BACTERIOLOGICAL QUALITY OF DRINKING WATER SUPPLIES:

A Comparative Study of Eldoret and Kitale Municipalities

A Dissertation submitted in partial fulfillment for the award of degree of Master of Science in Medical Microbiology,

Department of Medical Microbiology, University of Nairobi

By

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DECLARATION

I, **Salinah Jeptoo Rono**, do hereby declare that this Dissertation is my original work and has not been published or presented for a degree in any other university.

Signature ------------------------------------- Date 19th MARCH, 2008 ------------------------------------

SUPERVISOR

This dissertation has been submitted for examination with my approval as a supervisor.

Prof. Isaac A. Wamola **Signature**------------------------------ **Date**19.03.08

Department of Medical Microbiology

SCHOOL OF MEDICINE

UNIVERSITY OF NAIROBI

DEDICATION

To my beloved husband Ben for his moral, spiritual and financial support during my entire study period and to my children George, Sharon, Diana and Meshack for their prayers, patience and encouragement.

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ABSTRACT

Introduction: Access to safe drinking water is an important basic need. A large proportion of people in developing countries lack access to safe drinking water. This has resulted in high morbidity and mortality due to diarrhea and other related gastrointestinal infections.

Objectives: To determine and compare the bacteriological quality of treated and untreated water supplies in Eldoret and Kitale municipalities, identify possible risk possible risk factors leading to bacterial contamination and also evaluate the efficiency of the treatment process in both municipalities.

Study design: This was a cross-sectional comparative study.

Sampling technique: A purposive sampling technique was used to group residential areas based on socio-economic status of residents. Stratified random sampling was further used to categorise water source and consumer points thus; treated water taps, wells, boreholes, rivers and springs.

Study population: A total of 350 samples were collected from 209 treated water taps, 123 from wells, 12 from boreholes, 4 and 2 from river and spring respectively.

Methodology: Bacteriological analysis involved the use of Membrane filter technique to isolate total coliforms and faecal thermo-tolerant coliforms contaminants on Endo agar and MacConkey agar respectively. These were further identified by subculture, microscopy and biochemical tests. Researcher administered questionnaires were also used to collect data from residents and water supply operators.

Data analysis methods: This involved the use of Statistical Package for Social Sciences computer package (SPSS) to process and analyze data, which was then presented in form of tables, graphs and charts. Pearson Chi- square-test was used to test the relationships among variables and draw appropriate conclusions based on the stated objectives and hypotheses.

Results: Treated water recorded 25% bacterial contamination in Eldoret and 61.2% in Kitale respectively while untreated water had 89.3% in Eldoret and 77.3% in Kitale Municipality. Resident responses on the efficiency of water treatment was rated 87.7% in Eldoret and 63% in Kitale .The percentage of faecal coliforms isolated in all 350 samples water was rated 34% in Eldoret and 64.35% in Kitale Municipality. However, isolation of faecal thermo-tolerant coliforms was 22.6% and 24.3% in Eldoret and Kitale respectively.

The diversity of faecal bacterial contaminants isolated were as follows; *E. coli* (30.4%), *Klebsiella* (21.1%), *Salmonella* (17.4%), *Pseudomonas* (14.4%), *Proteus* (7.3%), *Citrobacter* (3.26%), *Shigella* (2.72), *Streptococcus faecalis* (1.96%)

and *Enterobacter* (1.35%).

Conclusion: The results obtained indicated that there was a significant difference in the level of bacterial contamination of treated water supplies between Eldoret and Kitale Municipalities. However, there was no significant difference in bacteriological quality of untreated water supplies in both Municipalities. Eldoret Municipality recorded a lower level of isolation of faecal coliforms than Kitale Muncipality. However, there was no difference in isolation of faecal thermo-tolerant coliforms in both sites. Some of the risk factors found to have significant influence on the quality of drinking water included depth of well / borehole, distance from possible contaminating source, poor housing and sanitation, delay in repair of burst pipes and absence of protective cover in wells and boreholes.

ABBREVIATIONS

BOD	Biological Oxygen Demand
BQDWS	Bacteriological Quality of Drinking Water Supplies
EAEC	Entero-aggregative *Escherichia coli*
EHEC	Entero hemorrhagic *Escherichia coli*
EPEC	Enteropathogenic *Escherichia coli*
ELDOWAS	Eldoret Water and Sanitation Company
ETEC	Enterotoxigenic *Escherichia Coli*
GEMS	Global Environmental Monitoring System
GIT	Gastrointestinal tract
GOK	Government of Kenya
H_2S	Hydrogen sulphate
ICDR	International Development Research Centre
IMViC	Indole, Methyl Red, Voges Proskaeur test
LF	Lactose fermentor
MAC	MacConkey medium
MFT	Membrane Filter Technique
$MgSO_4$	Magnesium sulphate
$Na_2SO_3.5H_2O$	Hydrated Sodium sulphate
NaOH	Sodium Hydroxide
NLF	Non lactose fermentor
NTU	Nephelometric turbidity unit
NZOWASCO	Nzoia Water and Sanitation Company
P_H	Hydrogen ion concentration
PSI	Pounds per square inch pressure
RH	Relative Humidity
RTI	Respiratory tract infection
TSI	Triple Sugar Iron
UNICEF	United Nations Environmental Programme
UON	University of Nairobi
UTI	Urinary tract infection
VP	Voges Proskaeur
WHO	World Health Organization.

DEFINITION OF TERMS

Aerobe	A micro-organism that requires the presence of oxygen for life and growth
Aquifer	An underground stratum of rock or sediment that contains water and transmits water readily.
Bacteria	A micro-organism which lacks a distinct nuclear membrane and hasunique cell wall composition.
Borehole	Deep underground water source which is normally accessed by drilling.
Chlorination	Addition of non-injurious traces of chlorine to water supplies before human consumption to ensure that disease causing organisms are destroyed.
Coliform bacteria	A group of gram-negative rod-like bacteria that are normally found in gastro-intestinal tract and have the ability to ferment the sugar lactose. The group includes the genera *Enterobacter, Escherichia coli* and *Klebsiella.*
Culture	A population of microorganisms, usually bacteria grown on liquid or solid media.
Diarrhoea	Frequent bowel evacuation or the passage of liquid stool caused by intestinal infections or other forms of intestinal inflammation.
Dysentery	An infection of the intestinal tract that causes severe diarrhea with blood and mucus.
Gram-negative bacteria	An organism that stains red during gram staining.

Gram-positive bacteria	An organism that stains purple during gram staining.
Hydrological cycle	Cycle in which water evaporated from soils, vegetation, oceans and other bodies of water; accumulates as water vapor in clouds; returns to the earth, oceans and other bodies of water as rain or snow, and runs off as river flow, through the soil or an aquifer.
Incubation	A process in which bacteria is grown in culture for a specific period under suitable conditions.
Infection	Invasion of the body by pathogens such as bacteria, fungi, rickettsia or viruses.
Nasocomial infections	Hospital acquired infections.
Run-off	Water originating as rain or snow that runs off the land in streams, rivers and eventually reaching oceans, inland seas or aquifers.
Urban population	Population living in urban areas.
Well	Shallow under ground water source.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Access to safe drinking water and sanitation are universal needs, which constitute an indispensable component of primary health care.[1] There is substantial evidence that provision of adequate sanitation services, safe water supply and health education represent an effective health intervention that reduces mortality and morbidity caused by diarrhoeal disease. [2]

According to WHO/ UNICEF (2000), diseases related to contaminated drinking water, unsanitary food preparation, inadequate excreta disposal and unclean household environments constitute a major burden on the health of individuals in the developing world and are among major leading causes of ill health.[3] It is estimated that approximately 4 billion cases of diarrhoea due to contaminated water occur each year. This accounts for all child deaths under the age of five years in developing countries.

A report by IDRC (1989), states that only 3% of the earth's water is fresh water. However, much of this water exists in glaciers and polar ice, services largely unavailable for human use. Similarly, much of the world's groundwater is locked up in deep rock formations, out of reach of conventional technology.
Though, this makes a small fraction of the world's water, the planetary supply of accessible fresh water including hydrological cycle is more than enough to sustain the world's growing population. However, the major problem for villagers, city dwellers, governments and development agencies is how to deliver this water to users at affordable price and without degeneration of its quality. [4]

Over the past decades, the natural quality of watercourses has been massively altered by the impact of various human activities.[5] Medieval reports and complaints about inadequate excreta disposal, sanitation, foul and stinking watercourses within overcrowded cities and other similar problems were an early manifestation of water pollution. The first time that a clear causal link between bad quality water and human health effects, was in 1854 when John Snow traced the outbreak of cholera epidemics

in London, to Thames River, which was grossly polluted with raw sewage.[6] Consequently, waterborne disease outbreaks have become an exceptional event in all industrialized countries and are mostly limited to gross negligence or technical failure. However, in developing countries, this is still a common phenomenon.
Poor piping infrastructure, waste disposal and hygiene conditions continue to contribute to widespread cases of diarrhoea and gastrointestinal infections.[3]

1.2 STATEMENT OF THE PROBLEM

Contamination of drinking water at source or collection points is a normal phenomenon.[7] A large proportion of Kenyans lack safe drinking water either because piped water facilities are inadequate or due to insufficiency in the treatment processes. It has been noted that 75% of the Kenyan Population lives in rural areas where piped water facilities are lacking. In this case, most households draw water from wells, boreholes, rivers or streams. The likelihood of bacterial contamination especially due to faecal coliforms is high and it is no wonder that most children under five, suffer from diarrhoeal diseases and further still related gastro intestinal infections do occur in adults.

Eldoret and Kitale municipalities were selected as sites for this study with an attempt to survey the status of water resources as far as bacteriological quality is concerned. The two towns experience similar problems faced in developing countries where basic infrastructure for water resources is not fully established.[8, 9] The major water sources for Eldoret Municipality are Chebara dam whose water is drawn from Cheboyit forest in Marakwet hills, Kipsinende and Kaptagat dams whose source is Kaptagat Forest. The water is tapped at source in the latter two of the sources and is made to flow by gravity to Eldoret town where it is treated at Sosiani and Kapsoya water treatment plants before it is distributed to consumers. The water from Chebara is treated at source and released to flow by gravity for storage and distribution at Kapsoya.

Kitale Municipality obtains most of its water from River Nzoia, which crosses densely populated farmlands of Trans Nzoia possibly carrying along large amounts of agricultural and domestic waste, which is presumably checked by the treatment process at Nzoia Water treatment plant. The major task for these town's municipal authorities is to provide safe and adequate drinking water for its residents at an affordable cost.

1.3 OBJECTIVES OF STUDY

1.3.1 General objective

To assess the bacteriological quality of drinking water supplies in Eldoret and Kitale Municipalities.

1.3.2 Specific objectives

1. To determine the level of bacterial contamination in treated water supplies in Eldoret and Kitale Municipalities.

2. To determine the level of bacterial contamination in untreated water supplies in Eldoret and Kitale Municipalities.

3. To identify the possible risk factors to bacterial contamination in the two Municipalities.

1.4 HYPOTHESIS

1. H_o: There is no significant difference in bacteriological quality of treated water supplies between Eldoret and Kitale Municipalities.

   H_A: There is a difference in bacteriological quality of treated water supplies between Eldoret and Kitale Municipalities

2. H_o: There is no significant difference in bacteriological quality of untreated water supplies between Eldoret and Kitale Municipalities.

   H_A: There is a significant difference in bacteriological quality of untreated water between Eldoret and Kitale Municipalities.

1.5 JUSTIFICATION OF THE STUDY

Water facilities in Eldoret and Kitale include piped treated water systems, boreholes, springs, rivers and wells. Despite the availability of piped water facilities in many parts of these sites, Kitale town still experiences constant water problems due to technical faults and inadequate supply.[4] Similarly, Eldoret town is expanding at a very high rate due to rapid development and consequent influx of residents into the newly sold EATEC farms in the outskirts of the town. However, the water supply agency has not been able to keep pace with this sudden increasing demand and hence most of the new residents still lack piped and treated water.

This study therefore tried to determine whether, water consumed by the residents in the two Municipalities had any bacterial contamination and also attempted to identify any possible risk factors contributing to bacterial contamination of the water in each of the selected sites and specific locations in the study area..

It is expected that the findings of this study will be of benefit to the residents when measures are taken to curb against any predisposing factors to bacterial contamination of drinking water sources. This is likely to prevent morbidity and diarrhoeal disease through proper hygiene and appropriate water treatment processes.

The Municipal authorities are also expected to benefit from the results and recommendations made in order to improve their water supply and sanitation services. The government of Kenya (GOK) is expected to benefit from the findings as this will enhance the quality of life of its citizens as far as water quality and health is concerned. The researcher was also glad to evaluate safety of water consumed by the residents and to unearth any mysteries surrounding prevalence of gastrointestinal diseases such as typhoid among others, that has constantly affected residents particularly of Trans-Nzoia disrict.

1.6 SCOPE OF THE STUDY

The scope of this study included water resources in Uasin Gishu and Trans Nzoia districts in Rift Valley Province. It involved treated water in piped systems, and untreated water in wells, boreholes, springs and rivers. However due to limited time and resources, the study was confined to Eldoret and Kitale Municipalities where bacteriological analysis of water from selected locations was done.

1.7 LIMITATIONS OF THE STUDY

1. Financial constraints limited the study to only two Municipalities, Eldoret and Kitale whereas a wider study involving the two districts in which the two towns lie would have been covered.

2. The study was carried out within a period of three months mainly during a rainy season. However, a longer period would have allowed for seasonal variations to be studied and to ascertain whether this would have any impact on bacteriological quality of water.

3. Laboratory analysis did not fully identify some of the bacterial isolates to species level. For instance, 39% of the isolates belonged to the genus *Salmonella.* Similarly, a large proportion of faecal coliforms isolated were of the species *Escherichia coli* but specific strains were not fully identified to species level since the isolates were not linked to any current disease outbreak that warranted urgent attention.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Water accounts for 70% of the human body weight and 90% of body volume.

Water is responsible for normal cell structure, function and its organization into tissues and organs.[1] Indeed, the entire human life revolves around water for domestic use, agriculture and Industry among others. However, not all water is safe for human consumption. Natural water bodies get polluted by domestic waste, sewage, agricultural and industrial waste and therefore there is need to ensure that drinking water is safe for human health through various treatment processes. [5]

2.2 WATER QUALITY GUIDELINES.

According to WHO (1984), guideline values for drinking water quality represents the level of constituents that ensures an aesthetically pleasant water that does not result in any significant risk to the health of consumer. In studies on Community Water Supplies in developing countries, the parameters used in assessing and measuring water quality include mainly microbiological, physical and chemical parameters. Chemical parameters include the residual level of chlorine and other dissolved chemicals existing as pollutants from agricultural and industrial waste. [6]

Physical parameters used to assess water quality include turbidity, colour, taste and odour.

Turbidity refers to the level of cloudiness of the water. High levels protect micro-organisms from the effects of disinfection, stimulate growth of bacteria and exert a significant chlorine demand. Turbidity must always be below 1NTU for effective disinfection. Levels of turbidity in excess of 5 NTU are noticeable and objectionable to consumers.

Colour is due to the presence of colored organic compounds such as hemi substances including Iron, Manganese or highly colored wastes.
When water displays aesthetically displeasing levels of colour, consumers turn to alternative and perhaps unsafe sources. Drinking water should always be colorless.

Taste and Odour is mainly due to the presence of organic substances.
Some odours are indicative of increased biological activity or industrial pollution.
The combined perception of senses of taste and smell are generally described as "taste". Changes in the normal taste of public water supply may signal changes in the quality of raw water source or deficiencies in the treatment process.
The quality guidelines criterion on "taste" is water that is not offensive to most consumers.

