adopted systematic random sampling approach to gather quantitative data for the household survey. Stratified random sampling technique was applied to pick a village in each sub locations bordering the River Athi. These were Mumbeeni, Iiani, Kyase, Kikome and Kwanyaa. Kwanyaa was however away from the River Athi and was used as control point.

Sampling for Government chemist analysis was done from Iiani village point. This Water was basically to confirm published information that the river water is polluted. Guidelines on sample collection and procedures according to AOAC methods were followed to ensure national and international standards are adhered to.

3.9 Methods of Data analysis

The choice of data analysis methods was guided by the study objectives. The collected data was coded and entered into the computer for analysis using the Statistical Package for Social Sciences (SPSS) and Microsoft Excel. On qualitative data, thematic analysis was derived from the administered questionnaires. The main themes and patterns in the responses were identified and analyzed to determine the adequacy, usefulness and consistency of the information. The themes and patterns included people responses and opinions. Quantitative data was analyzed using descriptive statistical tools such as frequencies, percentages and means accordingly. Chi square test was used to test levels of significance. The results of data analysis were presented in percentage tables. Answering of the research questions was done by interpreting the tables. Implications from the different data sets integrated logically to give the required information.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter deals with the salient socio-economic characteristics in the study area, and the causes of river pollution and the health effects on the downstream riparian communities in Makueni County who live close to River Athi. It also deals with the government efforts towards the intervention to control and address the problem of water pollution in the area.

4.1.1 Socio-economic characteristics of the respondents

In this study a total of 51 households were interviewed. Out of the respondents interviewed, the males recorded a mean of 32.4% and females 67.6% respectively. The majority had attained primary level education with a mean of 62.5%, followed by those who had secondary education 19.1, with only a few of those with a mean of 8.72% reporting to have had no formal schooling. The average size of households were between 2-5 children with a mean of 57.5%, who were the majority, followed by households with between 6-9 people with a mean of 25.6%. The majority of the respondents who were interviewed ranged from 31-40 years with a mean of 34.3%, those aged between 21-30 (21.9%) and 41-50 years (20.2%) respectively. The households derived their livelihoods from farming and trading with a mean of 44.4% respectively. The survey indicated that most of the respondents had lived in the basin for quite a considerable time with those who had lived there for between 6-10 year registering a mean of 58.9% and those with over 10 years with a mean of 9.0%. A large number of the respondents 61.2% did not have a toilet in their homesteads, with those found to have had toilet facilities taking a mean of 38.8% (Table 4.1).

Table 4.1: Socio-Economic Characteristics of selected households in the study area (N=51)

Socio	Economic	Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa	Mean
Variable		(%)	(%)	(%)	(%)	(%)	(%)
Gender of respondent	Male	25	23	25	44.4	44.4	32.4
	Female	75	77	75	55.6	55.6	67.6
Household size	Below 2	12.5	0	25	22.2	0	11.94
	2- 5	50	53.9	61.5	77.8	44.4	57.5
	6-9	37.5	38.5	7.7	0	44.4	25.6
	10 and above	0	7.7	5.8	0	11.1	4.9
Age of the respondent	Below 10	0	0	0	0	0	0
	11-20	12.5	15.4	0	0	11.1	7.8
	21-30	37.5	38.5	33.3	0	0	21.9
	31-40	37.5	23.1	33.3	55.6	22.2	34.3
	41-50	12.5	23.1	33.3	22.2	22.2	20.2
	51- 60	0	0	0	11.1	44.4	11.1
	Above 60	12.5	0	0	11.1	0	4.7
Nature of work	Govern ment	0	6.3	87.5	6.3	11.1	22.24

	Farming	80	13.5	12.5	13.7	44.4	32.82
	Trading	20	80	0	80	44.4	44.88
Period at the basin(years)	Less than I	11.1	0	6.7	9	0	5.4
	1-5	33.1	12.5	13.3	17.6	56.9	26.7
	6-10	44.4	62.5	80	64.7	43.1	58.9
	More than 10	11.1	0	0	13.7	0	9.0
Level of education	Primary	70	60	75	62.5	66.7	62.5
	Secondary	10	13.3	12.5	37.5	33.2	19.1
	Tertiary/ University	20	6.7	0	0	0	5.34
	Never schooled		20	12.5	0	11.1	8.72
Sanitation infrastructure	Toilet available	25	38.5	41.7	44.4	44.4	38.8
	Toilet missing	75	61.5	58.3	55.6	55.6	61.2
	Both	62.5	61.5	50	44.4	55.6	55.8

	missing							
Average	Below	88.8	87.5	11.1	100	80	73.5	
income from	Kshs							
employment	5000							
monthly if self	Kshs	11.1	12.5	0	0	6.3	6.0	
employed	5000-							
	10,000							
	Above	0	0	88.9	0	13.7	20.5	
	Kshs							
	10,000							

Table 4.2: Results of the chemical analysis of the river water (Government chemist).

Chemical tests	Government chemist mg/l(ppm)	Result	Max guideline Value WHO mg/l(ppm)	Public health laboratories results mg/l(ppm)
Components				
Total Alkalinity as CaCO ₃	152.0		500	
Phenolphthalein (CO ₃)	Nil		-	
Methyl Orange (HCO ₃)	152.0		-	
Chloride (CL)-	40.0		250.0	
Sulphate (SO ₄)	24.0		250.0	
Nitrate (NO ₃)	8.8		50.0	
Nitrite (NO ₂)	3.2		3.0	
Fluoride (F)	2.0		1.5	
Sodium (Na)+	69.9		200.0	
. Potassium (K)+	6.4		-	
. Calcium (Ca)+	8.4		-	
. Magnesium (Mg)++	3.1		-	0.39
. Iron (Total) (Fe)+++	0.07		0.3	-
. Manganese (Mn)++	0.5		0.5	
. Carbonate Hardness as CaCO ₃	34.8		-	
. Total Hardness as CaCO ₃	34.8		500	
. Silica (SiO ₂)	34.0		-	
. Oxygen absorbed. 4hrs at 27 ⁰ C	48.0		1.0	
. Total Dissolved Solids, Residue dried at 180 ⁰ C	280.0		1000	Present
Optional Parameters (done on request)				
Lead (pb ²⁺)	Not detected		0.01	Not detected

Copper (Cu ²⁺)	Not detected	2.0	
Zinc (Zn ²⁺)	Not detected	5.0	
Phosphate (PO ³⁺)	5.3	-	
Dissolved Oxygen	3.2	-	
Dissolved Oxygen			
Physical tests			
Colour	Green	-	Brown
PH	8.0	-	
Taste	-	-	
Turbidity	Turbid	-	
Deposits	Black deposits	-	Present with soil particles

4.1.2: Residents awareness on water quality of River Athi as their main source of water

The study revealed that the residents in Kathonzweni Sub-County who used the water from river Athi were aware of the dangers posed by river pollution. They indicated that to the majority it was the main source of water for domestic and irrigation use. The study indicated that there were three main sources of water in the study area including; river, rain water and shallow wells (Table 4.2 and 4.3). Across all the five villages' river Athi dominated as the major source of water with Mumbeeni village and Kikome village exclusively depending on river water. In Kyase village and Iiani village 87% and (80%) respectively depended on river water, whereas in Kwanyaa only 11.1% depended on river water. Rain water was commonly used in Kwanyaa village (88.8%) placed at a fairly long distance from the river. The study revealed that Iiani village 6.3% of the residents used shallow wells as source of water, mostly located close to the river.