2.3 DOMESTIC WATER SUPPLIES

Rural sources of water for domestic use include rivers, streams, lakes, dug wells, and boreholes and in a small scale piped water. The surface and shallow ground water often shows a high degree of bacteriological or chemical pollution due to human excreta disposal and agricultural activity.[6] Groundwater is usually of good bacteriological quality due to filtration through soil layers. However, surface run off and unhygienic handling of water collection vessels can pollute it.
The location of boreholes and wells should be sited at a safe distance of at least thirty meters from habitats likely to harbor pathogens such as latrines, septic tanks or refuse damps. In addition to suitable location, wells need to be protected from contamination by proper lining, head walls drainage aprons and covers. [7]

Rainwater can be harvested from roofs or ground and stored in barrels or tanks.
The quantity of rainwater depends on the amount of rain falling and the size of runoff area. Storage facilities may be made of cement bricks, concrete or plastic and to avoid deterioration of water quality, these needs to be covered.
The common reservoir of surface water in rural areas is the dam, river or pond and when not properly protected, these reservoirs are often heavily polluted and unsuitable for domestic use. Urban water supplies include piped and non-piped water sources.

Efficient treatment by respective water agencies should yield water free from coliform organisms.

The detection of a sample of water entering the distribution system showing a deviation from this negative value calls for immediate investigation into the efficacy of the treatment process.[5] Water that is of potable quality on entering the distribution system may undergo deterioration before it reaches the consumer. Water in the distribution system may also become contaminated through cross-connections, back-siphonage, leaking service connections, defective storage tanks and service reservoirs or damaged hydrants, during main laying and repair or through non-expert repairs to domestic plumbing systems. Such contamination is as dangerous as the distribution of insufficiently treated water.

2.4. WATER RELATED INFECTIONS

The deterioration in water quality is associated with various diseases, which can be prevented by the improvement of water supplies.[10] In terms of global assessment; principal distinctions have to be made with regard to the source of pollution, route of entry into the human body and the life cycle of the pathogen and its eventual vector organism. Mc Junkin (1982), classified water-related infections in three categories. [13]

2.4.1 Waterborne diseases

These include enteric diseases (diarrhoea, dysentery etc) due to pathogens in drinking water, which are of faecal origin. A variety of **Bacteria** (*Salmonella, Shigella, E-coli, Vibrio,* etc), **Enteroviruses** (Rotavirus, poliovirus, Norwalk agent etc), **Protozoa** (E*ntamoeba histolytica*) and **Helminthes** (*Dracunculus medinensis, Ancylostoma duodenale etc*) are etiologically possible causes of high infant mortality due to diarrhea and other GIT infections.

2.4.2 Water hygiene diseases

These are also called **water washed diseases** and are due to inadequate use of water to maintain personal cleanliness. Enteric diseases eye (Trachoma) and skin (Scabies) as well as louse borne typhus diseases are examples. Water quantity appears to be of higher priority than quality in this category.

2.4.3 Water habitat diseases are vector-borne

These are the most important group of diseases related to the developments of surface water resources. Three different types of vectors are involved in disease transmission: Snail vectors are essential link in transmission of Schistosomiasis. It has been noted that more than 70 countries in the tropics and sub-tropics are affected and the disease is spreading due to new irrigation projects, which create favorable environment for the aquatic host of that disease vector. Mosquito Vectors are responsible for widespread occurrences of Malaria, Filariasis and arbovirus infections.

Fly vectors transmit Onchocerciasis (river blindness) and Trypanosomiasis (sleeping sickness). Highly aerated, running water is the preferred breeding habitat for the vector, *Simulium* fly, the causative agent of Onchocerciasis.

Parts of South-West Africa and Central America have suffered seriously with blindness rates of up to one third of the adult population in the affected rural areas.

2.5 WATERBORNE BACTERIAL PATHOGENS

Faecal pollution of drinking water may introduce a variety of intestinal pathogens, which include bacterial, viral and parasitic. Intestinal bacterial pathogens are distributed worldwide. Those known to have occurred in contaminated drinking water include strains of *Salmonella, Shigella, enterotoxigenic E-coli* (ETEC), *Vibrio cholera, Yesinia enterocolitica* and *Campylobacter fetus.* These organisms may cause diseases that vary in severity from gastroenteritis to severe and sometimes fatal dysentery, cholera or typhoid. Similarly, other organisms naturally present in the environment and not regarded as pathogens may also cause opportunistic infections among the young, elderly, debilitated or immunosuppressed individuals.

Potable water used by such patients containing excessive numbers of organisms, such as *Pseudomonas, Flavobacteruim, Acinetobacter, Klebsiella* and *Serratia*, if used for drinking and bathing, may produce a variety of infections of the eye, ear nose and throat .[3]

2.5.1. Rationale for the use of indicator bacterial organisms

The recognition that microbial infections can be waterborne has led to the development of methods for routine examination to ensure that water intended for human consumption is free from excremental pollution. Bacteriological examination offers the most sensitive test for the detection of organisms normally present in faeces of man and other warm blooded animals. These are known to be indicators of excremental pollution as well as a measure of the efficacy of water treatment and disinfection, thereby providing a hygienic assessment of water quality with a sensitivity and specificity that is absent in routine chemical analysis.

Priority must always be given to ensuring that routine bacterial examination is maintained whenever manpower and facilities are limited. The results of routine bacteriological examination must always be interpreted in the light of a thorough knowledge of water supplies, including their service, treatment and distribution. Whenever changes in conditions lead to deterioration in quality of water supplied or even suggest an increased possibility of contamination, the frequency of bacteriological examination should be increased so that a series of samples from well chosen locations may identify the hazard and allow remedial action to be taken. [14, 15]

2.5.2 Organisms indicative of faecal pollution

The use of normal intestinal organism as indicators of faecal pollution rather than the pathogens themselves is a universally accepted principle for monitoring and assessing the microbial safety of water supplies. Ideally, the presence of such indicator bacteria should denote possible presence of all relevant pathogens. Indicator organisms should be abundant in excreta but absent or present only in small numbers in other sources, where they can be easily isolated, identified and enumerated and should be unable to grow in water. They should also survive longer than other pathogens in water and be more resistant to disinfectants such as chlorine. Coliform organisms such as *E.coli* are the only ones that meet the above criteria.

Other supplementary indicators are faecal *streptococc*i and sulfite-reducing *clostridia.* Anaerobic bacteria such as *Bacterioides* and *Bifidobacteria* are more abundant than coliform organisms in faeces. *Pseudomonas aeruginosa*, *Proteus species*, and *Aeromonas* may be present as environmental contaminants. However, detection is not routinely made because anaerobic conditions are required.

2.5.2.1. Coliform organisms (total coliforms)

These are recognized as suitable microbial indicators of drinking water quality because they are easy to detect and enumerate in water. They are characterized by their ability to ferment lactose at 37^0C and include *Escherichia coli, Citrobacter, Enterobacter, Aeromonas and Klebsiella* species.

Escherichia coli are gram negative, motile, non-capsulated rods that are facultative anaerobes and produce lactose-fermenting colonies on MacConkey agar (MAC).
The organisms can be identified by lactose fermentation (LF), IMViC test and serology. They are Indole and Methyl red positive. Specific antiserum is used in identification of strains (EPEC, ETEC, EHEC, and EAEC). ETEC strains are major causes of childhood diarrhoea and are responsible for high mortality in children under five years. It is also known to cause UTI, bacteremia, wound infections and appendicitis.

Klebsiella species are gram-negative, non-motile capsulated rods that produce large, usually mucoid lactose fermenting colonies on MacConkey agar and produce phycocyanin pigment on blood agar. They are Citrate test and Voges Proskaeur (VP) positive and are known to cause urinary tact (UTI) as well as respiratory tract infections (RTI).

Enterobacter species are gram negative, non-capsulated, non-motile rods that produce large lactose fermenting colonies on MacConkey agar. They are Indole and Methyl red negative and do not utilize Citrate. They are commonly associated with urinary tract infections.

Citrobacter species are gram-negative, motile rods that can be late lactose fermenters or non-NLF and require differentiation from *Salmonella.* They however ferment sucrose especially *C.freundii* whereas *Salmonella* is a non-sucrose fermentor.
These coliform organisms should not be detectable in treated water supplies and if present suggest inadequate treatment or a possibility of post-treatment contamination; hence coliform test is used as indicator of treatment efficiency.[16]
Under certain conditions, coliform organisms may also persist on nutrients derived from non-metallic construction materials. In such cases, the presence of small numbers of coliform organisms (1-10 organisms per 100ml), particularly in untreated groundwater may be of limited sanitary significance provided faecal coliform organisms are absent.

2.5.2.2 Faecal (thermo tolerant) coliform organisms

These are coliform organisms able to ferment lactose at 44^0C or 44.5^0C.

They comprise genus *Escherichia* and to a lesser extent occasional strains of *Enterobacter, Citrobacter* and *Klebsiella. E .coli* is the only one specifically of faecal origin being and always present in faeces of man, animals and birds in large numbers but rarely found in water or soil that has not been subject to faecal pollution. Complete identification of *E coli* in terms of modern taxonomy would require an extensive series of tests, which would be impracticable for routine water examination. Hence, detection and identification of these organisms as faecal organisms or presumptive *E.coli,* is considered to provide sufficient information to assess faecal nature of pollution.

2.5.2.3 Other indicators of faecal pollution

When coliform organisms are found in the absence of faecal coliform organisms and E.coli other indicator organism may be used to confirm the excremental nature of contamination. The secondary indicator organisms include faecal *streptococci* and sulfite reducing *clostridia.* Other indicators of water quality other than secondary indicators include *Pseudomonas aeruginosa, Salmonella* and *Shigella.* .

Salmonella and *Shigella* can be indicators of recent faecal pollution especially in wells, boreholes and open water systems and are pathogenic to man.

Faecal *Streptococci* (*Streptococci faecalis*) are gram positive, non-motile, non-capsulated, bacteria that produce distinctive small dark red colonies on MAC and may be alpha, beta, or gamma hemolytic on blood agar. They can be distinguished from other Streptococci by the bile aesculin test, which is positive.

The occurrence of faecal *streptococci* in water generally indicates faecal pollution.[18] The term refers to those streptococci normally present in faeces of man and animals. These include *S.faecalis, S.faecium, S.durans, S.bovis* and *S.avium* as well as strains with properties intermediate between them.

These organisms rarely multiply in polluted water and may be slightly more resistant to disinfection than coliform organisms. However, this indicator group has rarely been recommended for control of drinking water quality because of their persistence in water with moderate salt concentration such as might occur with blended water supplies. [20]

Furthermore, widespread occurrences of *S, faecalis var liquifaciens* may detract from the significance of numbers of faecal streptococci less than 100per 100ml in drinking water unless strain identification is part of the routine procedure. When used as a supplementary bacterial indicator, the ratio of faecal coliform organisms to faecal *streptococci* may be useful in locating the origin of faecal pollution in heavily contaminated sources of raw water, provided sufficient data is collected.

In addition these organisms can be used to assess the significance of doubtful results with coliform test, particularly if faecal streptococci organisms are found in absence of faecal coliform organisms. They can also be of value in checking water in the distribution system following repairs to mains. [5]

Sulfite reducing ***clostridia*** include anaerobic spore forming organisms, of which the most characteristic, *C perfiringens (C.Welchii*) is normally present in faeces though in much smaller numbers than *E.coli. Clostridial spores* can survive in water longer than organisms of the coliform group and they can resist disinfection if the concentration, contact time or P^H is unsatisfactory. Their persistence in disinfected water may thus indicate deficiencies in treatment process.[21]

However, it would not be desirable to consider these organisms for routine monitoring of distribution systems since they tend to survive and accumulate thus may be detected remote in both time and place from the original source of pollution and consequently give rise to false alarms.

The use of other microorganisms such as *pseudomonas aeruginosa* has not been advocated in assessing the hygienic quality of drinking water.[22, 23]

However, examination of these organisms as well as their colony counts is essential for routine monitoring of hygienic quality. They are of value in certain circumstances in giving an indication of the general cleanliness of the distribution system and in assessing the quality of bottled water. *Pseudomonas aeruginosa* is a gram--negative rod that is a non-lactose fermentor on MAC and produces yellow green phycocyanin pigment on blood agar; it is oxidase positive and produces an alkaline slope and butt on TSI.

Pseudomonas aeruginosa is often present in the faeces of man but in much lower numbers than other coliform organisms. It is an opportunistic pathogen of the very young, old and those debilitated by disease, being frequently isolated from persons with urinary tract infections, skin burns and post-operative wounds and are therefore a common cause of nasocomial infections.[23] The organisms usually occur in raw water, in the presence of other coliform organisms. However, in drinking water, it may occur in the absence of other coliforms.24· [26] The ability of some materials used in the construction of distribution and plumbing systems to support the growth of the organisms may account for this. [25]. Although the presence of the organisms in portable water should not be ignored, it may not be used for routine examination of water for the presence of faecal pollution. Examination for *P.aeruginosa* may be of importance in rehydration mixtures, baby foods and pharmaceutical preparations as well as surveillance of hospital water supplies and bottled water. [27]

Salmonella species such as *S.paratyphi* and *S.typhi* are excreted in urine and faeces of infected individuals. These can contaminate water sources through hands and feet of individuals drawing water from wells and boreholes. *Salmonella* are gram-negative motile rods that produce pink non-lactose fermenting colonies on MAC.
They can be identified by subculture on TSI where they produce an alkaline slope and acid butt with blackening due to hydrogen sulphide (H_2S) production.
Serological techniques are further used to identify strains using specific antiserum.
They are known to cause typhoid fever, osteomyelitis, abscesses of the spleen and gastrointestinal infections. *S.typhimurium* is known to cause food poisoning.
S typhi is generally known to cause diseases of morbidity and mortality in humans of all ages.

Shigella species are gram-negative non-motile rods that are NLF and produce an alkaline slope and acid butt but no blackening on TSI. Species such as S. *dysentriae* are responsible for the highest incidence of Shigellosis in areas of poor sanitation and where water supplies are grossly polluted or in areas where sewage treatment is inefficient. [25] A survey done in Bangladesh by WHO (2000) indicated that even in the absence of adequate sanitation facilities, the washing of hands after visiting the toilet and before eating, greatly reduced the incidence of shigellosis.
Shigellosis is responsible for high mortality among young children and severe disease in adults.

2.6 DISINFECTION

The principal reasons for disinfecting drinking water are to ensure the destruction of pathogens, to maintain a protective barrier against pathogens entering the distribution system and to suppress bacterial growth in the pipe environment.

Disinfection is therefore important in safeguarding the hygienic quality of potable water supplies and should be done efficiently at recommended time intervals.

2.6.1 Disinfectant efficiency

Colony counts are essential in assessing the safety of potable water supplies, although a sudden increase in colony counts from groundwater service may be an early sign of pollution of the aquifer. [24] Colony counts are useful in determining the efficiency of the water treatment process, specifically coagulation, filtration and disinfection.

They are also important in assessing the cleanliness and integrity of the distribution system and the suitability of water for use in manufactured foods and drink to minimize risk of spoilage. The main value of colony counts lies in the comparison of results obtained from regular samples from same supply so that any significant deviation from a normal range in particular location can be detected .[6]

The commonly used disinfectants in water treatment include chlorine, chlorine dioxide and ozone. Others include chloramines, which are only slowly biocidal.

Their use as primary disinfecting agents for water treatment purposes is not recommended, although they may be used for maintenance of residuals in distribution systems where the contact time is longer. Similarly; in decreasing order,

the relative resistance of different types of micro-organisms and their probable survival may listed as follows; protozoan cysts, enteroviruses and enterobacteria.

Although there are distinct differences in the time required to inactivate enteroviruses as compared with enterobacteria, the minimum conditions of disinfectant residual and contact time required ensuring microbiologically safe water supply can be achieved readily. It is, therefore, recommended that water from potentially polluted sources should always be disinfected. This would ensure inactivation of certain organisms, including some viruses, which may be relatively more resistant than faecal indicator bacteria. [3, 27]

2.6.2 Disinfectant residuals

An important consideration is the ability of these agents to remain as residual disinfectants during storage and distribution of potable water. Except for Ozone, all of the other practicable disinfectants provide a persistent residual for continued microbial control once the treated water enters the distribution network.

Chloramines, however, are such slow biocides that any decision as to their use should be evaluated carefully, with sufficient bacteriological data collected throughout the distribution system. This is to demonstrate effectiveness in controlling microbial growth and provides protection against a moderate degree of contamination from cross-connection. [27]

All supplies obtained from surface sources should be provided with disinfection as minimum treatment maintenance and monitoring of chlorine residual offers two benefits. They suppress the growth of organisms within the system and afford some protection against contamination entering through cross-connection or leakage.

The sudden disappearance of the residual provides an immediate indication of the entry of oxidisable matter into the system or a malfunction of the treatment process. When chlorine is employed, it is desirable that a free chlorine residual of 0.2 to 0.5 mg/litre be maintained and monitored throughout the entire system.

Incase the residual in the supply is less than that routinely expected at a particular point, then remedial action including increased chlorination, flushing and a sanitary survey, should be considered as the loss of residual may indicate the entry of pollution into the pipe-work. Booster or relay chlorination may be needed to ensure that this residual is maintained throughout the system. It is recognized that excessive levels of free chlorine may react with organic matter to produce tastes and odours in some waters. In such cases, the control agency or medical officer of health should encourage necessary improvements in treatment or distribution and as temporary measure establish a suitable concentration of chlorine residual to ensure microbiologically safe water.[3, 6]

2.6.3 Effect of turbidity

Effective disinfection depends upon contact between the disinfecting agent and the microorganisms to be inactivated for an adequate period of time.

Various bacteriological and virological studies have demonstrated a marked difference in the extent to which various types of particulate matter in water, shield microorganisms from effects of disinfectants. Inorganic particles such as clay and water flocculating agents have little protective effect. However, organic particulate, matter, whether cell debris, sewage, solids, living or dead organisms can provide marked protection to microorganisms associated with them.
The degree of protection thus affordable is determined to a large extent by the nature of particulate matter rather than the amount present as indicated by turbidity measurement.

In all processes in which disinfection is practiced, the turbidity must always be low, preferably between 1 NTU and 5NTU. Otherwise the particulate matter will interfere with the efficiency of disinfection either by exerting disinfectant demand or shielding microorganisms even in the presence of a residual disinfectant otherwise sufficient to ensure a kill. Excessive water turbidity may also interfere with the bacteriological examination. Any organic particulate matter present in portable water during distribution exerts a chlorine demand, which reduces the available free chlorine residual, especially in dead end sections of the system. Regular flushing of the mains is desirable to avoid such accumulations. Organic turbidity also serves as a source of nutrients, which may contribute to bacterial growth within the distribution network, especially in slow-flowing parts. Bacterial growth may enhance the accumulation of iron by bioflocculation, resulting in formation of a matrix of slime, calcium carbonate and other debris attached to the pipe walls, resulting in deterioration of water quality.

2.7 GLOBAL PERSPECTIVE OF WATER AND BACTERIAL DISEASE.

Bacterial contamination of water as measured by indicator organisms is a common problem in all continents wherever cities discharge raw sewage [24] A study done by Global Environmental Monitoring system (2002), indicated that high population concentrations in Europe especially in the Rhine river basin, result in large faecal contamination levels despite substantial sewage treatment practiced throughout the region. [4] The study revealed that in terms of health risks, the high coliform counts in European rivers were of little significance since the vast majority of municipal water supplies were treated or may have been disinfected. However, in Asia, Africa and

Latin America, the situation is different. The high coliform counts in these regions was a contributing factor to the high morbidity of adults and consequent mortality rates of infants mainly due to diarrhoea and other gastrointestinal infections related to consumption of contaminated water.

A study done by ICDR (1989), in India revealed that that out of India's 3119 cities, only 217 had partial and 209 or full sewage treatment facilities.
Thus the 48-kilometre stretch of the Jumuna River, which flows through New Delhi, contained 7500 coliform organisms per 100ml water entering the capital but after screening an estimated 200 million litres of untreated sewage every day, it leaves New Delhi, carrying 24 million coliforms per ml. [4] Faecal pollution has also been detected through high counts of coliform and faecal *Streptococci* in more than two thirds of the GEMS/WATER groundwater monitoring stations in developing countries. These contrasts with negligible counts recorded at baseline stations remote from human impact.[1]

According to IDRC report, a case study done in Egypt indicated that villagers faced serious diarrhoea and parasitic diseases transmitted via contaminated drinking water. Pathogens thrive in an environment where drainage of wastewater from households is inadequate and children defecated in the streets because latrines were designed for adults.[4] A similar study in Uganda revealed that only 6 % of the country's rural dwellers have access to an acceptably safe supply of water. The poor storage capacity aquifers limit the availability of groundwater especially in the Eastern and Western areas.[4]

Another case study in Mali, indicated that urbanization was taking place so rapidly that the provision of potable water and sanitation did not keep pace.
The percentage of population with access to potable water ranged from more than 60% in regions of Kayes, Kaulikoro and Sikasso. About half the rural populations had access to potable water and sanitation. The prevalence of infectious diseases including diarrhoea, cholera and onchocerciasis was very high leading to high mortalities.[5]

A study done by Zimmerman in Pennsylvania indicated that serious waterborne illness occurred as a result of contamination of wells but unfortunately most homeowners were unaware of the bacterial contamination.
The implementation of construction regulations for new wells and maintenance of existing wells was likely to reduce the prevalence of bacterial contamination of both new and existing private wells.[31]

Jabu G.C, in a study on the Assessment and Comparison of microbial Quality of drinking water in Chikwana Malawi, found that all stored drinking water in the two villages under study tested positive for coliforms and other indicator bacteria.[32]
De Zuanne, in his study to investigate hygienic handling practices of drinking water from source to point of use, was also able to assess the level of personal and domestic hygiene and environmental sanitation as well as determinants of drinking water quality at household level. He concluded that majority of people relied on unsafe drinking water with the majority being in Asia and Sub Saharan Africa. [33]

In Latin America, many important rivers run through cities and industrial areas and thus become polluted with untreated domestic and industrial waste.[35]
It is therefore apparent that, whether you live in the long established cities of the west or a mushrooming Metropolis city of the third world, environmental degradation seems to go hand in hand with industrialization and urban living.[33]

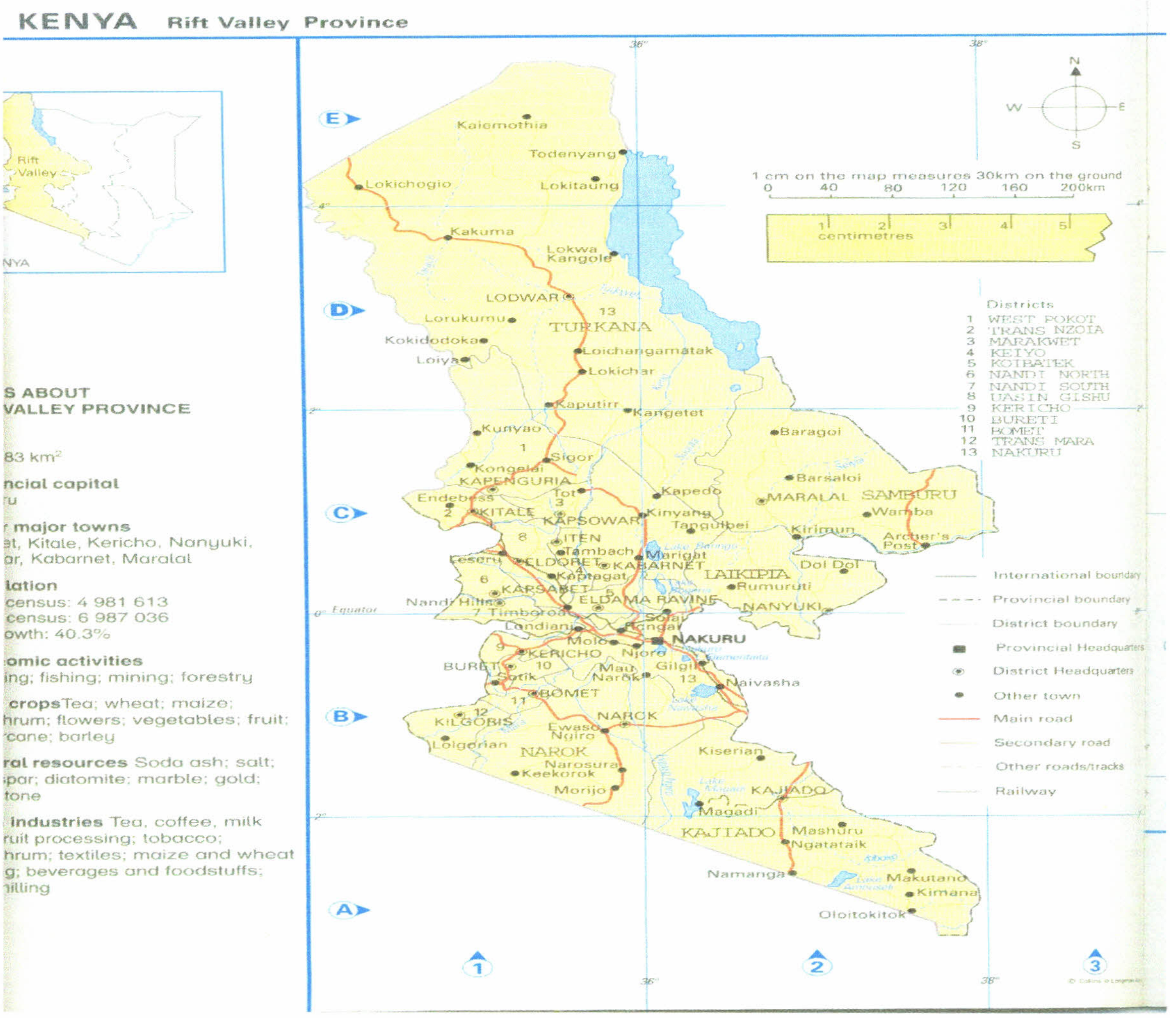
CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 SITE OF STUDY

The study was carried out in Eldoret and Kitale Municipality in Uasin Gishu and Trans Nzoia Districts of Rift Valley Province respectively.

Figure 1: Map of Rift Valley province



3.1.1 Position and Size

Uasin Gishu district is one of the seventeen districts in Rift Valley Province.

It extends between 34° 50' and 35° 30' East and 0° 03' and 0° 55' North.

It shares common borders with Trans Nzoia district to the North, North Nandi to the West, Lugari to the North West, South Nandi to the South and Koibatek to the South East. Eldoret town is the headquarters of the district, which occupies an area of 3218 Km^2 constituting two percent of the area of the province.[8, 9]

Trans Nzoia district, also in Rift Valley province, is bordered by the Republic of Uganda to the North, Lugari to the South west, Bungoma to the West, Mt. Elgon to the North West, West Pokot to the North East, Marakwet to the East and Uasin Gishu district to the South. It lies 0^o 52' and 1^o 18' North of the Equator.

It covers an area of one 1.4% of the whole province and is the headquarters of the district. The study therefore involved water supplies in these two Municipalities.

The two towns are sited about 60 Km apart, a distance of about one hour's drive by road along the main Eldoret- Kitale highway.

3.1.2 Population Profile

According to 1999 census, Uasin Gishu District had population of 644, 394.

The population growth rate was 3.7 per cent. Based on this figure, the district population was projected to reach 832,108 in 2006. Eldoret town is the main urban centre in the district that has attracted a large population over the past few years.

According to Uasin Gishu District Development Plan (1997-2001), the population of Eldoret Municipality was projected to 335,884 in 2005.

Data projections based on 1999 statistics indicated that Trans Nzoia District population was expected to reach 760,366 in 2005. Central division, which includes Kitale Municipality, was expected to have a population of 158,240 in 2005.

This indicated that the population of Eldoret Municipality was about three times greater than that of Kitale Municipality.

3.1.3 Water Resources

Most surface water in Eldoret originates from the Southern part of the District.

Eldoret Municipality draws its water from Cheboyit Forest in Marakwet District.

The district generally has few rivers, all of them draining into Lake Victoria.

There are several dams constructed during the colonial times including Kesses, Kerita, Koitoror, Ziwa, Kipkabus and Kaptagat. Some of these dams have been used to provide piped water to Eldoret Municipality.[9]

Water supply and sanitation in Eldoret Municipality is run by a private agency called Eldoret Water and Sanitation Company **(ELDOWAS).** Water supply in the Municipality is generally adequate except in mushrooming estates such as parts of Langas, Maili Nne and Huruma where piped water connections are under progress or not available at all in the slum areas. The residents in these areas obtain water from wells constructed by individual households or from piped water kiosks within the surrounding.

Water facilities in Kitale municipality are obtained from surface and underground sources. Surface water obtained includes piped water schemes, boreholes and wells. Water resources in the district are mainly from rivers flowing from Mt.Elgon and Cherangani hills. The main river is Nzoia joined by a number of streams on its way to L. Victoria. Water supply in Kitale Municipality is generally inadequate and cannot keep pace with the growing urban population. It is affected by changes in seasonal variations of rainfall thus reduced volume of rivers, dams and boreholes.
Several households use wells as alternative sources of water.[8]
The Nzoia Water and Sanitation Company obtains its raw water from River Nzoia which runs through the rich agricultural and densely populated farmland of Cherangani Hills and slopes of Mt Elgon, carrying with it large volumes of agricultural and other waste, which is presumably eliminated by the treatment process. Eldoret Municipality therefore has a better water source compared to that of Kitale, which is likely to have high level of contamination and hence requires efficient treatment procedure in order to render the water safe for the consumer.

Figure 2: Photograph of a section of river Nzoia, the main water source for Kitale Municipality

3.2 RESEARCH DESIGN

The study was a cross-sectional survey.

3.2.1 Inclusion criteria

This included all water points (taps, wells, springs, boreholes, rivers) containing either treated or untreated water and recognized as sources of drinking water by the residents within Eldoret and Kitale Municipalities. Selected sites included households in residential estates, schools, hospitals and business premises such as hotels and markets in the specified locations.

3.2.2 Exclusion criteria.

All water points (taps, wells, boreholes or rivers) containing treated or untreated water and are recognized as sources of drinking water but located outside the selected site were not included in the study. Rainwater in storage tanks and indoor drinking water in storage containers was also excluded from the study.

3.3 TARGET POPULATION

These included all drinking water sources and consumer points such as rivers, springs, wells, and boreholes and treated tap water supplied by ELDOWAS and Nzoia Water and Sanitation Company (NZOWASCO), in Eldoret and Kitale Municipalities respectively.

3.4 SAMPLE SIZE DETERMINATION

Previous studies have documented the prevalence faecal contamination in drinking water in Kenya as 35%. This was based on a study done by Chemuliti (2002) on the Bacteriological quality of indoor and outdoor drinking water in Kibera, Nairobi.

To calculate sample size, the researcher applied Fischer's statistical formula

$$n = \frac{Z^2pq}{E}$$

Where n = is the desired sample ,

Z = standard deviation at required confidence interval

p = estimated proportion of 35% = 0.35

E= standard statistical error at confidence interval = 0.05

q = 1- p

0.65 = 1- 0.35

$$n = \frac{1.96^2 \times 0.35 \times 0.65}{0.05 \times 0.05} = \mathbf{350}$$

The sample size of **350** was distributed in the ratio of 1: 3 between Kitale and Eldoret Municipality respectively in relation to ratio of human population living in the two towns, thus 115 and 235 respectively.

3.5 SAMPLING TECHNIQUE

Purposive sampling method was employed to select residential areas from each Municipality to be included in the study. The criterion used in selection was the economic status of the residents namely; high income, middle level and low-income groups. The selected sites thus included Milimani (high income), Kibomet (middle level), Matisi and Kipsongo (low income) in Kitale, while in Eldoret the estates included; Elgon View (high income), Kapsoya and Huruma (medium income), Langas and Maili Nne ranked in the low income category. Stratified random sampling was used to select households based on their water sources and consumption points namely; river, wells, boreholes, springs and treated tap water. Any public utilities such as markets, schools and health centres within the selected sites were included among the selected households.