Table 4.3: Main sources of water in the selected study sites (%)

Main sources of water	Villages					Mean
	Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa	
River	100	80	87.5	100	11.1	75.7
Rain water	0	13.7	12.5	0	88.8	23.0
Shallow well	0	6.3	0	0	0	1.26

Main source of water chi-square goodness of fit.

HO: There were no statistically significant differences among the various water sources

H1: There were statistically significant differences among the various water sources

	Observed N	Expected N	Residual
River	39	17.0	22.0
Rainwater	11	17.0	-6.0
Shallow well	1	17.0	-16.0
Total	51		

Test Statistics Values

Chi-Square	45.647 ^a
Df	2
Asymp.	.000

From our table above, the test statistic is statistically significant: $X^2(2) = 45.647$, $P < 0.0005$. Therefore the null hypothesis was rejected and conclusion made that there are

statistically significant differences among the water sources, with less people getting water from shallow wells (n=1) compared to either rain water (n=11) or river (n=39).

4.3.1: Common causes of river pollution

Results from the study revealed some of the common causes of river pollution in the study area such as, up-stream pollution from industries and sewage/municipal waste disposal systems located in the cities and urban centres in the upstream (Table 4.4). This situation was reported in Iiani village by 93.3% of its households. Similarly a fairly large number of respondents, in the other sites, reported pollution of the River to be from the upstream Kikome 62.5%, Mumbeeni 60% and Kyase 50% respectively and Kwanyaa. 33.3%. Agricultural chemicals were also mentioned as another common cause of river pollution, emanating from fairly far places as well as in the river immediate locality, with a mean of 58.92% and 24.28% respectively.

The respondents intimated that many agricultural activities and contamination by pesticides resulted from encroaching on fragile ecosystems and increased farming on the river banks. In Kyase village this situation was reported by 37.5%, of its households while in Mumbeeni village and Kikome village, 30% and 25% of their households reported agriculture activities as one of the main causes of river water pollution. In Kwanyaa and Iiani villages, a total of 22.2% and 6.7% respectively, also believed that agricultural activities increased pollution in the riparian zone.

The majority of respondents in Iiani village believed that both upstream pollution and disposal of agricultural waste into the river were the main cause of the river pollution. Kwanyaa village had the highest number of respondents who were not aware of the cause of the river pollution 44.55% whereas in Kyase and Kikome concurrently, 13.5% of their respondents were not aware of the cause of the river pollution. Mumbeeni village 10% of the households were also not aware of the cause of the river pollution. The study's findings indicated that, this kind of knowledge was as a result of community sensitisation to the residents through public Barazas, by government officers (public health workers)

and other media avenues like radio. The study established that the community believed that up-stream pollution from industries and sewage was the highest river polluter.

Table 4.4: Common causes of river pollution in selected areas of study sites (%).

Common causes of Villages river pollution						
	Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa	Mean
Up-stream pollution from industries and sewage	60.0	93.3	50.0	62.5	33.3	59.82
Dispose from agricultural chemicals	30.0	6.7	37.5	25.0	22.2	24.28
Not aware	10	0	13.5	13.5	44.5	16.3

Common causes of river pollution chi-square goodness of fit test

HO: There were no statistically significant differences among the river pollution processes.

H1: There were statistically significant differences among the river pollution processes

	Observed N	Expected N	Residual
Upstream pollution from industry and sewage	30	17.0	13.0
Dispose agricultural chemicals	13	17.0	-4.0
Not aware	8	17.0	-9.0
Total	51		

Test Statistics

Chi-Square	15.647 ^a
Df	2
Asymp. Sig.	.000

The findings indicated that the test statistics were significant: $X^2(2) = 15.647$, $P < 0.0005$. Therefore the null hypothesis was rejected and conclusion made that there were statistical differences among the causes of upstream pollution, with less people not aware ($n=8$) compared to either disposal of agricultural chemicals ($n=13$) or industry and sewage ($n=30$).

4.1.4: Methods of disposing of wastes by the households

In the study area, households were found to have practiced several ways of refuse and waste disposal which included: open space dumping, burning, compositing, burying and dumping (Table 4.5). Burning was the most common method of waste disposal practiced. In Kikome village burning was reported by households as the leading method with 62.5%, followed by Mumbeeni village with 60% of households burning their waste and Iiani village had 40% of their households using burning as their main waste disposal method. Open space dumping was the second major method of refuse disposal with Kwanyaa village leading with 44.4%, Iiani village had 40% of its households using open space dumping as their main refuse disposal while Kyase village and Mumbeeni village 37.5% and 30% used open space refuse disposal respectively.

The results indicated that refuse compositing was highly practised in Kyase village and Kikome village households at 25% and was lowly practiced in Mumbeeni village households at 10%. Refuse burying was only practiced by Kikome village households at 12.5% and Kwanyaa village with 11.1% of the households. The study showed that some households dumped refuse into the river with Kyase village leading by recording 12.5% of its households and Iiani village at 6.7%.

Table 4.5: Ways of disposing refuse in the selected study sites (%)

Ways of Villages disposing refuse		Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa	Mean
Open space dumping		30.0	40.0	37.5	0	44.4	30.4
Burning		60.0	40.0	25.0	62.5	33.3	44.2
Composited		10.0	13.3	25.0	25.0	11.1	16.9
Buried		0	0	0	12.5	11.1	4.7
Dumped into or near the river		0	6.7	12.5	0	0	3.8

Ways of disposing refuse (waste) chi-square goodness of fit test

HO: There were no statistically significant differences among the ways of disposing refuse in the various villages.

H1: There were statistically significant differences among the ways of disposing refuse in the various villages

Way of refuse disposal	Observed N	Expected N	Residual
Open dumping	16	10.2	5.8
Burning	22	10.2	11.8
Composited	10	10.2	-.2
Buried	2	10.2	-8.2
Dumped into/near river	1	10.2	-9.2
Total	51		

Test Statistics

Chi-Square	31.843 ^a
Df	4
Asymp. Sig.	.000

The test statistics were statistically significant: $X^2_{(4)} = 31.843$, $P < 0.0005$. Therefore the null hypothesis was rejected and conclusion made that there were statistically significant differences among the ways of disposing refuse, with less people disposing near/into river (n=1) compared to either burying (n=2), composite disposal (n=10), open dumping (n=16) or burning (n=22).

4.2 Health effects resulting from the pollution of the Athi- River in Kathonzwani district

4.2.1 Common uses of the river water in the study area

The survey established that there were seven water major uses in the study area. These were watering of crops, domestic use which included; washing, drinking, cooking and bathing, fishing and brick making (Table 4.6). The study revealed that in Mumbeeni village and Iiani village the river was the only source of drinking water. In Kwanyaa village 66.7% used the river water for cooking as compared to Kikome and Iiani villages (87.5%), this was significantly lower than it was the case in Mumbeeni village 100%. Mumbeeni had equal need for water for bathing and watering crops 60%. The study indicated that 12.5% of Kikome village households, 10% of Mumbeeni village households and 4.2% of Kyase village ($X^2=6.0811$) were using the river water for making bricks.

The households were also noted to have been fishing in the river mostly in Kyase village and Kikome village each with 25%, respectively. In Mumbeeni village and Iiani village, the households 20% were involved in fishing activities. The use of river water for cooking was the most common water use cutting across all the villages. It had the greatest percentage of households use compared to the other documented uses. Mumbeeni village was leading 90%, Kikome village 87.5%, Iiani village with 86.7% whereas, Kikome village and Kyase village were at 66.7% and 50% respectively using the river water for

cooking which constituted the main domestic water use. ($X^2=0.0033$). The water use for bathing was, also higher in Mumbeeni village 60% and the least in Iiani village 6.7% as reported by the households.