3.6 MATERIALS

Materials required for collection and bacteriological analysis of water samples in the laboratory included; Sample bottles, cool box, hot air oven, autoclave, incubators (37^0c, 44^0c), dilution bottles, culture tubes, pipettes (1ml, 10ml), membrane filters, PH metre, Petri-dishes (disposable), marker pen, labels, Binocular microscope, hand lens, and Membrane filtration apparatus. The reagents used included; Methylated spirit, Sodium thiosulphate, Endo agar, MacConkey agar, sterile Phosphate buffer, Sodium hydroxide, Potasium dihydrogen phosphate, Magnesium sulphate, absolute alcohol, distilled water, Oxidase test paper strips, Koser Citrate agar, Triple sugar iron (TSI) agar, Carbol Fuchsin, Crystal violet, Grams Iodine Solution, Acetone, Neutral red, Oil immersion and Indole test reagent [35, 38]

Figure 3: Photograph of Membrane filtration apparatus

3.6.1 Membrane filtration apparatus, ancillary equipment and reagents

1. **Membrane filters**

   The membrane filters used were made of cellulose acetate manufactured to give a controlled pore size of 0.45 microns. These were available in pack sizes of 50 and 100.

2. **Petri dishes or culture plates**

   The researcher used disposable plastic culture plates available in packs of 20. These were assumed to be sterile and dispensed with sterile media.

4. **Selective growth media**

   Endo agar medium and MacConkey agar medium were weighed and prepared as per manufacturers instructions and sterilised by autoclaving at 121^{o}c for 15-30 minutes. It was then allowed to cool then dispensed appropriately onto culture plates.

5. **Sterile phosphate buffer solution.**

   This included two solutions; stock solution I and II used to dilute samples and to rinse membrane filters. Stock solution I was prepared by dissolving 34g of potassium dihydrogen phosphate (KH_2PO_4) in 500ml of distilled water and pH adjusted to 7.2 with 1N sodium hydroxide (NaOH). This was then diluted to 1 litre to produce a stock solution. Stock solution II on the other hand was prepared by dissolving 60g of magnesium sulphate ($Mg\ SO_4.7H_2O$) in 1 litre of distilled water.

6. **Working phosphate buffer solution.**

   This was used for dilution bottles and was prepared by adding 1.25ml stock solution I and 5.0ml of stock solution II, to a bottle of distilled water and diluting to 1 litre. This was sterilized before use in four batches of 250ml each.

3.7 SAMPLE COLLECTION AND TRANSPORT

Sample collection was done according to WHO guideline procedures in order to avoid contamination and to ensure accurate results.

3.7.1 Preparation of sample bottles

Since the water to be sampled from taps was likely to contain chlorine then 0.1ml of 1.8% solution of Sodium thiosulphate ($Na_2\ S_2\ O_3\ 5H_2O$) per 100ml of bottle capacity was added to neutralize any residual disinfectant (up to 5mg/l available chlorine).

The addition of Sodium thiosulphate at this concentration has no significant effect on faecal coliform organisms in chlorinated water. The screw caps were loosely fastened prior to sterilizing and then only tightened when cooled following sterilization. [37]

3.7.2 Sterilisation of sample bottles

Plastic bottles of at least 200ml capacity with plastic screw caps were cleaned thoroughly, and then rinsed with distilled water and sterilized by autoclaving at $121^{o}c$ for 15 minutes. Other materials used in bacteriological analysis such as dilution bottles, small cylinders, beakers, tubes, buffer solutions and pipettes were also sterilized.

3.7.3 Sampling procedures

Water samples for bacteriological analysis were collected in sterile bottles which were kept unopened until the time of filling. The cork was removed and bottle held by the other hand around the base of the bottle. The researcher ensured that bottle was not rinsed with sample during collection and that the bottle was not completely filled to allow for shaking prior to analysis. Surface waters such as rivers were sampled away from the banks as much as possible.

3.7.4 Sampling from surface waters

In areas where residents draw water from rivers such as Kipsongo slum in Kitale, samples of water from four collection points was taken. Samples were collected about 30cm deep (1ft) below the surface. The base of the bottle was held and opened into the current. When full, the bottle was turned backwards opened and water collected then closed tightly and placed in the cool box.

3.7.5 Sampling from wells and boreholes

For wells and boreholes equipped with a pump, it was operated for a few minutes to clear any standing water in the water column. The outlet pipe was then sterilized using a flame from a burning cotton swab soaked in Methylated spirit.

The pump was operated and allowed to run for 2 minutes and sample collected in the flowing stream of water. A sample from the water collector's bucket was taken, as this was more representative of what was actually being consumed by the household. This sample was therefore poured into the sample bottle directly from the bucket.

3.7.6 Sampling from a tap

It was important to check that the tap was fed directly from the pressure mains and not a cistern or roof tank. The surface of the tap was then cleaned and then opened and allowed to run to waste for 4-5 minutes. The tap was then closed and dried with a clean piece of cloth then sterilized using an alcohol flame. It was then turned on and sample collected from a flow run at the normal usage rate but avoiding splashing. When sampling from copper or galvanized pipes, the flushing time was increased, as the metals were likely to have bactericidal effect on the sample.

3.7.7 Sampling from chlorinated supply

For chlorinated supplies, it was necessary to neutralize any residual chlorine in the water otherwise any bacteria present would be killed or prevented from growing on the culture medium. Sodium thiosulphate was used to inactivate the chlorine and was added to the sample bottles in solution before sterilization. This was done for all sample bottles regardless of whether they were for collection of chlorinated or non-chlorinated water.

Transport and storage of samples

Samples collected on site were stored in cool boxes containing ice during transport so that the temperature was kept between 4°C and 10°C but not frozen.

Examination of the samples commenced as soon as the samples reached the laboratory, a period less than 24 hours.

The research was carried out between the months of June and September 2006. Bacteriological analysis of the samples was done in Eldoret Water and Sanitation Company (ELDOWAS) laboratories in Eldoret town. The lab had the necessary infrastructure for the required to carry out all the intended laboratory tests.

3.8 LABORATORY PROCEDURES

There are two techniques available for the determination of faecal coliforms thermotolerant coliforms and faecal *streptococci* in drinking water supplies. These are multiple tube method (MTM) and membrane filtration techniques (MFT).

For this study, the researcher employed standard procedures including the Membrane filtration culture technique, colony counts and biochemical tests to assess the bacteriological quality of drinking water in the selected sites.

The membrane filtration technique was preferred because it has the following advantages over the multiple tube method (MTM). It is requires smaller quantities of media, is more accurate, may be operated using portable incubator and needs less manipulation. This contrasts with multiple tube method, which requires large quantities of media, is expensive, less accurate, not appropriate for field use, suitable for turbid samples, laborious and requires long incubation period of up to 72 hours. The MF technique is however, unsuitable for highly turbid water and capital costs for basic equipment is relatively high.[14]

3.8.1 Membrane Filtration Technique

The membrane filtration procedure involved filtration of a measured volume of sample or an appropriate dilution of it, through a membrane filter with a pore size of 0.45 micrometers made up of cellulose acetate. Micro-organisms were retained on the filter surface which was then incubated face upwards on Endo agar at 37^{o}C and MacConkey agar medium containing lactose at 44^{0}c. Characteristic acid producing colonies developed on the membrane and these were counted as either presumptive coliform or feacal coliform organisms depending on the incubation period.[3, 37, 38]

Since gas production could not be detected on membranes, it was assumed that organisms that produced acid or aldehyde from lactose produced gas. The visible colonies were counted and expressed in terms of the number present in 100ml of the original sample (WHO 1983). Isolates of these colonies were then picked from the membrane and sub cultured on MacCkonkey agar at 37^{o}C, for further identification. By incubating the cultures at 37^{o}C or 44^{o}C, it was possible to determine directly the number of the number of faecal coliforms and thermotolerant coliforms within 24 hours thus allowing for more rapid remedial action if deemed necessary.

3.8.2 Dilution procedures

Whenever counts of bacteria were expected to be high, the sample was diluted to obtain a count on the incubated membrane filter of 20-120 visible colonies.

The dilutions were made using sterile pipettes capable of measuring 1ml accurately to sterile buffer solutions in 15x150mm clean screw cap culture tubes for 1:10 dilutions and 100ml screw cap dilution bottles for 1:100 dilutions. The dilution blank was prepared by measuring 102ml of phosphate buffer solution to the screw cap dilution bottle and for culture tubes 9.5ml and then sterilizing in autoclave at 121°C for 15-20 minutes with caps loosely screwed on. The sterile blanks were then stored in a cool dark place to prevent photo-degradation. When small volumes were taken from dilution bottles and tubes, the filtered sample had to be rinsed on the membrane filter with at least 30ml sterile buffer to even out the distribution of faecal indicator organisms on the membrane filter surface.

3.8.3 Filtration of sample

Sterile filter units were used at the beginning of each filtration series as a minimum precaution to avoid accidental contamination. The apparatus was decontaminated by flaming the filter holder. To filter the sample, a sterile membrane filter (grid-side up) was placed over a porous plate receptacle using sterile forceps. A matched funnel unit was carefully placed over the receptacle and locked in position. The sample was then filtered in a partial vacuum. A 100 ml water sample or diluted sample was filtered through a membrane filter. The volume of water for filtration varied according to the type of water [35] as indicated below;

Treated water	50 – 100 ml
Untreated drinking water	10 - 50 ml
Surface water	01-10 ml

3.8.4 Determination of total coliforms

The membrane was carefully removed using sterile forceps and placed onto Endo agar media by a rolling motion to avoid entrapment of air and covered then inverted and incubated at 37°C for 18-24 hours under 100% humidity. A piece of wet cotton wool was placed in the incubator to provide the humid conditions.

Colonies of coliform bacteria isolated were medium or dark red in colour, with a greenish gold or metallic sheen. This sheen in some cases was seen to cover the entire colony or appeared only in the centre of the colony. Other type colonies were also enumerated and all isolates were sub-cultured on to MAC and incubated at 37°C.for 18-24 hours.

Biochemical tests were then done to identify the organisms such as *Klebsiella, Pseudomonas, Salmonella, Shigella, Citrobacter and Enterobacter.*

The tests performed included TSI, IMViC, Oxidase and Urease for faecal coliforms and bile Aesculin test for faecal *streptococci.* Total coliform colonies were counted with the help of a magnifying hand lens and the number of total coliforms calculated as follows:

$$\textbf{Total coliforms per 100ml sample} = \frac{\textbf{Number of coliform colonies counted x 100}}{\text{Number of ml of sample filtered}}$$

3.8.5. Determination of Faecal coliforms (thermotolerant coliforms)

The procedure used for faecal coliforms was similar to that used for determining total coliforms. The sample was filtered as described earlier and membrane filter inoculated onto a plate containing MacConkey agar and incubated at $44^{o}C \pm 0.5$ for 24 hours under high humidity. Colonies of thermotolerant *Escherichia coli* are lactose fermentors (LF) appearing yellow in colour. These colonies were also counted with the help of a magnifying lens and calculated as follows:

$$\text{Faecal thernotolerant coliforms} = \frac{\text{No. of faecal coliform counted x 100}}{\text{No of ml sample filtered}}$$

$$\text{Percentage verified coliform} = \frac{\text{No. of verified colonies x 1000}}{\text{Total No. of coliforms subjected to verification}}$$

3.9 DATA COLLECTION

This was achieved by bacteriological analysis, which included culture, microscopy, sub-culture and biochemical tests and recording of results in laboratory data sheets attached to the questionnaires. The mean number of faecal coliforms per 100ml of sample was calculated and the diversity and numbers of bacterial isolates in the sampled water determined. Similarly, data on individual households and their water sources was collected by use of researcher-administered questionnaires.

3.10 DATA ANALYSIS

The tabulated data was coded in data forms and entered into a computer database. Data was analyzed using SPSS computer package and presented in frequency tables, percentages, charts and graphics. Pearson Chi-square test was used to establish relationships among variables from computer-generated contingency tables. Statistical significance for each variable was also calculated in order to draw appropriate conclusions and test the stated hypotheses.

3.11 ETHICAL CONSIDERATIONS

The research proposal was reviewed approved by the KNH Research and Ethics committee. Permission was sought from selected households or institutions included in the study. A letter of authority to conduct research from the town clerks of individual Municipalities was also obtained for this exercise. No incentives were given to participants in order to respond to questions as this was done at will.

The findings of this study will be communicated to them to appropriate government agencies and participating institutions so that appropriate action is taken to improve the quality of drinking water for the residents.

CHAPTER FOUR

4.0 RESULTS.

4.1 INTRODUCTION TO DATA ANALYSIS AND PRESENTATION.

This chapter presents the findings of the study carried out in Kitale and Eldoret Municipalities in selected locations and in different water sources.

Data collected by use of questionnaires was first coded and entered into computer database. Statistical package for social sciences (SPSS) and MS Excel were used in data processing and analysis where Pearson's Chi square test statistic was used to test the relationships between variables and compare proportions from computer generated tables.

4.2 GENERAL DETAILS ON RESIDENTS.

4.2.1. Education status.

Table 1: Level of Education

Level of education		Eldoret Municipality	Kitale Municipality	Total
Primary	Count	29	10	39
	% within category	74.4%	25.6%	100.0%
	% within site	16.6%	14.3%	15.9%
Secondary	**Count**	59	21	80
	% within category	73.8%	26.3%	100.0%
	% within site	33.7%	30.0%	32.7%
University/College	Count	12	39	51
	% within category	23.5%	31.0%	100.0%
	% within site	6.85%	55.7%	21.4%
Unspecified	Count	6	70	76
	% within category	7.8%	28.6%	30.0%
	% within site	3.42%	100.0%	100%
Total	Count	175	70	245
	% within category	71.4%	28.6%	100.0%
	% within site	100.0%	100.0%	100.0%

Chi-Square Tests	Value	df	Asymp. Sig (2-sided)
Pearson chi-square	.725 (a)	3	.696
Likelihood Ratio	.727	3	.695
Linear-by-Linear Association	.625	1	.429
No. of Valid Cases	.245		
0 cells (.0%) have expected count less than 5. The minimum expected count is 11.14.			

Table 1, above indicates that 15.9% of the residents interviewed had some education to the level of primary school or none at all. 32.7% had secondary level of education while, 21.4% had education to tertiary or university level. However, 30% of the residents did not specify their level of education. This was because at the time of the study, actual homeowners were away at work and the caretakers who responded to the questionnaires were not sure of their employer's level of education. The level of education has a direct bearing on the basic knowledge of an individual on health, hygiene and consequently what they consider to be safe drinking water.
Chi square test at 2 df showed no significant difference between Eldoret and Kitale Municipalities as far as Education status was concerned, ($p > 0.05$).

4.2.2 Distribution of sample population based on socio-economic status of residents

Table 2. Sample population based on socio-economic status of residents

Site	Location	Socio-economic Status of residents	Frequency	Percent	Cumulative percent
Eldoret Municipality	Elgon View	High income	47	13.4	13.4
	Kapsoya	Medium income	52	14.9	28.3
	Langas	Low income	57	16.3	44.6
	Huruma	Low income	45	12.9	57.5
	Maili Nne		34	9.7	67.2
Kitale Municipality	Milimani	High income	38	10.9	78.1
	Kipsongo	Low income	8	2.3	80.4
	Kibomet	Medium income	35	10	90.4
	Matisi	Low income	34	9.6	100.0
TOTAL			350	100	

Socio-economic status of an individual has a direct bearing on choice of area of residence. This was an important factor considered in selection of study locations within the two municipalities. Milimani and Elgon view residential areas represented the high-class category; Kapsoya and Kibomet in the middle level category while Huruma, Maili Nne and Langas in Eldoret, Kipsongo and Matisi in Kitale represented the low class category. The study revealed that the type of residence as dictated by Socio- economic class also determined the type of drinking water used by the residents. All the residents in the high-class category had piped water sources and some had alternative sources such as wells/ boreholes to supplement tap water during rationing and the dry spell. Majority of the residents in the middle level class used either well or piped water but most of those in the low income category used either well or spring water and in extreme cases river water as seen in Kipsongo slum in Kitale. Surface water from rivers, springs and shallow wells are naturally prone to high level of contamination if not well protected.

4.2.3 Resident responses on experience of waterborne diseases.

The results in Table 3, indicate that 57.6% of the residents had not experienced waterborne diseases such as typhoid, diarrhea and vomiting while the rest had been affected by one disease or the other at some point in time. Kitale residents had slightly higher percentage of experience with typhoid 22.6% compared to 13.6% in Eldoret municipality. Diarrhoea and vomiting was rated 12.8% and 23.5% in Eldoret and Kitale respectively. Diseases of morbidity su.ch as typhoid are of concern as the affected individuals are unable to contribute effectively in national development. It is therefore that the causes of such ailments are identified early so that appropriate measures are taken to prevent further spread of infections to other members of the community. Chi square test revealed significant difference between Eldoret and Kitale Municipalities as far as experience of waterborne diseases was concerned.

Table 3: Resident responses on experience of waterborne diseases

Disease		Eldoret Municipality	Kitale Municipality	Total
Unspecified	Count	12	10	22
	% within category	54.5%	45.5%	100.0%
	% within site	5.1%	8.8%	6.3%
None	Count	150	50	200
	% within category	75.0%	25.0%	100.0%
	% within site	64.1%	44.2%	57.6%
Typhoid	Count	32	26	58
	% within category	55.2%	44.8%	100.0%
	% within site	13.6%	22.6%	16.6%
Diarrhea & Vomiting	Count	30	27	57
	% within category	52.6%	47.4%	100.0%
	% within site	12.8%	23.5%	16.2%
ALL	Count	11	2	13
	% within category	84.6%	15.4%	100.0%
	% within site	46.8%	1.74%	3.71%
Total	Count	235	115	350
	% within category	67.4%	32.6%	100.0%
	% within site	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig (2-sided)
Pearson chi-square	25.750 (a)	5	.000
Likelihood Ratio	29.073	5	.000
Linear-by-Linear Association	7.005	1	.008
No. of Valid Cases	350		

4.2.4. Responses on whether residents attributed any of the ailments to the water consumed.

The results in Table 4, below reveal that 12.1% of the residents attributed the ailments to the water consumed with 4.7% and 27.5% in Eldoret and Kitale respectively. However, 24.2% of the residents did not attribute the ailments experienced to drinking water but possibly to other causes with 24.5% and 23.5% rating in E ldoret and Kitale respectively. However, an overall 63.7% thought question was not applicable, as they had not experienced any ailments with 70.8 % and 49.0% ratings in Eldoret and Kitale respectively. Chi square test to compare the responses in the two towns at

2 df, showed that the differences were significant; ($p < 0.05$). Most of the residents in Kitale attributed the ailments to the water consumed meaning that a large proportion of them did not trust their drinking water.

Table 4: Residents views on possible association between water consumed and waterborne disease

Residents Responses		**Eldoret Municipality**	**Kitale Municipality**	**Total**
Yes	Count	10	28	38
	% within category	26.3%	73.7%	100.0%
	% within site	4.7%	27.5%	12.1%
No	Count	52	24	76
	% within category	68.4%	31.6%	100.0%
	% within site	24.5%	23.5%	24.2%
N/A	Count	150	50	200
	% within category	75.0%	25.0%	100.0%
	% within site	70.8%	49.0%	63.7%
TOTAL	Count	212	102	314
	% within category	67.5%	32.5%	100.0%
	% within site	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig (2-sided)
Pearson chi-square	34.547 (a)	2	.000
Likelihood Ratio	32.401	2	.000
Linear-by-Linear Association	14.256	1	.000
No. of Valid Cases	314		
O cells (.0%) have expected count less than 5. The minimum expected is 12.34.			

4.2.5. Resident perception on the safety of their drinking water

Table 5: Resident perception on the safety of their drinking water

Do you consider your water safe for human consumption?		Eldoret Municipality	Kitale Municipality	Total
Yes	Count	189	46	235
	% within category	80.3%	19.7%	100.0%
	% within site	80.4%	40.0%	67.1%
No	Count	46	69	115
	% within category	40.0%	60.0%	100.0%
	% within site	19.6%	60.0%	32.9%
TOTAL	Count	235	115	350
	% within category	67.1%	32.9%	100.0%
	% within site	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson chi-square	56.799 (b)	1	.000		
Continuity Correction (a)	54.987	1	.000		
Likelihood Ratio	55.670	1	.000	.000	.000
Fisher's Exact Test					
Linear-by-Linear Association	56.639	1	.000		
No. of Valid Cases	350				

According to the results in Table 5 above, 67.1% of the residents felt that their water was safe for consumption with 80.4% in Eldoret and 40% in Kitale. However, 32.9% thought it was unsafe with 40% and 60% in Eldoret and Kitale respectively. A large proportion of the presumably safe water in Eldoret was treated tap water while in Kitale, a number of residents indicated that even the treated tap water was considered unsafe. Chi square test statistic at1 df, revealed a significant difference in perception on safety of drinking water between the two Municipalities, ($P < 0.05$).

4.2.6 Measures taken to render water safe for consumption

The study findings recorded in Table 6 below, indicated that some of the measures applied by residents to render their drinking water safe for human consumption included boiling, refrigeration, and use of alum in wells among others. 74% of the residents in Eldoret and 38.3% in Kitale Municipalities did not apply any methods. An overall 26% of the residents boiled their drinking water with 19.6% and39.6% in Eldoret and Kitale respectively. This was a significant difference between the two sites. Refrigeration was rated equally in both sites. It was clearly evident that more people in Kitale had taken appropriate precautions to avoid infections related to water contamination.

Table 6: Measures taken to render water safe for consumption

Method	Eldoret Municipality		Kitale Municipality		Total	
	Count	%	Count	%	Count	%
None	174	74.04	44	38.26	218	62.3
Boiling	46	19.6	45	39.1	91	26
Refrigeration	6	2..5	3	2. 6	9	2..5
Use Alum	4	1.14	0	0	4	1.14
Other	5	1. 4	23	6..5	28	78
Total	235	67.1	115	32.9	350	100

4.2.7. General rating of water quality:

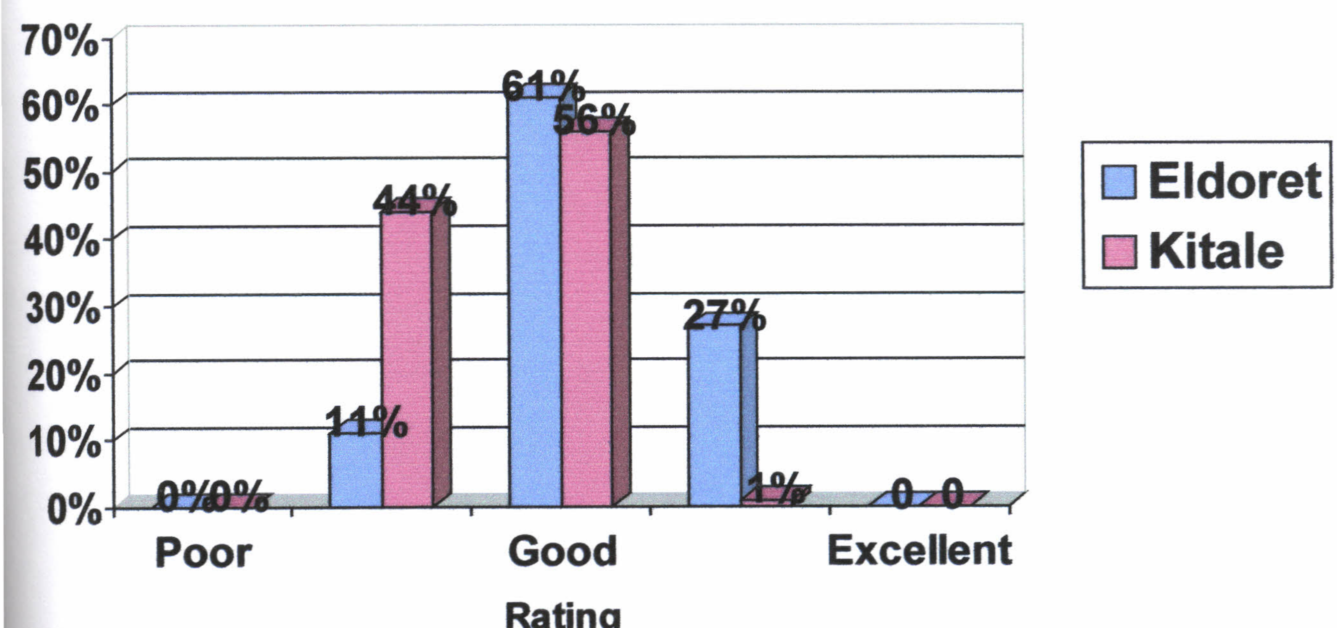
The general rating of water quality as given by residents is indicated in Table 7 below. The residents rated 21.7% of the water as average, 59.4% as good, 18.3% as very good and 0.3% as excellent and poor respectively. There was no significant difference in the rating between Eldoret and Kitale Municipality.

These ratings determined the use of alternative methods of water treatment used by the residents incase they considered their water unsafe for consumption as indicated earlier.

Table 7: General rating of water quality

Rating		Eldoret Municipality	Kitale Municipality	Total
Poor	Count	1	0	1
	% within category	100.0%	0%	100.0%
	% within site	.4%	0%	.3%
Average	Count	26	50	76
	% within category	34.2%	65.8%	100.0%
	% within site	11.1%	43.5%	21.7%
Good	Count	144	64	208
	% within category	69.2%	30.8%	100.0%
	% within site	61.3%	55.7%	59.4%
Very good	Count	63	1	64
	% within category	98.4%	1.6%	100.0%
	% within site	26.8%	.9%	18.3%
Excellent	Count	1	0	1
	% within category	100.0%	0%	100.0%
	% within site	.4%	0%	.3%
Total	Count	235	115	350
	% within category	67.1%	32.6%	100.0%
	% within site	100.0%	100.0%	100.0%

Fig 3: General rating of water quality.



4.3 DATA ON WATER SOURCES AND CONSUMER POINTS

4.3.1 Distribution of water sources

Table 8: Distribution of water sources

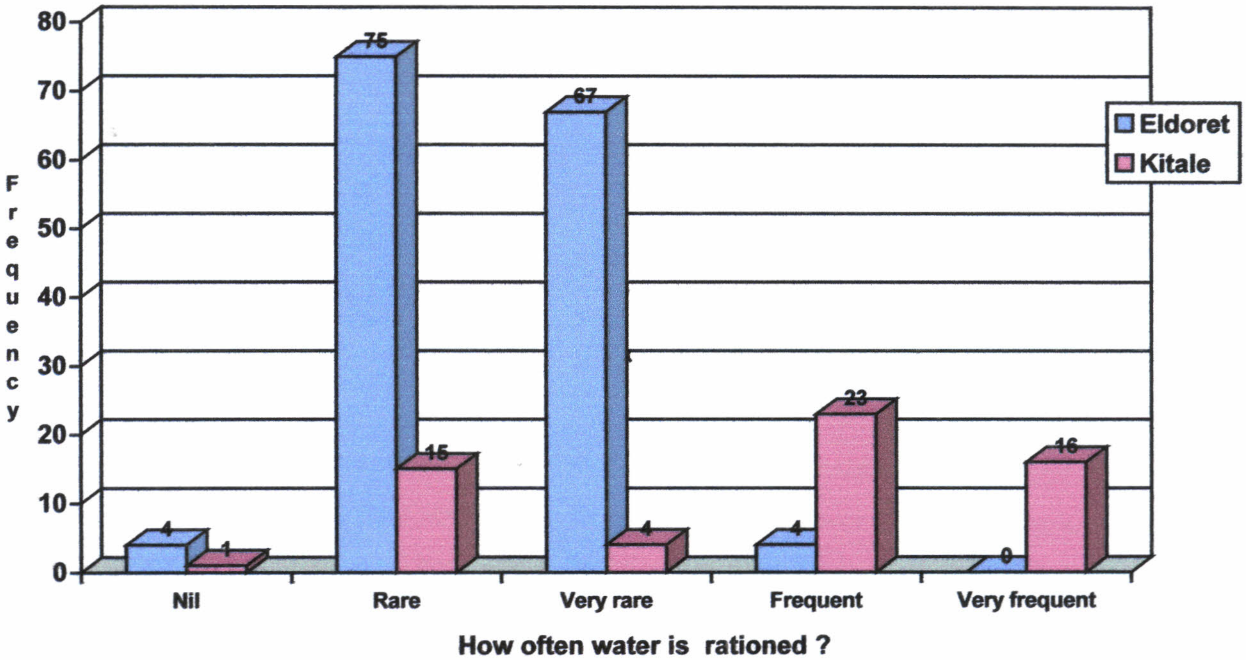
		Eldoret Municipality	Kitale Municipality	Total
Treated	Count	160	49	209
	% within category	76.6%	23.4%	100.0%
	% within site	68.1%	42.6%	59.7%
Untreated	Count	75	66	141
	% within category	53.2%	46.8%	100.0%
	% within site	31.9%	57.4%	40.3%
Total	Count	235	115	350
	% within category	67.1%	32.9%	100.0%
	% within site	100.0%	100.0%	100.0%

This population profile of the two Municipalities as indicated earlier in the District Development Plan revealed that the ratio of human population settlement between Eldoret Municipality and Kitale Municipality was 1: 3. Since this was directly related to water use and consumption, the same ratio was applied. Both treaed and untreated water samples were analyzed as indicated in Table 8 above.

A total of 59.7 % of water samples collected were from treated water sources with 68.1 % and 42.6 % from Eldoret and Kitale Municipalities respectively. However, 40.3% were untreated water samples with 31.9% and57.4% from Eldoret and Kitale respectively. These included 209 treated tap water samples, 123 samples from wells, 12 samples from boreholes, 4 and 2 samples from rivers and springs respectively.

.2 Resident responses on frequency of water rationing

Figure 4: Resident responses on frequency of water rationing



Water rationing of piped water supplies is a common phenomena in most urban settings where population growth is rapid. Respondents gave varying views on the status of water rationing in their towns. An overall 2.3 % in both Municipalities experienced no water rationing at all, 43.1 % had it on rare occasions, and another 33.9 % had rationing on very rare occasions whereas 12.9 % had frequent rationing. Similarly, 7.6 % had rationing very frequently with episodes occurring on very many months of the year.

4.3.3 Efficiency of sewerage system

Table 9: Efficiency of water treatment.

Is Sewage Treatment Efficient?		Eldoret Municipality	Kitale Municipality	Total
Yes	Count	136	29	165
	% within category	82.4%	17.6%	100.0%
	% within site	87.7%	63.0%	82.1%
No	Count	19	17	36
	% within category	52.8%	47.2%	100.0%
	% within site	12.3%	37.0%	17.9%
Total	Count	155	46	201
	% within category	77.1%	22.9%	100.0%
	% within site	100.0%	100.0%	100.0%

The results in Table 10 revealed that 82.1 % of the residents with piped water facilities considered their sewerage system efficient. However 17.9 % felt the sewage system was inefficient. There was a significant difference in responses with 87.7 % and 63.0 % rating of efficiency in Eldoret and Kitale municipalities respectively, while non-efficiency was rated 12.3 % in Eldoret and 37.0 % in Kitale Municipalities. Chi square test at 1df showed a significant difference in responses concerning the efficiency of sewerage treatment between the two Municipalities, ($p < 0.05$).

4.3.4 Level of training of water supply operators.

The data above indicates that the water supply operators in the two Municipalities had different levels of education. ELDOWAS staff of Eldoret Municipality had one certificate, one diploma holder, 3 graduates and one master's holder.

Kitale Municipality had one certificate and three diploma holders.

The level of education of water supply operators is a very important determinant of quality service to consumers. The process of water treatment requires highly skilled manpower to undertake quality control procedures involved in every step of the treatment process as well as final assessment of the quality of the product as far as physical, chemical and microbiological properties are concerned.

Table 10: Level of training of water supply operators.