Table 4.6: Uses of river water in selected areas of study sites (%)

Watering and domestic use	Villages					Mean
	Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa	
Watering crops	60.0	6.7	12.5	87.5	44.4	52.22
Washing	40	86.7	12.5	37.7	33.3	42.04
Drinking	100.0	100.0	12.5	25	66.7	60.84
Fishing	20	20.0	25.0	25.0	22.2	22.44
Cooking	90.0	86.7	50.0	87.5	66.7	76.18
Bathing	60.0	6.7	37.5	12.5	22.2	27.78
Brick making	10	0	4.2	12.5	0	5.34

Uses of river water chi-square goodness of fit test

HO: There were no statistically significant differences among the uses of water in the study area

H1: There were statistically significant differences among the uses of water in the study area

	Observed N	Expected N	Residual
watering crops	20	20.0	0
Washing	22	20.0	2.0
Drinking	31	20.0	11.0
Fishing	12	20.0	-8.0
Cooking	38	20.0	18.0
Bathing	14	20.0	-6.0

Brickmaking	3	20.0	-17.0
Total	140		

Test Statistics

Chi-Square	41.900 ^a
Df	6
Asymp.	.000

The study's test statistics were statistically significant: $X^2(6)=41.900$, $P<0.0005$. Therefore the null hypothesis was rejected and the conclusion was that there were statistically significant differences among the uses of water, with less people making bricks (n=3) compared to either fishing (n=14), bathing (n=14), watering crops (n=20), washing (n=22), drinking (31) or cooking (n=38).

4.2.2: Common illnesses and diseases in the study area

The survey findings showed that in study area the community suffered from seven common illnesses which included; Amoebiasis, malaria, diarrhoea, cholera, fever, typhoid and coughing (Table 4.7). Across the five Villages malaria was the major suffered illness with responses in Iiani village being 46.7%, followed by Kyase village and Kikome village each at 37.5% while Kwanyaa village was 22.2% with the lowest being Mumbeeni village at 20 %. This is a disease which is water habitat vector borne. The highly suffered illness in Mumbeeni village was diarrhoea reported by 40%. Typhoid was reported at 4.4% the lowest in Kwanyaa village and highest at Mumbeeni village 30%. In all villages sampled, Amoeba was reported by 25% and was only experienced in Kikome village, Cholera by 12.5% and was also only revealed in Kyase village. Resident's in Kwanyaa village suffered most from Malaria at 22% followed by coughing and fever at 11.1%.

Table 4.7: Common illnesses in the community within the selected study sites (%)

Common illness in community	Villages					Mean
	Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa	
Amoeba	0	0	0	25.0	0	5
Malaria	20.0	46.7	37.5	37.5	22.2	32.76
Diarrhoea	40.0	26.7	12.5	0	0	15.82
Cholera	0	0	12.5	0	0	2.5
Fever	10.0	6.7	12.5	12.5	11.1	10.54
Typhoid	30.0	20.0	12.5	12.5	44.4	23.88
Coughing	0	0	0	12.5	11.1	4.72

Common illnesses in the community chi-square goodness of fit test

HO: There were no statistically significant differences among the common illnesses affecting people in the villages

H1: There were statistically significant differences among the common illnesses affecting in the villages

	Observed N	Expected N	Residual
Amoeba	4	7.6	-3.6
Malaria	19	7.6	11.4
Diarrhoea	8	7.6	.4
Cholera	2	7.6	-5.6
Fever	6	7.6	-1.6
Typhoid	11	7.6	4.4
Coughing	1	7.6	-5.6
Total	51		

Test Statistics	Values
Chi-Square	30.075 ^a
Df	6
Asymp.	.000

The test statistics were statistically significant: $X^2(6) = 30.075$, $P < 0.0005$. Therefore the null hypothesis was rejected and a conclusion made that there were statistically significant differences among the common illness in the community, with less people suffering from coughing and cholera both ($n=2$) compared to either amoeba ($n=4$), fever ($n=6$), diarrhoea ($n=8$), typhoid ($n=12$) or malaria ($n=19$).

4.2.3: Residents perception on the causes of illness and diseases

The findings of the study indicated that the people believed that the general prescription and description of the common suffered illness in the area from health practitioners gave them an understanding of their causes. The trend revealed five major causes which included poor sanitation in neighbourhood, presence of mosquitoes, poor personal hygiene, contact with river water and climate change (Table 4.8).

A significant number of respondents did not know the causes of the illnesses. According to the respondents, contact with river water was the commonest cause of most illnesses where Kwanyaa village had the highest number of respondents with 55.6% of the households while Mumbeeni village and Kyase village both reported it at 50%, Iiani village 40% and in Kikome village 25% of its households reported contact with the river water was the main cause of illnesses. The second major cause of illness in study sites was presence of mosquitoes; Both Mumbeeni village and Iiani village reported by 20%, Kyase village and Kikome village by 25%, while Kwanyaa village 22.2% of its households reported mosquitoes from the rivers offshore water as their main cause of illnesses.

The study's findings revealed from health practitioners 'advice to residents indicated that poor sanitation in neighbourhood highly affected Mumbeeni village 20% and Iiani village 6.7%. Moreover, incidents of climate change led to illnesses in Kikome village 12.5%. This was as per the advice from the government officials who included agricultural officers. Highest numbers of respondents from Iiani village were not aware of the causes of illnesses 25.6%, while 25% of Kikome village and 21.9% Of Kwanyaa village could not identify cause of their illnesses. In Kyase village and Mumbeeni village, 21.95% and 7% of their households admitted not aware of the causes of their illnesses.

Table 4.8: Causes of illnesses in the selected study sites (%)

Causes of illness	Villages						Mean
	Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa		
Poor sanitation in neighbourhood	20.0	6.7	0	0	0	5.34	
Presence of mosquitoes	20.0	20.0	25.0	25.0	22.2	22.44	
Poor personal hygiene	3	6.7	12.5	12.5	0	6.94	
Contact with river water	50.0	40.0	50.0	25.0	55.6	44.12	
Not aware (no response)	7	25.6	16.5	25	21.9	19.2	

Causes of illness chi-square goodness of fit test

HO: There were no statistically significant differences among the causes of illness in the study area

H1: There were statistically significant differences among the causes of illness in the study area

	Observed N	Expected N	Residual
Poor sanitation neighbored	2	10.4	-8.4
Presence mosquitoes	12	10.4	1.6

Poor personal hygiene	5	10.4	-5.4
Contact with river water	23	10.4	12.6
Not aware(no response)	9	10.4	-.4
Total	51		

Test Statistics

Chi-Square 25.115^a

df 4

Asymp. .000

The test statistics indicated that the causes of illness were statistically significant: $X^2(4) = 25.115$, $P < 0.0005$. Therefore the null hypothesis was rejected and a conclusion made that there were statistically significant differences among the causes of illness, with less people contracting diseases due to poor sanitation neighbored ($n=2$) compared to either poor personal hygiene ($n=5$), not aware (no response) ($n=10$), presence of mosquitoes ($n=12$) or contact with river water ($n=23$).