SITE		ELDORET MUNICIPALITY	KITALE MUNICIPALITY	TOTAL
Certificate	Count	1	1	3
	% within category	50%	50%	100%
	% within site	0	25%	25%
Diploma	Count	3	3	6
	% within category	50%	50%	100%
	% within site	1%	25%	50%
Graduate	Count	3	0	3
	% within category	100%	0	100%
	% within site	1%	0	25%
Masters	Count	1	0	1
	% within category	100%	0	100%
	% within site	1%	0	1%
TOTAL	Count	8	4	
	% category	75%	25%	100%
	% within site	100%	100%	100%

4.3.2.4 Details of laboratory analysis tests done in water treatment plants.

Table 11: Laboratory analysis tests done in water treatment plants

SITE	Water treatment plant	LABORATORY TESTS DONE			
		Physical	Chemical	Bacteriological	Chemical used
ELDORET MUNICIPALITY	Sosiani	YES	YES	YES	Chlorine
	Chebara	YES	YES	YES	Chlorine
	Kapsoya	YES	YES	YES	Chlorine
KITALE MUNICIPALITY	Nzoia	YES forf	YES	NO	Chlorine Alum

The results indicated that both Municipalities carry out physical and chemical laboratory tests whereas bacteriological analysis of water samples is only done in Eldoret Municipality in each of the treatment plants. The culture technique employed is the plate count method; although membrane filters technique is also carried out on trial basis. Kitale Municipality is in the process of constructing a new water treatment plant with modern laboratory facilities to cater for physical, chemical and microbiological tests. The staff in Kitale appreciated the need to have a running microbiology unit in order to run all necessary tests and improve the quality of water supplied to consumers. However, for the moment, water safety in Kitale Municipality is only based on ascertaining the physico-chemical parameters. This is however a risky assumption that can have serious impacts on the health of residents if not addressed promptly.

4.4 LABORATORY FINDINGS

4.4.1 Isolation of total coliforms on Endo agar at 37^0c

Table 12: Isolation of total coliforms on Endo agar at 37^0c

Culture on Endo Agar At 37^0C		Eldoret Municipality	Kitale Municipality	Total
Nil	Count	155	41	196
	% within category	79.1%	20.9%	100.0%
	% within site	66.0%	35.7%	56.0%
	Count	80	74	154
Isolation present	% within Category	51.9%	48.1%	100.0%
	% within site	34.0%	64.3%	44.0%
	Count	235	115	350
Total:	% within category	67.1%	32.9%	100.0%
	% within site	100	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson chi-square	28.780 (b)	1	.000		
Continuity Correction (a)	27.563	1	.000		
Likelihood Ratio	28.912	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	28.698	1	.000		
No. of Valid Cases	350				

The results in Table 13 above indicate that 56 % of the water samples analyzed had no bacteria isolated hence considered safe water with 66 % and 35.7 % in Eldoret and Kitale respectively. Total coliforms were however isolated in 44 % of the samples with 51.9 % and 48.1 % isolation in Eldoret and Kitale respectively. Chi Square test at 1df indicated a statistical significant difference in bacteriological quality of water supplies between Eldoret and Kitale Municipalities.

4.4.2. Isolation of faecal thermo-tolerant coliforms

The study indicated that 76.9% of the samples did not contain faecal thermo-tolerant *Escherichia co*li while 23.1 % isolation was realized.

The isolation was predominantly from well water. There was no significant difference in percentage isolation between Eldoret (22.6%) and Kitale (24.3 %).

Further study indicated that most of the thermo-tolerant coliforms isolated were from river water serving Kipsongo slum in Kitale. This is in line with the commonly accepted norm about surface water sources being exposed to contamination from the surrounding environment. No thermo-tolerant coliforms were isolated from treated tap water in both Municipalities. Chi square test at 1df, showed no significant difference in isolation of thermotolerant coliforms between the two Municipalities.

There was also a clear indication that thermotolerant coliforms in these sites are a rare phenomenon.

Table 13: Isolation of faecal thermo-tolerant coliforms

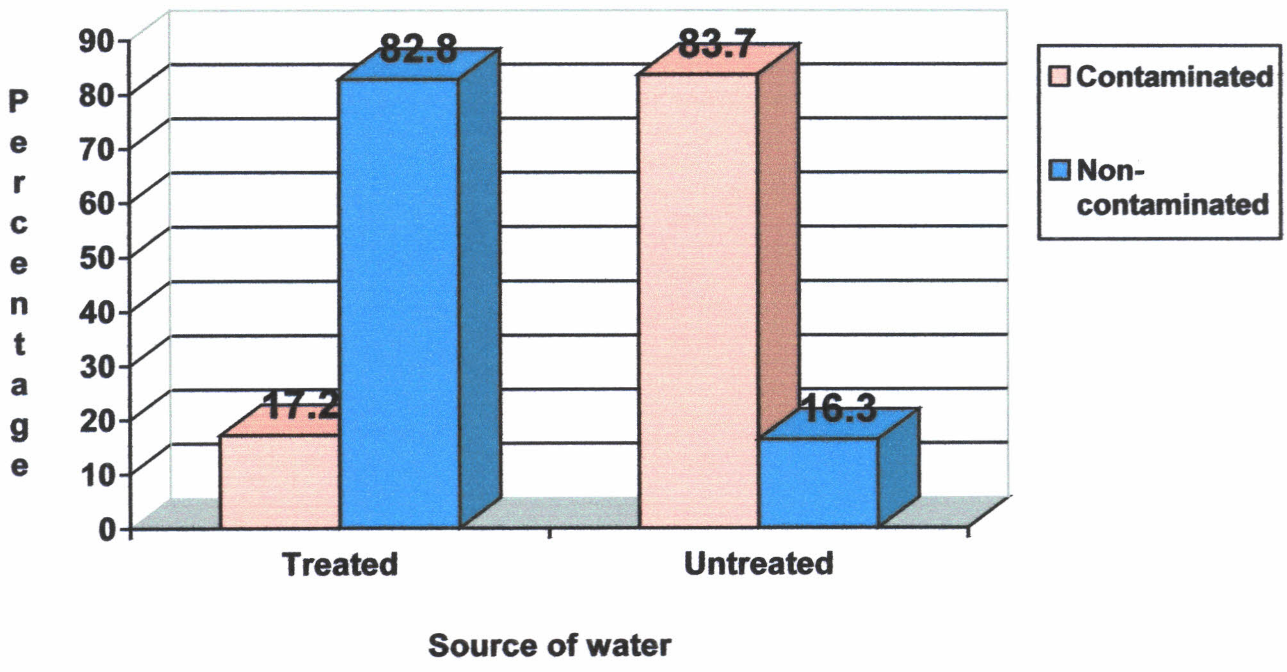
Subculture on MAC at 37^{0}C		**Eldoret Municipality**	**Kitale Municipality**	**Total**
Nil	Count	182	87	269
	% within category	67.6%	32.3%	100.0%
	% within site	77.4%	75.6%	76.9%
Isolation present	Count	53	28	81
	% within category	65.4%	34.6%	100.0%
	% within site	22.6%	24.3%	23.1%
Total	Count	235	115	350
	% within category	67.1	32.9%	100.0%
	% within site	100.0%	100.0%	100.0%

Chi square test

Pearson chi-square	28.780 (b)	1	.678		
Continuity Correction (a)	27.563	1	.678		
Likelihood Ratio	28.912	1	.678		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	28.698	1	.000		
No. of Valid Cases	350				

4.4.3 Relationship between water treatment and bacterial contamination.

Figure 5: Relationship between water treatment and bacterial contamination



The results in the graph above indicate that an overall 44 % of treated water had bacterial contamination, with 17.2% and 83.7% in treated and untreated water respectively.. However, an overall 56 % had no contamination at all with 82.8% and 16.3% in Eldoret and Kitale respectively. This clearly indicates that water treatment has a profound effect on reducing the level of contamination of drinking water and hence must always be applied to render water safe for drinking. The graph below reveals that there is a significant difference between treated and untreated water as far as bacterial contamination is concerned.

4.4.4 Relationship between type of water source and bacterial contamination

The results in Table 14 below revealed that 44% of all water had bacterial contamination while 56% had none and hence considered safe for drinking.

Out of all water sources 17.2% of piped water, 94% well water, 100% of river and spring water had bacterial contamination. However, 82.8% of piped water, 6% of well water and 100% of borehole water had no bacterial contamination. Surface waters are open to the environment and easily get contaminated with faecal material and animal excreta especially through surface run off during rains.

However, deep underground waters are more protected and bacteria normally get trapped as it drains through various soil layers.

Table14: Relationship between type of water source and bacterial contamination

SOURCE		Bacterial Contamination		
		YES	NO	TOTAL
Piped water	Count	34	175	209
	% within category	17.2%	82.8%	100%
	% within site	22%	89.3%	59.7%
Well	Count	114	9	123
	% within category	94%	6%	100%
	% within site	74%	4.6%	35.1%
Borehole	Count	0	12	12
	% within category	0%	100%	100%
	% within site	0%	6.1%	3.4%
River	Count	4	0	4
	% within category	100%	0%	100%
	% within site	2.5%	0%	.01%
Spring	Count	2	0	2
	% within category	100%	0%	100%
	% within site	.008%	0%	.006%
TOTAL	Count	154	196%	350
	% within category	44.0%	56.0%	100%
	% within site	100%	100%	100%

4.4.5 Comparison of the level of bacterial contamination in treated water between Eldoret and Kitale Municipalities

Table15: Comparison of level of bacterial contamination in treated water

SITE		Bacterial contamination		
		YES	NO	TOTAL
Eldoret Municipality	Count % within site % within category	4 2.5% 14.8%	156 75 % 71.4%	160 100% 76.6%
Kitale Municipality	Count % within site % within category	30 61.2% 83.3%	19 38.8% 28.5%	49 100% 23.4%
TOTAL	Count % within site % within category	34 16.3% 100%	175 83.7% 100%	209 100% 100%

The results in Table 15 above reveal that, 16.3% of treated water had bacterial contamination with 25% in Eldoret and 61.2% in Kitale.

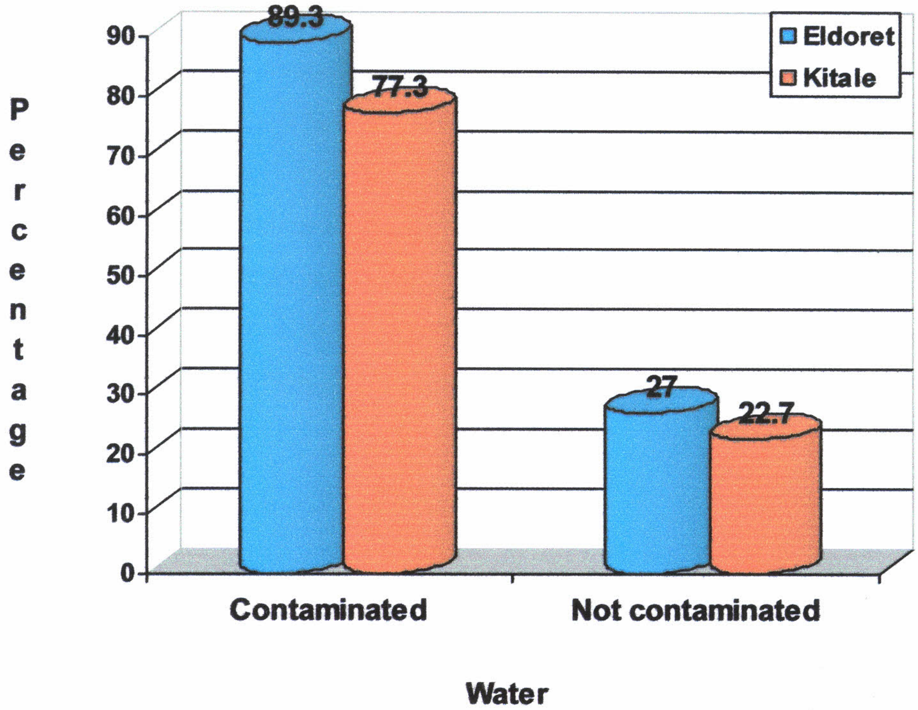
Non-contamination of treated water was rated 83.7%, with 97.5% and 38.8% in Eldoret and Kitale respectively. This clearly indicates that a large proportion of the water in Eldoret was found to be safe for consumption while much of the treated water in Kitale was unsafe for consumers. This confirmed the fears cited by most of the residents who did not consider their water safe for consumption.

There is therefore need for urgent measures to be taken by the water supply agencies to render the water safe for its consumers. These results indicate a significant difference in the degree of contamination between the two Municipalities.

Risk factors leading to bacterial contamination of water sources in these areas need to be critically identified and appropriate action taken to curb the problem and improve the quality of drinking water supplied to residents.

4.6 Comparison of the level of bacterial contamination in untreated water in Eldoret and Kitale Municipalities

Figure 6: Comparison of the level of bacterial contamination in untreated water in Eldoret and Kitale Municipalities.



The results in Figure 6 above, indicate that that 89.3% and 77.3% of the untreated water samples studied had bacterial contamination respectively while no contamination was rated 27% and 22.7% Eldoret and Kitale Municipalities. Untreated water naturally has high levels of contamination since water is one of the natural habitats for bacteria among other microorganisms. It therefore requires thorough treatment procedures by physical or chemical means to render it safe for human use. Home-based treatments such as boiling are quite handy in most households. The graph below shows no significant difference between the two Municipalities as far as bacterial contamination of untreated water was concerned.

4.4.7 Diversity of Bacterial contaminants in treated and untreated water

The results in Table 16 below, indicate that the common bacteria isolated as total coliforms on Endo agar included *Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa, Proteus species, Salmonella* species, *Shigella, Citrobacter* , *Enterobacter* species and *Streptococcus faecalis.*

Out of all the bacteria isolated, *Escherichia coli* rated 30.4%*Klebsiella* 21.1%, *Salmonella* species 17.4%, *Pseudomonas* 14.4% and others had smaller proportions including *Enterobacter and Shigella.*

This is a clear indication that waterborne bacterial infections in these sites are mainly due to *E. coli* and *Salmonella* species. The presence of a high percentage of *E coli* clearly indicates evidence of faecal contamination arising mainly due to faecal contamination rather than normal environmental organisms.

Untreated water as indicated earlier had higher counts of bacterial isolates compared to treated water. This is a true reflection of the fact that water is a natural habitat for many microorganisms including faecal coliforms and parasites.