4.3: Measures/interventions put in place by the government and residents in the study area to control the pollution of the River Athi

The study revealed that the households used three measures to control increased River pollution which included adherence to 30m riparian reserve by farmers and developers (Physical planning Act Cap 286 1996, Water Act 2002), not disposing refuse and pesticide cans in the river and residents not to wash near or in the river (Table 4.9). Despite the residents practicing these methods to control the effects of water pollution, the negative effects of pollution persists in their lives. Domestic water treatment which is practised by households has continued to face challenges due to financial constraints and limited livelihood options. The other reasons were increased river bank cultivation and bathing in the river which continues to pollute the river water.

Findings of this study showed that only households of Kikome village 25% and Iiani village 6.7% had imposed the rule of not disposing refuse and pesticide cans in the river. Observation of 30m riparian reserve measure by farmers and developers was only reported in Kikome village 12.5%. The measure of not to wash near or in the river was practiced by the residents of Kyase village 12.5%. All respondents of Mumbeeni and Kwanyaa villages were not aware of any measure to control river pollution, followed by those of Iiani village and Kyase village by 76.5% and 75% respectively. In Kikome village the respondents reported to be aware of only two measures of river pollution control namely control of pesticides to river and observing 30 metre distance from the river. Residents of Iiani village 17% practiced WASH techniques together with those of Kyase and Kikome villages both at 12.5% and this could have been occasioned by Cholera outbreak reported in the areas at some point.

Table 4.9: Residents measures to control river pollution in selected study sites (%)

Residents measures to control river pollution	Villages					Mean
	Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa	
Number of refuse and pesticide cans cases reported	0	6.7	0	25	0	6.34
Adopting WASH techniques	0	17	12.5	12.5	0	8.4

Adherence to 30 m riparian reserve by farmers and developers	0	0	0	12.5	0	2.5
Number of residents washing in or near river	0	0	12.5	0	0	2.5
Not aware(no response)	100	76.3	75	50	100	43.66

Residents measures to control pollution chi-square goodness of fit test

HO: There were no statistically significant differences among the residents measures to control river pollution

H1: There were statistically significant differences among the residents measures to control river pollution

	Observed N	Expected N	Residual
Number of refuse and pesticide cans in the river	3	10.4	-7.4
Adopting wash technology	5	10.4	-5.4
Adherence to 30M riparian reserve by farmers and developers	1	10.4	-9.4
Number of residents washing in or near the river	2	10.4	-8.4
Not aware	40	10.4	30.6
Total	51		

Test Values	Statistics
Chi-Square	113.385 ^a
Df	4
Asymp. Sig.	.000

From our table above, our test statistic is statistically significant: $X^2(4)=113.385$, $P<0.0005$. Therefore the null hypothesis was rejected and a conclusion made that there are statistically significant differences among the residents measures to control pollution, with less people adhering to 30m riparian reserve by farmer and developers (n=1) comparing to either washing in/near the river (n=2), number of refuse and pesticide cans in the river (n=3), adopting wash technology (n=5) or not aware (n=41)

4.3.1: Government river water pollution control measures

The study also investigated the government measures to control pollution in the study sites and found four common measures (Table 4.10) these measures were; carrying Environmental Impact Assessment (EIA), ensuring that there was no disposal of refuse and pesticide cans into the river and lastly ensuring no disposing of dead animals into water. According to the study findings all these governmental measures were observed across Kyase village (12.5%). However from the discussion with NEMA and public health officers there were concerns in Makueni County to put up pollution control and detection apparatus at Miangeni village which is the immediate point of river from Machakos County to Makueni County. However the installation of this vital facility they reported was subject to availability of funds. Respondents from the other four villages were not aware of any government measures to control river pollution.

Table 4.10: Governments measures to control river pollution in selected study sites%

Governments measures to control pollution	Villages					Mean
	Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa	
No disposal of refuse and pesticide cans in the river	0	0	12.5	0	0	2.5
Carrying EIA before building structures	0	0	12.5	0	0	2.5
No river pollution	0	0	12.5	0	0	2.5
No disposing of dead animals into water	0	0	12.5	0	0	2.5
Not aware(no response)	100	100	50	100	100	90

Government measures to control pollution chi-square goodness of fit test

HO: There were no statistically significant differences among the government measures to control pollution in the study area

H1: There were statistically significant differences among the government measures to control pollution in the study area

	Observed N	Expected N	Residual
No. of disposal of refuse and pesticides cans in the river	2	9.6	-7.6
Carrying EIA before building structures	2	9.6	-7.6
No river pollution	2	9.6	-7.6
No disposing of dead animals into water	2	9.6	-7.6
Not aware(no response)	40	9.6	30.4
Total	48		

Test Statistics

Chi-Square	120.333 ^a
df	4
Asymp. Sig.	.0251

The study's test statistic were statistically significant: $X^2(4)=120.333$, $P>0.0005$. Therefore we failed to reject the null hypothesis and concluded that there were no statistically significant differences among the government measures to control pollution in the study area.

The Survey findings from the inputs of key informants like NEMA officers, Public Health Officers, agricultural officers and Water Services providers officials on the recommendations and solutions to water pollution indicated urgent measures, were needed to control pollution. These measures included; arresting the offenders, educating residents on the need to protect the river, provision of enough drainage systems, community sensitization on pollution control measures, provision of clean water by the County government, the government to enact regulation to control river pollution, fencing along the river banks, construction of water dams, digging terrace to control surface run off and construction of latrines by every household (Table 4.11).

Among all these recommendations, education of residents on the need to protect the river from pollution was the most approved by households across the five villages the highest being Kikome village 87.5%, Iiani village by 80%, Mumbeeni village by 60%, Kwanyaa village by 55.6% and Kyase village by 25%. Besides educating the residents, respondents of Mumbeeni village approved recommendation for community sensitization on pollution control by 60% compared to Iiani village which further approved recommendation to arresting offenders by 30% of its households. Kyase village approved provision of enough drainage systems, Community sensitization on pollution control measures and that all households should have latrines each by 37.5%; while

Kikome village approval for recommendation to arrest of offenders was by 37.5% of the sampled households and this was the second measures from education of residents which had 87.5% approval of respondents. Respondents of Kwanyaa village accepted recommendation for provision of enough drainage systems, community sensitization as pollution control measures and provision of clean water by the county government by 44.4%. The least approval of the recommendations across the five villages included fencing along the river banks by 10% and was only reported in Mumbeeni village.

Construction of dams was reported in Iiani village 6.7%, Kyase village and Kikome village each by 12.5% while Kwanyaa village approved the recommendation to construct dams as alternative water sources by 11.11% of the household respondents. Digging of terraces to control surface run off getting into the river was only approved in Kyase village and Kikome village both by 12.5%. Recommendation for Households to have latrine only got approval in Kyase village by 37.5% of the household respondents.

Table 4.11: Recommendations and solutions to water pollution in selected study sites (%)

Solutions to water pollution	Villages					Mean
	Mumbeeni	Iiani	Kyase	Kikome	Kwanyaa	
Arrest offenders	30.0	33.3	12.5	37.5	11.1	24.88
Educate residents on the need to protect the river	60.0	80.0	25.0	87.5	55.6	61.62
Provision of enough drainage systems	10.0	26.7	37.5	12.5	44.4	26.22
Community sensitization on pollution control measures	60	20	37.5	12.5	44.4	34.88

Provision of clean water by the county government	10	20	12.5	25	44.4	22.38
The government to enact regulations to control river pollution	20	20	25	12.5	0	15.40
Fencing along the river banks	10	0	0	0	0	2.0
Construction of dams	0	6.7	12.5	12.5	11.11	8.56
Dig terraces to control surface run off	0	0	12.5	12.5	0	5.0
All households should have latrines	0	0	37.5	0	0	7.5

Solution to water pollution chi-square goodness of fit test

HO: There were no statistically significant differences among the solutions to address water pollution in the villages

H1: There are statistically significant differences among the solutions to address water pollution in the villages.

	Observed N	Expected N	Residual
Arrest offenders	12	12.3	-.3
Educate the residents on the need to Protect the river	31	12.3	18.7
Provision of enough drainage system	14	12.3	1.7
Community sensitization on pollution Control measures	18	12.3	5.7
Provision of clean water by the county government	22	12.3	9.7

Government to enact regulations to control river pollution	9	12.3	-3.3
Fencing along the river banks	1	12.3	-11.3
Construction of river banks	3	12.3	-9.3
Dig terraces to control surface runoff	1	12.3	-11.3
Total	111		

Test Statistics

Chi-Square	67.459 ^a
df	8

From the table above, the test statistic is statistically significant: $X^2(8) = 67.459$, $P < 0.0005$. Therefore the null hypothesis is rejected and a conclusion made that there are statistically significance differences among the solutions to water pollution, with less people preferring fencing along the river and digging the terraces to control surface runoff both (n=1), compared to either government enacting rules to control river pollution (n=9), arresting offenders (n=12), provision of enough drainage system (n=14), community sensitization on pollution control measures (n=18), provision of clean water by the county government (n=22) or educating the residents on the need to protect the river (n=31) respectively

CHAPTER FIVE

5.0 DISCUSSION

5.1 Causes of the pollution of the River Athi in Kathonzwi Sub-County

The study's findings indicated the majority of household heads had achieved primary level of education, which confirmed that, most of the respondents had some formal education, which definitely impacts positively on people's knowledge and perception about health and sanitation issues. According to the survey, Kyase village had the highest number of residents who had attended primary level of education (75%). This may be attributed to high commercial farming activities along the river supported by NGOs in the area, which offered employment opportunities to the families to be able to send their children to school. Kikome village (37.5%) recorded the highest secondary school education level attainment, which could also be attributed to the high small-scale irrigation opportunities in the area.

Mumbeeni and Iiani with (20%) and (6.7%) respectively were the only villages with residents reported to have had university level of education. This could be attributed to high presence of better established primary and secondary schools and health facilities close to the sites and commercial activities to enable finance schooling to tertiary institutions. Exposure to better schools and reduced absenteeism from school due to illnesses contributes to maximisation of time for children to concentrate in their studies.

The study's findings corroborate earlier studies (Kithiia, 2007; Abednego *et al.*, 2013), who confirmed that River Athi is the main sources of water for both domestic and irrigation use to downstream communities in Machakos and Makueni counties. Across the five villages the river dominated as the main source of water. This is in agreement with UNESCO (2003) which indicates out that rivers are potential sources for fresh-water and also the World Water Council (2005) which recorded that of the 3% of fresh water, only 0.3% is found in rivers and lakes. Household's in Mumbeeni and Kikome villages

depended entirely on the River water. This could be attributed to the proximity to the river in the locality and people's perception of it as a convenient option for fetching water.

In contrast more households in Kyase village (88.8%) recorded rain water as their main source. This is partly due to the long distance to the River Athi, availability of piped water and limited awareness, among the respondents, owing to a large number of new comers, who had hired land to do agricultural activities in the riverine of the village. Ostensibly the source of the piped water comes from river Athi which majority of the respondents overlooked when confirming their sources of water.

The study also, revealed that (6.3%) of Iiani village households had shallow wells as source of water. However most of these shallow wells were dug close to the river banks of the main river to escape the problems posed by river pollution. This was much done by some of those households considered to have better income either from employment and farming activities. This could be attributed to the local community's perception of high water table as the river basin is shallow and the realisation that the river water is increasingly being polluted to offer quality domestic water. Public health officers opined that it is an emerging trend in the area in search of alternative sources of water.

According to UNEP (2006) and Abednego *et al.*, (2013) anthropogenic factors such as agricultural development, population growth, urbanization and industrialization as well as market policy failures have been identified as the root causes of water pollution. In the study area, households practiced several ways of refuse disposal. These practices included: Open space dumping, burning, and compositing, burying and dumping. Burning was the commonest method of disposal in the study site; Kikome village, burning was practiced by 62.5% while in Mumbeeni village 60% of the households used the method to dispose- off refuse. In Kyase village 25% of the household respondents reported to use the method of burning.

Sunday, January 18, 2015

Punish firms polluting River Athi, says official



Plate 5.1: A section of River Athi. Makueni County government wants action taken against companies dumping waste in River Athi. FILE PHOTO | NATION MEDIA GROUP

The use of burning method to dispose refuse could be attributed to the fact that refuse burning is a cheap and faster way of waste disposal, and that government officers were reluctant in enforcing regulations against poor waste disposal and which contributes to pollution other media like air. This is in agreement with Omane (2002 who agrees that the laws prohibiting indiscriminate dumping of refuse or pollution of rivers exist but the enforcement of these laws proves difficult. Open space dumping was the second major method of refuse disposal reported in Kwanyaa village (44.4%), Iiani village (40%), Kyase village (37.5%) and was least used in Mumbeeni village as was reported by 30% of the respondents. This could have been caused by uncontrolled solid waste disposal in the study site by either residents or the County government and could be attributed to

large open spaces in their community land coupled with the community lack of awareness that surface runoff finds its way into the River water resource.

The findings of the study established that refuse composting was highly practiced in Kyase and Kikome village both by 25% of the respondents. It was lowly practiced in Mumbeeni village by 10%. The practice could be attributed to need for production of manure for farming activities along the river and also need for manure to sell in heavy farming zones along the river. The two study sites were found to have had higher agricultural activities and saw most of agricultural wastes flow into the river as effluent, a fact also noted by other similar studies (Kithiia, 2007; Abednego *et al.*, 2013). These included cut off horticulture wastes, pesticides wastes and manure. Refuse burying was only practiced in Kikome and Kwanyaa villages at by 12.5% and 11.1% respectively. This was mostly because of presence of Non-governmental Organizations (NGOs) and Community Based Organizations (CBOs) which supported and trained communities on manure production and on the need to control contamination of the river water from the waste in case of runoff. This was found to be a good measure as it ensures that minimal refuse flow into the river.

The study revealed that some households dumped refuse into the river and this was common in Kyase village (12.5%) a phenomenon which could have been influenced by lack of public awareness on good waste management practices in that village to control increased river pollution. According to Obuobie *et al.* (2006), In Kumasi many people attribute the increasing water pollution in the Kumasi metropolis to the failure to collect, treat and dispose of waste water efficiently. Though Kumasi was an urban area, this could be interpreted to mean a site draining to a downstream and hence failure of the residents in one rural area to treat their waste affects the quality of water getting to another rural area on its downstream.

The study indicated that most residents in the study area believed that much of the pollution of River Athi water was from upstream. Their argument was informed by regular information from NEMA and public health officers who sampled the water especially during the dry period. They believed up-stream pollution from industries and sewage in neighbouring Machakos and other counties like Thika and Nairobi bore the most blame of polluting river Athi. This pollution included disposal of municipal sewage waste, agro-chemicals residues and industrial chemical pollutants including heavy metals (Muiruri *et al.*, 2013). UNESCO (2003) argues that some two million tons of waste per day are disposed off within receiving waters, including industrial wastes and chemicals, human waste and agricultural wastes such as fertilizers, pesticides and pesticide residues.