Table 16: Diversity of Bacterial contaminants in treated and untreated water

Bacterial species		Bacterial contamination		
		Treated	Untreated	Total
E. coli	Count	22	90	112
	% within category	80.4%	80.4%	100%
	% within site	30.5%	30.4%	30.4%
Klebsiella	Count	14	64	78
	% within category	17.95%	82.05%	100%
	%within site	19.4%	22.0%	21.2%
Pseudomonas Aeruginosa	Count	6	47	53
	% within category	11.3%	88.7%	100%
	% within site	8.33%	15.9%	14.4%
Proteus	Count	6	21	27
	% within category	22.2%	77.8%	100%
	% within site	8.33%	7.1%	7..3%
Salmonella	Count	19	45	64
	% within category	29.7%	70.3%	100%
	% within site	26.3%	15.4%	17.4%
Citrobacter	Count	3	9	12
	% within category	25%	75%	100%
	% within site	4.17%	3.04%	3. 26%
Enterobacter	Count	0	5	5
	% within category	0%	100%	100%
	% within site	0%	1.7%	1..35%
Shigella	Count	0	10	10
	% within category	0%	100%	100%
	% within site	0%	33.7%	2.72%
Streptococcus faecalis	Count	2	5	7
	% within category	28.5%	71.5%	100%
	% within site	20%	1.66%	1.90%
Total	Count	72	296	368
	% within category	20.0%	80.0%	100%
	% within site	100%	100%	100%

Table 17: Relationship between ownership of water sources and Bacterial contamination

Ownership		Bacterial contamination		
		YES	NO	TOTAL
Private	Count % within category % within site	60 72.3% 55.6%	23 27.7% 100%	83 100% 63.4%
Community	Count % within category % within site	48 100% 44.4%	0 0% 0%	48 100% 36.6%
TOTAL	Count % within category % within site	108 82.4% 100.0%	23 17.6% 100%	131 100% 100%

Chi square tests

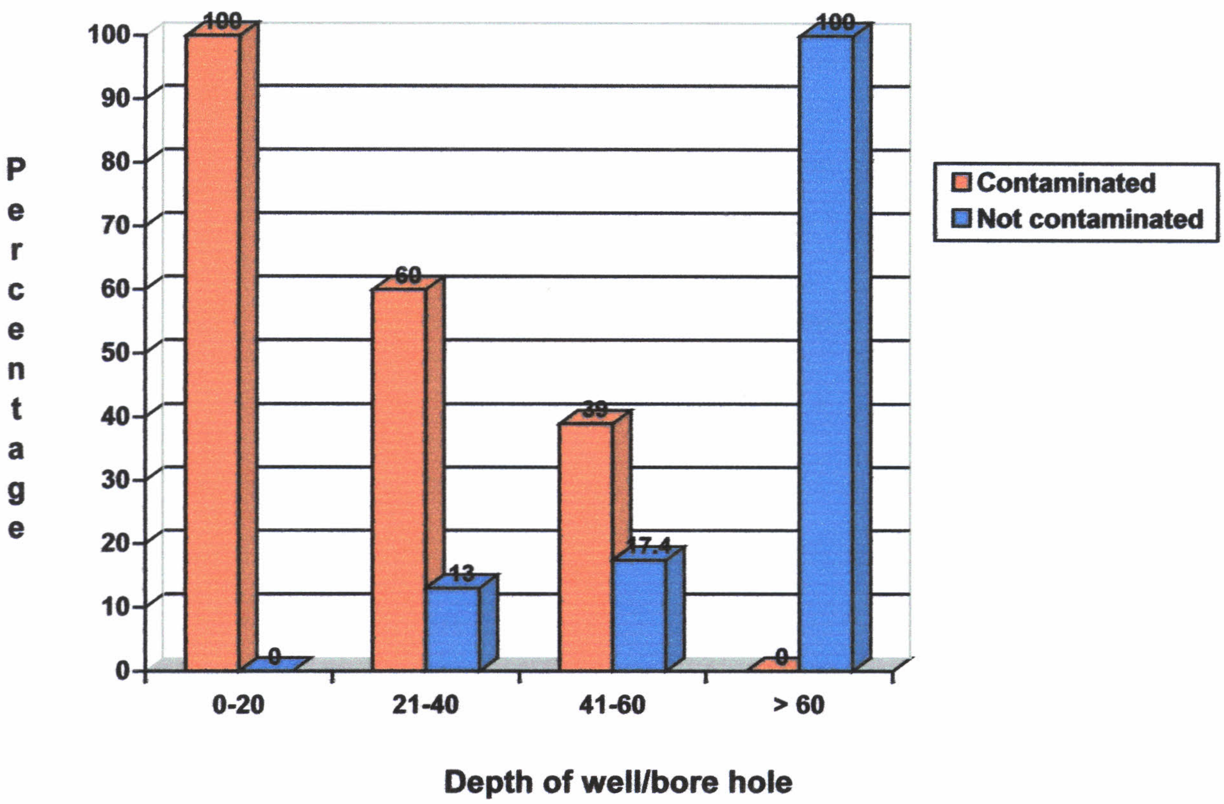
	Value	Df	Assym. Sig (2 sided)	Exact sig (2 sided)	Exact. Sig (2 sided)
Pearson chi Square	16.134	1	.000		
Continuity correction	14.276	1	.000		
Likelihood ration	3.23.755	1	.000		
Fischer's exact test				.000	.000
Linear by linear Association	16.011		.000		
No. of valid cases	131				

The study revealed that 100% of community owned wells were contaminated compared to 55.6% of private owned wells. This clearly indicates that community wells that normally have many handlers are more contaminated than private wells with few handlers. Chi square test at 1df revealed a strong relationship between well ownership and bacterial contamination, ($P<0.05$).

4.5 RISK FACTORS TO BACTERIAL CONTAMINATION OF WATER SOURCES

4.5.1. Relationship between depth of well/borehole and bacterial contamination.

Figure 7: Relationship between depth of well/borehole and bacterial contamination of water sources



The results indicated in the graph above, reveal that bacterial contamination was highest, 60% in wells of depth ranging from 21-40ft and 39% in wells of depth ranging from 41-60ft. No contamination was seen at depths above 60ft. These findings indicate that bacteria can thrive luxuriantly in wells between depths of 0-20ft and decrease with depth. However, above 60ft depth conditions cannot support further bacterial growth since temperatures are extremely low. In this study only one of the wells sampled had a depth of between 0-20ft. Under normal conditions shallower wells are expected to have higher levels of bacterial contamination due to ambient temperatures. This is clearly indicated in the graph, which shows a sharp decline in the level of contamination as the depth increases.

Mineral content is also known to increase with depth thus providing rather unfavorable conditions due to variations in P_H.

4.5.2 Relationship between presence of raised protective platform and bacterial contamination

The results in Table 18 below indicate that out of 85.4% wells that had bacterial contamination, only 69.5% of the wells had a protective platform while 30.5% had none. Non-bacterial contamination was rated 94.4% in protected wells compared to 5.6% in non-protected wells. This shows that the presence of a protective platform has some profound effect on shielding wells and boreholes from contamination.

Chi square test at 1df showed a significant relationship between presence of protective platform and bacterial contamination, ($p<0.05$

Table 18: Relationship between presence of raised protective platform and bacterial contamination

Presence of impermeable		Bacterial contamination		TOTAL
		YES	NO	
Presence	Count % within category % within site	73 81.1% 69.5%	17 18.9% 94.4%	90 100% 73.2%
Absence	Count % within category % within site	32 97.0% 30.5%	1 3.0% 5.6%	33 100% 26.3%
TOTAL	Count % within category % within site	105 85.4% 100.0%	18 14.6% 100.0%	123 100% 100%

Chi square test

	Value	df	Assym. Sig (2 sided)	Exact sig (2 sided)	Exact. Sig (2 sided)
Pearson chi Square	4.861	1	.027		
Continuity correction	3.674	1	.055		
Likelihood ration	6.220	1	.013		
Fischer's exact test				.040	.020
Linear by linear Association	4.822	1	.028		

4.5.3 Relationship between distance from pit latrine and bacterial contamination of well / borehole

Table 19: Relationship between distance from pit latrine and bacterial contamination of well / borehole

Distance from Pit latrine (m)		Bacterial contamination		
		YES	NO	TOTAL
0-10	Count	60	1	61
	% within category	98.4%	1.6%	100.0%
	% within site	54.5%	6.7%	48.8%
11-20	Count	42	7	49
	% within category	85.7%	14.3%	100%
	% within site	38.2%	46.7%	39.2%
>20	Count	8	7	15
	% within category	53.3%	46.7%	100.0%
	% within site	7.3%	46.7%	12.0%
TOTAL	Count	110	15	125
	% within category	88.0%	12.0%	100.0%
	% within site	100.0%	100.0%	100.0%

Chi square tests

	Value	df	Assym. Sig (2 sided)
Pearson chi Square	23.514	2	.000
Likelihood ratio	20.6.7	2	.000
Linear by linear Association	21.104	1	.000
No. of valid cases	125		

The results presented in Table 19, indicates that there was 98.4% contamination in 0-10m distance, 85.7% in 11-20m and 53.3% in greater than 20m distance away from possible contaminating source. It is therefore evident that the shorter the distance from a contaminating source such as a pit latrine, the greater the level of contamination. Contaminants of water sources are carried through hands and feet of handlers who draw water after visiting the latrines.

In this case, as the distance increases most of the contaminants carried through feet are removed gradually as the individual walks farther away and hence likely to cause minimal contamination of water source. Chi square test at 2df showed a significant relationship, ($p < 0.05$). A clear evidence of this factor was seen in Matisi, Kitale where some residents were drawing water from a well located 5 meters away from a pit latrine sited at a higher ground and a food kiosk situated less than 5 meters from the same well.

4.5.4 Poor housing and sanitation

The study revealed that some of the residents live in dilapidated slum dwellings with no proper housing conditions but mainly shacks made of plastic bags with no sanitation facilities. These crowded and poor hygienic conditions in the surrounding environment contribute to gross contamination of river water as seen in Kipsongo slum. All the residents here draw their water from a river that borders the slum.

An interview with some of the residents indicated that most of them constantly suffer from typhoid and other gastrointestinal infections. Below is a photograph showing a section of the slum with a section of the river lying in the bottom right.

Figure 8: Photograph of a section of Kipsongo slum in Kitale Municipality.

4.5.5 Delay in repair of burst pipes and leaking sewers.

Residents served by piped water facilities cited this as some of the major complaints. It has been noted that when such a problem is not addressed promptly,

it frequently become a source of contamination of treated water as noted in some areas within the study sites. Conditions such as those seen in the file photo below are not uncommon in many urban settings and can frequently, be a possible risk due to back- siphonage, leaking service connections and contamination of treated water with sewage. The water collected by the children in this photograph is likely to be highly contaminated.

Figure 9: File photograph of children fetching water from a burst pipe in a city Estate.

Source: Daily Nation; May 14th, 2007.

4.5.6 Unprotected water catchments

A survey of the surrounding environment and supporting bacteriological results seen earlier indicated that spring water had 100% bacterial contamination.

This was observed in Ziwani daraja spring in Kitale Municipality.

The area was noted to be lying on the rugged foothills of Mt. Elgon.
It was densely populated with evidence of intensive farming even on the hillsides.
Most of the residents here obtained their water from the spring an interview with some of the women found drawing water on the quality of the water indicated that it was not safe. This was because many of the inhabitants living uphill had dug pit latrines that could possibly be a source of contamination of the spring water tapped downhill.

Figure 10: Photogragh of Ziwani daraja spring in Kitale Municipality.

Some of the water vendors fetch drinking water from dams and swamps during the dry seasons to sell to unsuspecting customers in the urban centres.
This becomes a possible source of waterborne diseases as these waters used by both man and animals. The recent outbreaks of Leptospirosis in Chesamisi in Western Kenya were due to consumption of water contaminated with excreta of livestock among other causes. Studies in various parts of Kenya reveal that water shortages in urban settings has forced residents to resort to use of water supplied from vendors from questionable sources.

4.5.7 Lack of alternative water sources

Residents also noted this factor as a possible cause of consumption of contaminated water. Due to compounding factors of poverty, illiteracy and ignorance, some residents use any available water source for domestic use. The file photograph below taken from a shallow well at a village in Bulawayo, Zimbabwe shows how majority of people in developing counties still grapple with acute water shortages.

This scenario is common in various parts of Kenya including Kitale and Eldoret Municipality and leads to indiscriminate use of any available water thus posing high risk waterborne diseases to consumers.

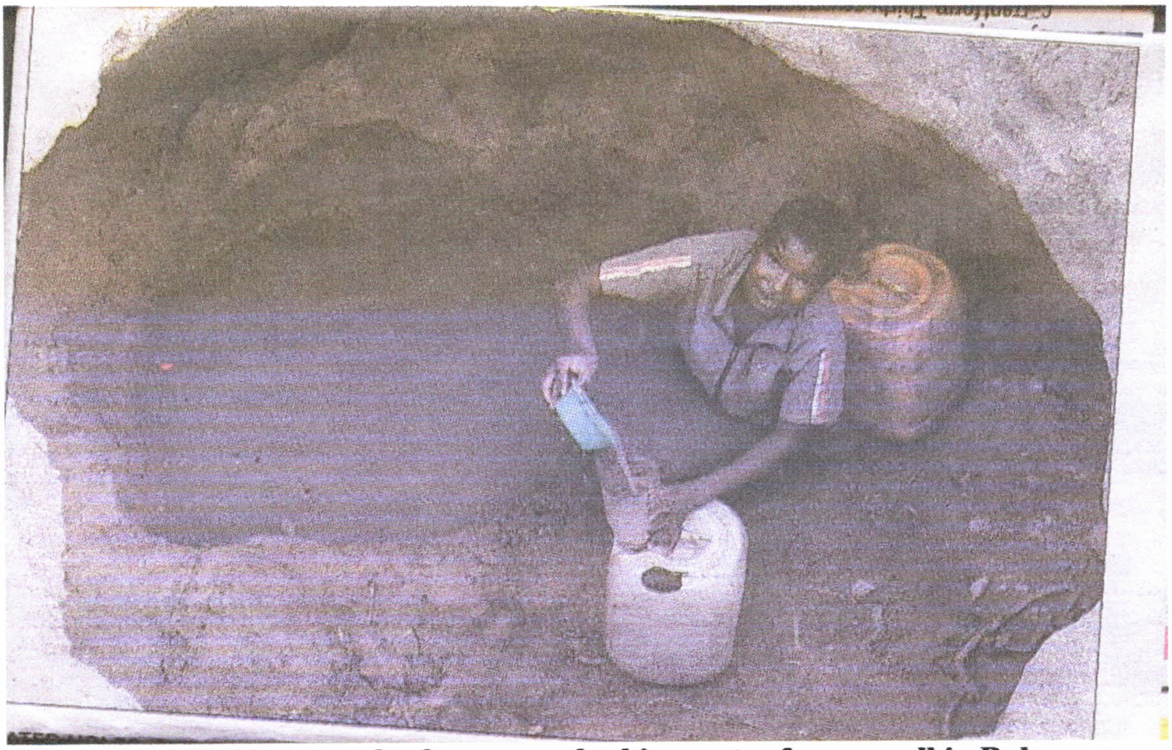


Figure 11: File Photograph of a woman fetching water from a well in Bulawayo, Zimbabwe

Source: DAILY NATION, November 5th, 2007

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 DISCUSSION

A recent study in Huruma; Nairobi, indicates that much of the drinking water in most urban residential areas is contaminated and not fit for consumption.[41]

The study concluded that water from standpipes as well as that stored in food kiosks was contaminated with high levels of disease causing organisms.

In this study carried out in Eldoret and Kitale Municipalities, bacteriological analysis of treated and untreated water, revealed a high level of contamination in untreated water (83.7%) compared to treated water (17.2%). These findings are similar to those of a study done to assess the bacteriological quality of groundwater supplies in Northern West Virginia (1987), which showed that out of 155 untreated water samples, 105 exceeded environmental Protection agency (EPA) Standard Maximum contamination levels of one total coliform per 100ml.

Water treatment through chlorination is therefore important in eliminating a broad spectrum of pathogenic organisms that contaminate water rendering it unsafe for consumption.[42]

A study to compare the different water sources in relation to bacterial contamination indicated that surface waters such as rivers and springs had the highest levels (100%) while deep wells had low levels and boreholes had none.

These findings were similar to those of a study in West Virginia which revealed that bacterial densities were related to the type of water supply, with drilled wells containing fewer faecal coliforms, total coliforms and faecal streptococci than dug wells or springs. Water supplies that were that were shallower, older and lacking adequate casing were characteristically more heavily contaminated with sanitary indicator bacteria than supplies that were deeper or of more recent construction and with sufficient casing. Bacteria find favourable conditions of temperature and oxygen at the surface. Another study carried out to assess the bacteriological quality of drinking water supplies in Kaffa administrative region, South West Ethiopia (1986) showed that the so-called protected wells were in undesirable sanitary conditions.

Bacteriological quality of the water was also found in unacceptable levels

(> 50 coliforms per 100ml of sample). The poor quality of water was thought to be responsible for the predominance of waterborne and related diseases observed in the region. A comparative study of bacterial contamination between treated and untreated water in Eldoret and Kitale municipalities showed 61.2% contamination in Kitale compared to 3.75% in Eldoret. Chi square test showed a significant statistical difference in bacterial contamination between treated and untreated water sources.
A survey of the surrounding environment and the analysis of views from the residents indicated that sewage disposal system in Kitale Municipality was rather inefficient, with many residents citing frequent leakages and delay in repair of burst pipes among others. This was the most probable reason for the high level of contamination of treated water especially where back siphoning occurred through burst pipes.

These findings were similar to those of a study done in Huruma: Nairobi which established that environmental sanitation was so poor that some of the sewers had burst emptying sewage into open drainage systems. Some of the standpipes were old and rusty and others were found to have rubber tubing around them to seal leakages from damaged areas. Worse still, the study found that some standpipes were being operated from within buildings but had some sections protruding outside for water collection as shown in figure 14.[41]

Similarly, in other Kenyan towns such as Nakuru, water and waste crises has hampered the towns' development. Studies indicate that many companies have relocated elsewhere due to inconsistent water supply. Most residents buy water from vendors at exorbitant prices. However, the source is suspect, possibly from illegal connections and some of the buildings are not connected to the main sewer.
A spot check at a sewerage treatment plant revealed that most of the machines have collapsed and the employees at the plant treat the sewage manually.