The sampled community approved understanding from the key informants like public health officer that up-stream pollution from industries and sewage was the highest river polluter which could be attributed to negligence by industrial owners on treatment of their industrial wastes and sewage before disposing to system which end up into the River at its up-stream and eventually flows affecting the downstream riparian communities. Pollution by agricultural chemicals from the farming activities in the downstream was the second common mentioned cause of River pollution. Respondents in all the villages mentioned it as a major concern in the area.

This could be could be ascribed to the surface run off flowing back into the River especially after heavy rainfall and prolonged irrigation exercise. This was occasioned by the heavy agricultural activities in the riparian zone. Low levels of awareness with the local human labour could also have led to local pollution as most casual labourers are ignorant of these local pollution sources especially on application of organic and inorganic fertilizers. These pesticides were found to be used close to the river due to the increased river bank cultivation. The pesticide cans and bottles were found to have been indiscriminately disposed even direct to the river water. The practice obviously endangers the life of aquatic life and the people who use the water for their domestic needs. The

practice confirms widely acknowledged observation that some kinds of water pollution can occur through natural processes but the major pollution is mostly as a result of human activities (Patty, 2006).

5.1 Health effects resulting from the pollution of the Athi- River in Kathonzwani district

The survey findings on the uses of the River water within the five villages revealed four major land water uses including watering crops, Domestic water use consisting of; washing, drinking, cooking and bathing, fishing and brick making. This was supported by UNESCO (2006) report which revealed that, adequate water supply promotes good health and improves the prospects of new livelihood activities which are otherwise denied and are a key step out of poverty. The results from this study showed that residents of Mumbeeni and Iiani villages depended on the River for drinking water whereas 66.7% of Kwanyaa village households used the river water for drinking mostly probably because most households had no other source of clean water for drinking as compared to Kikome village whose (87.5%) of its households used the River water for irrigation of crops and cooking.



Plate 5.2: Community members fetching water from River Athi (source?)

It was clear that the households in the five villages required the river water for domestic use and irrigation purposes (Abednego *et al.*, 2013). More-over in Kyase village, the river water was commonly used for cooking. The study indicated that people in all the villages were using the river water for making bricks for house building which was provided affordable to the community house construction materials. Some sold the bricks to supplement their livelihoods options hence proper resource utilization of natural resources to reduce poverty in the area. This confirmed the use of the water for alternative livelihood improvement. Some of the respondents in Kyase and Kikome reported to have been using the river water for fishing. Fishing was found to have been an alternative source of food in all the villages.

The use of fish as food to human could pass pollution health effect to those consuming it in short, medium or long term (Muiruri *et al.*, 2013). Across the five villages cooking was one of the common water uses and had the greatest percentage. The study established that

the use of the river water for cooking, compared to the rest of other water uses most was the most important and discernible use in the area.

The study results revealed that within the study area, the community suffered seven common illnesses which included amoeba, malaria, diarrhoea, cholera, fever, typhoid and coughing. Across the five villages malaria was the most common disease mentioned by the respondents. This could be attributed to presence of mosquitoes in the study site due to the substantial amounts of water in the river. Mosquitoes could be found in stagnant waters cut off to the shore by the main river during flooding, which hosts a variety of carriers with disease pathogens which cause waterborne and water contact diseases. It is also imperative to note that fish in highly polluted rivers may not be health as those found in clean river flowing water and may pose health risks to people if consumed (Muiruri *et al.*, 2013). According to Niyogi (2005) and (Muiruri *et al.*, 2013) concentration of pathogens in the water present a greater health risk to people using river water for drinking, bathing, irrigation of crops eaten raw, fishing, and recreational activities.

The common reported illness in Mumbeeni village was diarrhoea which is also a clinical symptom of amoeba or typhoid both of which result from organic water pollution. This situation was corroborated by a report from a chemical analysis of water undertaken by government chemists on 25th March 2015 Nairobi. The quality of freshwater at any point on a landscape reflects the combined effects of many processes along water pathways and both quantity and quality of water are affected by human activity on all spatial scales (Peters and Meybeck, 2000). Organic matter may pose health challenge to river inhabitants in terms of illnesses, poor health and many bed hours making a community not available for more productive exercise and eventually leave the community languishing in poverty as most of income is spent on treatment.

Some cases of Amoeba were reported in Kikome village overly attributed to the low use of pit latrines in the village. The government chemist result on water analysis showed the

water is contaminated with organic matter a causative agent of cholera and other related illnesses like amoeba. This is more to do with pollution of water with human waste. Cholera case was as well reported in Kyase village which could have been mostly caused by lack of latrine use among the households in study site. The incidence could also be attributed to off shore water stagnated after flooding in the area, especially during flash floods. The residents used the water for fishing and bathing and since its water is stagnant, the increased level of pollution increased chances of contacting the waterborne disease. This stagnated water is inclusive of organic matter with causative pathogens of diseases like Cholera as revealed by government chemist analysis results.

Hardoy *et al.*, (2001), point out that, “River pollution from city based industries and untreated sewage can lead to serious health problems in settlements downstream (Hardoy *et al.*, 2001; Abednego *et al.*, 2013). In Kikome village 12.5% and Kwanyaa village 11.1% of the households were infected by cough that could be termed the initial clinical symptoms of medical disease like Malaria, Typhoid, Amoeba and Cholera. The results further showed that fever were commonly experienced in Kyase village and Kikome village both at 12.5%. These villages commonly experienced high attack by mosquitoes from the stagnant water by the main River hence causing malaria. Diseases like cholera are communicable and if attention is not accorded it may be a disaster or even keep on recurring in an area where they initially occurred. This agrees with finding by Hammer *et al.*, (2006), People who use polluted water are in danger of contracting water-borne and water-contact or water-habitat vector diseases.



Plate 5.3: Photograph of a green colour (quadrant) left on the sand at the River Athi bed and below residents getting into the river to fetch water for domestic use (source?)

Five major causes of illness which included poor sanitation in neighbourhood, presence of mosquitoes, poor personal hygiene, and contact with river water and climate change were revealed. Contact with river water was the common cause of most illnesses. In Kwanyaa village (55.6%) of the household reported contact with the river water as the main cause of illnesses within them. Mumbeeni village and Kyase village both reported the same reason (50%) while Iiani village had 40% of the households. This could be attributed to people's belief that by living close the river for long period of time and advice from health personnel, they were bound to experience illness instances.

Another major cause of illness recorded in Mumbeeni village (20%) was presence of mosquito together with poor sanitation in the neighbourhood. The study established that poor sanitation in neighbourhood highly affected Mumbeeni village (20%) and Iiani village (6.7%) this could be attributed to their closeness to the river water and overdependence on the river as source of water for all their basic needs. Most sanitation

infrastructure for instance latrines were either absent or broken down. Occasional flooding that changed the river course periodically led to illness in Kikome village as reported by 12.5% and this could be attributed to the number of the aged residents who had witnessed patterns of climate and weather change over time affecting their social economic and geographical land forms. Respondents cited change from normal rain to splash rains which bring about fast floods and un-anticipated droughts, increased number of mosquitoes and Elnino rains. This further, could be attributed to perennial floods leaving behind stagnant water in water pans that became breeding places of mosquitoes and other waterborne diseases. Mumbeeni village reported smallest number of respondents who were not aware of causes of their illnesses compared to rest of respondents in other villages indicating a knowledge gap that can be filled by educating and sensitizing the community on the causes of the persistent illnesses.