In Eldoret Municipality, bacterial contamination was detected in some primary school taps that were sited close to ablution blocks and pit latrines where pupils washed their hands after visiting the facilities. All the pupils also drank water from these taps with some drinking directly from the taps thus not only contaminating the taps but also posing a possible source of cross-infection of pathogenic organisms from one pupil to another. A similar study in the city of Merida, Mexico (1995) involving city tap water samples revealed significant levels in 21.7% of samples, with the highest being from sewage water and faecal sources. [45]

A study of the risk factors to bacterial contamination revealed that well ownership, depth of well / borehole, nearness to pit latrine, presence of protective platform, contact of collection vessels (rope and bucket) by the handler were major contributing factors. A similar study carried out in Ontario, USA (1998) examining the relationship between bacteriological quality of drinking water from private wells, revealed that at least 30% rural wells were faecally contaminated thus exceeding the current government standards for safe drinking water. There is evidence that the greater the number of handlers during water collection, the greater the level of contamination and vice versa. The depth of well or borehole was noted to have positive correlation to bacterial contamination with shallow wells being highly contaminated while those above 60ft with minimal contamination or none at all.[43]

This is due to the fact that water gets naturally filtered as it passes through the soil layers thus most of the organisms are trapped at shallow depths making deep underground waters such as boreholes free of bacterial contaminants.

Temperatures get naturally lower as depth increases and hence due to unfavorable conditions, few organisms survive.

In a study on Water quality analysis of Kargi wells, Northern Kenya (2002), Shivoga noted that the possible reason for high level of bacterial contamination was the very lukewarm temperatures of water due to residual volcanic influences, high mineral content and presence of toxic waste. It was speculated that the ambient conditions in old wells were conducive to the manufacture of H_2S, a potentially lethal compound produced by *Salmonella* microbes when oxygen conditions are low and free sulphur is abundant. Water quality in younger wells was seen to be better than older wells.[35]

5.2 Conclusions

1. Water treatment through chlorination is not 100% effective.
   Bacteriological testing and close surveillance at treatment plants and distribution system by water supply operators, is necessary to ensure that safe water is supplied to consumers.

2. Treated water can be contaminated by unhygienic handling of taps, collection vessels, burst pipes and leaking sewers and poor housing lacking appropriate sanitation facilities. These were identified as potential risk factors to bacterial contamination of treated water.

3. Untreated water especially river water is not fit for drinking and requires home-based treatment measures such as boiling to render it safe for consumption. This was indicated by 100% bacterial isolation in all the river and spring water samples.

4. The diversity of bacterial contaminants was highest in untreated water and included *Escherichia coli, Klebsiella pneumonia, Proteus vulgaris, Pseudomonas aeruginosa, Salmonella species* and *Streptococcus faecalis*.
   Faecal coliforms such as *E. coli* were the most abundant indicating recent faecal contamination of rivers, wells and some taps.

5. Risk factors that were found to have a significant positive influence in bacterial contamination of untreated water sources included depth of wells, absence of protective casing, distance from possible contaminating source and poor housing and sanitation conditions.

6. There was a significant difference in the level of contamination of treated water between Eldoret and Kitale Municipalities;

   $H_{0:}\ BC_{TWE} = BC_{TWK}$

   $H_{A:}\ BC_{TWE} \# BC_{TWK}$

   Where BC_{TWE} = Bacterial contamination of treated water in Eldoret Municipality

BC_{TWK} = Bacterial contamination of treated water in Kitale Municipality

X^2 calculated (39.639) > X^2 **critical value**, (34.119) at 1 df, ($p<0.05$)
Hence we **reject the H_O**, that there is no significant difference in bacteriological quality of treated water between Eldoret and Kitale Municipality.
We therefore **accept the H_A**, that there is a difference in bacteriological quality of treated water between Eldoret and Kitale Municipalities.

7. There was no significant difference in the level of contamination of untreated water in Eldoret and Kitale Municipalities.

$H_{0:}$ $BC_{UWE} = BC_{UWK}$
HA: BC_{UWE} # BC_{UWK}

Where BC_{UWE} =Bacterial contamination of untreated water in Eldoret Municipality
BC_{UWK}=Bacterial con tamination of untreated water in Kitale Municipality

X^2 calculated (3.741) = X^2 **critical value,** (3.766) at 1 df, ($p < 0.05$),
Hence, we do not reject the H_O that there is no significant difference in bacteriological quality between Eldoret and Kitale Municipalities.

5.3 Recommendations

1. Immediate investigation action must be taken whenever *E. coli* or total coliforms are detected in treated water supplies. The minimum action in case of total coliforms is repeat sampling, and if detected in the repeat sample the cause must be determined by immediate further investigation.

2. Although E. coli is a more precise indicator of faecal pollution, the count of thermo-tolerant coliforms is an acceptable alternative.

If necessary, proper confirmatory tests must be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated water supplies.

3. Water treatment and sanitation agencies must strive to improve the general quality of water and sewage disposal system. To obtain and maintain good quality water, an integration plan and work system between various government agencies is crucial.

4. Public health officers need to strengthen health education of rural folk on home-based treatment measures such boiling of drinking, as this is effective rendering water safe for drinking and eliminating water borne diseases.

5. Water collection methods that minimize handling of water collection vessels and contamination of water sources such as use of hand pumps, mortars and winds mills should be encouraged for residents that lack treated tap water.

6. It is recognized that in a great majority of rural water supplies in developing countries, faecal contamination is widespread. Under these conditions, national surveillance agency should set targets for progressive improvement of water supplies, as recommended in the WHO Guidelines for drinking water quality.

7. Public health officers in conjunction with those in charge of environmental conservation need to work closely to ensure that water catchment areas such as rivers and springs are protected. Settlements should not be too close to these sites and the recommended rules on protection of water sources should be strictly followed to the letter. Law enforcement officers should deal with those who do not comply with this regulation.

8. Government agencies and municipal authorities need to work together towards achieving the Millennium Development Goals of providing safe drinking water and sanitation to all. The Government of Kenya has reaffirmed the importance of

sound water resources management and has a vision of achieving sustainable development and management of the country's water resources by the year 2015. Policy makers need to unite and direct Constituency Development funds to improving water facilities in their areas of jurisdiction. Greater emphasis by all stakeholders must be put to ensuring adequate access to safe quality water, which is essential for a healthy nation as emphasized in the file photograph below.

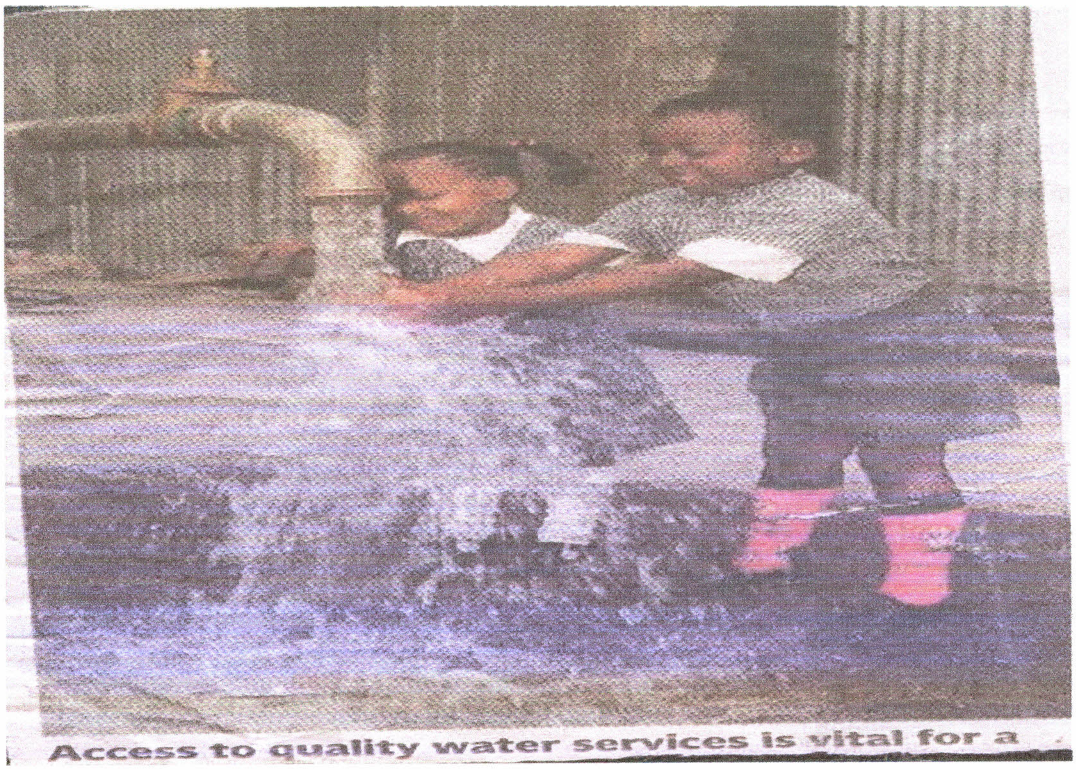


Figure 12: File Photograph of children ready to drink water from a school tap.

Source: DAILY NATION, March 21st, 2007

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APPENDICES

APPENDIX 1

QUESTIONNAIRE FOR RESIDENTS

A: General information

01. Name of Site______________________________

02. Name of location (estate, school, hospital, market etc) ________________

03. Name of Head of household, institution___________________________

04. Occupation ______________________________________

05. Number of members in household, school, institution________________

06. Level of education

    Primary ☐

    Secondary ☐

    University ☐

Source of water

(i) Piped water system

07. Name of water supplier. ____

08. Is the water treated Yes ☐ No. ☐

09. What is the source of this water _________________________________

10. How often do you get water raining in this town? ___________________

11. Do you have a sewerage system? Yes ☐ No ☐

12. Is the sewerage system efficient? Yes ☐ No ☐

13. If your answer to 12 is no, comment on your answer_________________

(ii) Ground water (well/ borehole)

14. What is the depth of your well/borehole? __________________________

15. It is at private or community project? _____________________________

16. Is the immediate vicinity free from any potentially polluting sources?

    Yes ☐ No ☐

17. What is the distance between the pit latrine and this water source?

    ____

18. Is the water raising system (bucket, rope) inaccessible to users?

    Yes ☐ No ☐

19. Does the water collected drain back into the well or borehole?

Yes ☐ No ☐

20. Is there any impermeable platform preventing any surface water into the well especially during the rains?

Yes ☐ No ☐

(iii) Surface water (river, stream, dam, and spring)

21. Is this water body seasonal?

Yes ☐ No ☐

22. Do you use the water from this water source for cooking, drinking?

Yes ☐ No ☐

23. What are you alternative services of water apart from this?

B: General questions

24. Is the water from this service adequate for your use throughout the year?

Yes ☐ No ☐

25. If your answer to 24 above is No, what is your alternative water source?

____

26. Do you consider your water safe for human consumption?

Yes ☐ No ☐

27. If you answer to 26 above is No, what other treatment measures do you apply to ensure that your water is safe for drinking?

28. Has any of the members in your household suffered any of the following ailments: Diarrhea, vomiting, typhoid?

Yes ☐ No ☐ Specify________________

29. Do you attribute any of these ailments to the water you consume?

Yes ☐ No ☐

Comment on you answer ______________________________________

____

30. What is your general rating of the quality of your water supply?

Poor ☐

Average ☐

Good ☐

Very good ☐

Excellent ☐

Consumer observations

31. Major complaints

(i) ____________________

(ii) ____________________

(iii) ____________________

(iv) ____________________

32. What suggestions can you make for future improvement of your water supply?

____

C: BACTERIOLOGICAL ANALYSIS

Name of site____________________

Location____________________

Sample No.____________________

Date____________________

Time____________________

1. **Culture on Endo agar at 37^0c**

No.	Morphology of bacteria	No. of colonies isolated
.		
TOTAL		

2. Culture on MacConkey agar at 44^{0}c

No.	Morphology of Bacteria	Number of colonies isolated
TOTAL		

3. Subculture of isolates on MacConkey agar at 37^0c

No.	Morphology of bacterial isolates	Number of colonies isolated
TOTAL		

4. Biochemical tests and identification of isolates

Morphology	Oxidase Test	Indole test	Methyl Red test	Citrate test	Urease test	TSI TEST	Identification of isolates	No.
TOTAL								

APPENDIX 2

QUESTIONNAIRE FOR WATER SUPPLY AGENCY

A. General information

01. Name of Locality

02. Name of water service

03. Owner (Private, municipality, public) ....

B. Population served by

04. House connections ....

Public fountains ....

05. Total number ....

C. Total water production

06. Daily average ....

07. Annual average ....

08. Unknown ....

D. Restriction in water supply during the past year:

09. Number of occasions ....

E. Process control laboratories

10. Are there facilities for microbiological analysis? ....

11. Are records of analysis and tests kept? ....

12. How often is bacteriological analysis done? ....

F. Disinfection

13. Is chlorination carried out continuously? ....

14. Is the chlorination equipment functioning correctly? ....

15. What is the contact time during chlorination? ....

16. Do you have sufficient chlorine or chlorine releasing substances in your store? ....

17. Do you have a mechanism of determining total or residual chlorine in treated water? ....

18. Are daily chlorination records kept? ....

Does the reservoir have an inspection manhole? ....

19. Is the inspection manhole protected by a cover and a lock? ....

20. Is rainwater prevented from entering the reservoir?

Distribution network.

23 Is the distribution system free from leaks? ....

24 Is pressure maintained continuously through the system? ....

25 Is the system free from back siphoning age problems? ....

Water supply operators

26 What is general profession level of the head of department (HOD)?

University ☐

Secondary ☐

Primary ☐

Others (specify) ______________________________

27. What is the level of training of the in-charge as regards to water treatment?

University ☐

Technical college ☐

Short course ☐

None ☐

28 How many years has the in-charge worked with water treatment?

29 What is the number of personnel currently employed? ....

30 Is the number of personnel adequate?

Yes ☐ No ☐

31. Is the quality of personnel currently employed adequate?

Yes ☐ No ☐

32 What is the adequate level of the head of laboratory section?

University ☐

Technical college ☐

Secondary ☐

Primary ☐

APPENDIX 3

SAMPLE COLLECTION FORM

Locality ....

Sample Site ....

Place of collection ....

Time ....

Depth ....

Temperature ....

Lab sample no. ....

TOTAL COLIFORMS ....

FAECAL COLIFORMS ....

Water bacteriologically GOOD ☐ BAD ☐

ACTION TAKEN...

....

....

....

Signature ....

Date ....

KENYATTA NATIONAL HOSPITAL
Hospital Rd. along, Ngong Rd.
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Email: **KNHplan@Ken.Healthnet.org**

Ref: KNH-ERC/01/3583

Date: 26th June, 2006

Salina Jeptoo Rono
Dept. Medical Microbiology
University of Nairobi

Dear Rono,

RESEARCH PROPOSAL:"BACTERIOLOGICAL QUALITY OF DRINKING WATER SUPPLIES A COMPARATIVE STUDY OF ELDORET AND KITALE MUNICIPALITIES " (P70/4/2006)

This is to inform you that the Kenyatta National Hospital Ethics and Research Committee has reviewed and **approved** revised version of your above cited research proposal for the period 26th June 2006 – 25th June, 2007

You will be required to request for a renewal of the approval if you intend to continue with the study beyond the deadline given.

On behalf of the Committee, I wish you fruitful research and look forward to receiving a summary of the research findings upon completion of the study.

This information will form part of database that will be consulted in future when processing related research study so as to minimize chances of study duplication.

Yours sincerely

PROF A N GUANTAI
SECRETARY, KNH-ERC

c.c. Prof. K.M.Bhatt, Chairperson, KNH-ERC
The Deputy Director CS, KNH
Supervisor: Prof Wamola, L.A.