5.3 Measures/interventions put in place by the government and residents in the study area to control the pollution of the River Athi

The study revealed that it was only households in Kikome and Iiani villages which had imposed the rule of not disposing refuse and pesticide cans in the river or it's riparian. This was in contrast with the other villages which seldom practised safe disposal of empty pesticides cans. This situation in the two villages thus could be attributed to most respondents having knowledge from public sensitisation and the media campaigns as well as higher levels of education. There was an undisputed correlation between education level and observance of sanitation and personal hygiene in those villages. Hayakawa *et al.*, (2006) confirmed that agriculture in some settings across the world requires the use of inorganic fertilizers and the application of pesticides. The application of such chemicals leads to the release of toxins as Nitrogen (N) and Phosphorus (P). These toxins leach into soils to contaminate underground water and also lead to pollution and the eutrophication of water systems. (Abednego *et al.*, 2013).

The observation of 30m riparian reserve measure by farmers and developers was only reported in Kikome village which could have been due to most households practicing farming with the support of NGOs, who had experienced the highest impacts from agriculture practice near the river especially during periodical flooding. Government enforcement was significantly low on adherence to pollution control measures. The residents were also not willing to report offenders. The community measure to ensure nobody would wash near or in the river and was approved by the residents of Kyase village, where most impacts of pollution were experienced. This was because the residents could have been using the river water for domestic purposes. It was also noted that within the study site there were two water service providers namely Matheani-Kithuki and Kitise water supply. Their presence could have contributed to increased residents awareness on the importance and appreciation of enforcement and adoption the water safety measures of avoiding the point-source as well as enforcing construction of toilets by households.

The study investigated the Governments' measures to control pollution in the study sites and documented four common measures which included carrying Environmental Impact Assessment (EIA), ensuring no disposal of refuse and pesticide cans into the river and lastly ensuring no disposal of dead animals into water. The use of these governmental measures were reported in Kyase village most probably because in this village there were government officers who were working with community groups in the area and were also enforcing the measures. The study also found that National Environmental Management Authority (NEMA) and Water Resources Management Authority (WARMA) which are government institutions were involved in conservation of river water by giving stop orders to offenders of river pollution and prosecuting people disposing effluent into the River Athi. However, the enforcement of this measure was not clear and strong because the institutions lack enough staff for enforcement as well as other logistical challenges. These offenders reside far from their work stations and others are outside their area of jurisdiction. Coordination between the two institutions and the County Government

departments like that of Public health, urban planning and environment directorate to implement the enforcement was also reported as a challenge, with limited co-ordination mechanisms and synergies for effective monitoring of river pollution. This had let down enforcement efforts of the available pollution control legislations on River Athi.

Recommendations and solutions to water pollution included the arresting of the offenders who break the set regulations by National Environmental Management Authority (NEMA) under Environmental Management and Coordination Act (EMCA) 1999 together with its 2015 amendments on treating waste water before disposal a same phenomenon revealed by Obuobie *et al.*, (2006) who noted that many people in Kumasi attributed the increasing water pollution to failure in treating and disposing of waste water efficiently. The other measures included educating and creation of public awareness to the residents on the need to protect the river with provision of enough drainage systems, community sensitization on pollution control measures, provision of clean water by the County Government, the government to enact regulations on the control of river pollution, fencing along the river banks, construction of water reservoir dams, digging terrace to control surface run off and construction of latrines by every household.

Among all these recommendations education of residents on the need to protect the river was the commonest approved by respondents across the five villages (Kikome village 87.5%, Iiani village 80%, Mumbeeni village 60%, Kwanyaa village 55.6% and Kyase village 25%). This is believed to increase public knowledge on protection of water sources and preservation of the entire river ecosystem. Apart from educating the residents, 60% of Mumbeeni village respondent's approved recommendation on the need for community sensitization on pollution control compared to Iiani village (30%) who approved recommendation on need to arrest the offenders mostly because the community in this village highly used the water for drinking hence the need to care for their health.

Respondents in, Kyase village (37.5%) were in agreement with the recommendation to provide adequate drainage systems. This could be attributed to the fact that the village had the highest number of diseases occurrence across the five villages. The residents believe drainage systems will control both point and diffuse pollution getting into the River Athi. Kwanyaa village 44.4% of the respondents approved the recommendation on provision of enough drainage systems, community sensitization on pollution control measures and provision of clean water by the County Government. This is because of the heavy human activities in their immediate upstream. The least respondents' approval was on recommendation to fence along the river banks 10% of Mumbeeni village. This could be due to high cost of fencing material hence this method was seen as a threat across the study site. Digging terraces to control surface run off was reported in Kyase village and Kikome village all by 12.5% of households.

The recommendation was not commonly accepted due to the costs involved of the river corridor. Recommendation on households having latrine was only approved in Kyase village 37.5% of the households where occurrence of cholera was earlier reported. This observation was also confirmed by Wolff, (1999) who commented that in many areas in less developed countries, toilets, latrines or proper drains are non-existent or have broken down; wastes are disposed of near or in the same river, lakes or wells used for drinking and food preparation.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

- River Athi water is polluted with organic matter from upstream with potential local pollution by the heavy agricultural activities along the river and poor waste management practices.
- Typhoid and Diarrhoea are the commonest waterborne diseases. Pollution affects the socio-economic status of the riparian community and their human health.
- The residents and government water pollution control measures are weak and poorly adopted in the study area. Their enforcement is weak.

6.2 Recommendations

- County government to develop an integrated environmental management and health plan
- The national and the county governments to embrace transboundary approach to address pollution control along River Athi.

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APPENDIX I: WATER SERVICE PROVIDERS IN THE STUDY SITES

Name of water service provider (institution)	Role of the institution	Control measure to river pollution by the institution
Matheani-Kithuki water supply	earth connected households and markets	-Supply of water to connected households and markets -Sensitization of community to avoid river bank cultivation. -Use of non-poisonous agro-chemicals -Building public toilets at their water supply outlets -Prevent community from to fetching using donkey in the river.
Athiani-Kitise water supply	Supply of water to connected households and markets	Sensitization of community to avoid river bank cultivation. -Use of non-poisonous agro-chemicals -Building public toilets at their water supply outlets

APPENDIX II: GOVERNMENT INSTITUTION INVOLVED IN CONSERVATION OF WATER IN STUDY SITES

Government institution involved in conservation of water.	Policy/act governing institution activity	Enforcements the to control pollution	Practical intervention to river water pollution	Reasons preventing optimal service delivery
National Environmental Management Authority (NEMA)	EMCA 1997 with 2015 amendments	Giving stop offenders of river pollution Prosecute people disposing effluent into the Athi-river	Partnering with other relevant agencies to enforce and clean the river from solid waste (Plastic bags) Annual public sensitization forums	Few technical officers Little annual budgetary allocation
Water Resources Management Authority (WARMA)	Water resources management act and water policy 2012.	No enforcement unit but liaise with NEMA for enforcement	Sensitizing community through Water Resource Users Association (WRUA)	Financial constraints

APPENDIX III: SURVEYQUESTIONAIRE FOR THE HOUSEHOLD INHABITANTS OF THE RIVER ATHI IN KATHONZWENI SUB COUNTY.

“Causes and Effects of River Pollution: The case of the River Athi in Kathonzwani district; Makueni County” The purpose of this questionnaire is to elicit information on the causes of the pollution of the River Athi and its effect on the health of residents of the river basin. The information provided will be used solely for academic purposes and would be treated as confidential. Thank you for your cooperation. Please tick or fill in where appropriate.

A. Background information

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

2. Age:

a. Below 10 () b. 11- 20 () c. 21-30 () d.31- 40 () e. 41-50 () f. 51- 60 ()

g. Above 60 ()

3. Marital Status:

a. Married () b. Single () c. Divorced () d. Widowed ()

e. Others (Specify).....

4. Are you employed?

a. Yes () b. No ()

5. What is the nature of your work?

a. Trading () b. Government () c. Farming () d. Student ()

6. How long have you lived in this basin?

a. less than 12 months () b. 1-5 yrs () c. 6- 10 yrs () d. more than 10 yrs.()

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

a. Primary () b. Secondary () c. University /college () d. Never Schooled ()

B. Causes of the pollution of the River Athi

1. How many persons are there in your household?

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

2. Do you have a bathing facility in your house?

a. Yes () b. No ()

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

a. Shared by household alone () b. Shared by entire family ()

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

a. Into septic tank () b. flowing freely into surface () c. Any other..... specify

5. What is the primary means by which wastewater from other domestic activities is disposed off?

a. into septic tank () b. flowing freely into surface () c. Any other..... specify

6. Does your house hold have pit latrine/ toilet?

a. Yes () b. No ()

7. Does all your household members use pit latrine/ toilet facility?

a. Yes () b. No ()

8. Are there open defecations washed into rivers?

a. Yes () b. No ()

b. If yes, what are those reasons?

.....

9. What is the most frequent means by which your household disposes of refuse?

a. Dumped into open space () c. Burnt () d. Composted () e. Buried ()

f. Dumped into or near the River Athi

10. Why do you use this means of disposing off refuse as mentioned in question 9?

.....

C. HEALTH

1. Which of the following is the most common illness in your community?

a. Malaria () b. Diarrhoea () c. Cholera () d. Fever () e. Typhoid ()

f. Others.....

2. What illnesses have you suffered in the last three months? (You may tick more than one option)

a. Malaria () b. Diarrhoea () c. Cholera () d. Fever () e. Typhoid ()

f. I've not suffered any illness () g. Other.....

3. What in your view were the causes of the illnesses in question 2 above?

a. Poor sanitation in neighbourhood () b. presence of mosquitoes () c. Poor personal hygiene () d. Contact with river water () e. Other

4. Do children in your household play and bathe in the River Athi?

- a. Yes () b. No ()

5. If yes, how often?

- a. Very Often () b. Often () c. less often ()

6. Do you know of any illnesses suffered by any of the children in your household in the last three months?

- a. Yes () b. No ()

7. If yes, which one? (You may tick more than one option)

- a. Malaria () b. Diarrhoea () c. Cholera () d. Fever () e. Typhoid ()

f. Skin disease () Other (Specify).....

8. In the past three months, how many times has your family members been diagnosed with the disease mentioned in Q7?

- a. Once () b. Twice () c. Three times () d. four times () e. other

9. Have you registered with the county NHIF?

- a. Yes () b. No ()

10. Please give reasons for your answer above.

.....

11. Do you use the River Athi water for other purpose?

- a. Yes () b. No ()

12. If yes please indicate which purpose(s)

- (a. Water crops () b. Fishing () c. Washing ()

d. Disposing waste () e. Drinking () f. Others

13. In your view, is the River Athi water safe for domestic use?

A. Yes () b. No ()

14. If no, Please mention in your view the most important cause of pollution of the River Athi water

15. Do you know of any laws that prohibit the pollution of rivers?

a. Yes () b. No ()

16. Which of the following uses would you put the River Athi to if it was not polluted?

(Please indicate 1st, 2nd, and 3rd, in order of most frequently)

a. Washing b. Cooking c. Drinking d. Bathing Fishing e. Other

17. Do persons in your house eat food crops watered with the river water?

a. Yes () b. No () If yes how often? A. Very often () b. Often () c. Less Often ()

18. Do persons in your house eat fish caught from the river?

a. Yes () b. No () If yes how often? A. Very often () b. Often () c. Less Often ()

D. MEASURES PUT IN PLACE TO CONTROL POLLUTION.

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

a. Yes () b. No ()

2. If yes, what are these measures?

.....
.....

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

a. Yes () b. No ()

4. If yes, what are these measures?

.....
.....

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

a. Arrest offenders

b. Educate residents on the need to protect rivers

c. Provision of enough drainage systems

d. Others

6. For those doing horticulture along the river do they have control over chemicals (pesticides, vermicides, fertilizers etc.) used in their farm finding their way into the River Athi?

7. Recommendations

.....
.....

APPENDIX IV: QUESTIONNAIRE SURVEY FOR THE WATER SERVICE PROVIDERS.

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

1. Kindly share name of your water service provider and your position in the institution.
2. What role does your institution play in the protection of River Athi from pollution?
.....
.....
3. Are there laws that exist on the protection of rivers and other water sources you know?
a. Yes () b. No ()
4. If yes what are these laws?
.....
.....
5. Are these laws being enforced? a. Yes () b. No ()
6. What are the challenges faced by the enforcement of laws concerning the protection of the river-Athi?
.....
.....
7. What is your perception on safety of the River Athi water? a. safe () b. Not safe ()

8. Has your institution carried out any analysis on the quality of water in the River Athi or shared information on the same in KathonzweniSub County

a. Yes () b. No ()

9. If yes, when were they carried out and how were the findings?

.....

10. What were the conclusions on each?

.....

.....

11. Does the pollution of the River Athi significant to have any consequences for users downstream or amidst? a. Yes () b. No ()

12. If yes, what are these consequences?

.....

.....

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

.....

APPENDIX V: QUESTIONNAIRE SURVEY FOR THE HEALTH INSTITUTIONS

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

1. what are the common ailments treated in your health Centre in order of frequency
.....
.....
.....

2. of the above, which is water hygiene related?

3. In your view is River Athi water safe for domestic use? a. Yes () b. No ()

4. If no, what is the best practice on the water treatment in the area?
.....
.....
.....

5. How does your health centre help the residents to avail safe and clean water for their domestic use from the river?

PUBLIC HEALTH PRACTITIONERS

1. Do you sample/ test River Athi water? a. No () b. Yes () (Data availability)

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

3. Is the River Athi water polluted?

4. If yes, from what?

5. From your investigation what is the source of pollution

a. upstream () b. local ()

6. Are you aware of any government interventions on River Athi pollution?

a) Yes () b. No ()

7. Please mention the functional ones and their capacities if any.

APPENDIX VI: QUESTIONNAIRE SURVEY FOR THE NATIONAL ENVIRONMENTAL MANAGEMENT AUTHORITY (NEMA)/ WATER RESOURCES MANAGEMENT AUTHORITY (WARMA)

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

1. Are there regulations to protect river pollution in the region? a. Yes () b. no ()

2. Does your institution monitor river pollution especially River Athi? a. yes () b. no ()

3. Is River Athi water safe for domestic use? a. yes () b. no ()

4. is there Policy/act governing your institution activity
.....
.....

5. What is your institution doing on the control of river pollution?
.....
.....

6. Any practical intervention to river water pollution?
.....
.....

7. Is there enforcement on the regulation within the river basin protection on pollution?

a. yes () b. no ()

8. How is the enforcement level on the control of the river pollution in the region?

a. Strong b. Weak. c. Absent

9. Are there any reasons preventing optimal service delivery?

.....

.....

10. In your own words what can you comment on River Athi pollution within the region.

.....