

**A SURVEY OF DRINKING WATER QUALITY AND COMMUNITY
AWARENESS OF WATER RELATED HEALTH RISKS IN NYERI
TOWN, KENYA**

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

I dedicate this work to my family: My husband Charles and our children Josephine, Mary Ann, Michael, Veronica, Rita and Linda. You stood by me when the going was tough. Your support, encouragement and the fulfilment I get will always be cherished. I love you all. May The Almighty God bless and keep you well.

It's also dedicated to my parents Mr. Mathew Mwangi and Mrs. Mary Wambui Mwangi for the support, care and encouragement since childhood. I love you.

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ACRONYMS AND ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
ADI	Acceptable Daily Intake
AIDS	Acquired Immune Deficiency Syndrome
AOAC	Association of Analytical Chemists
ATSDR	Agency for Toxic Substances and Disease Registry
BTW	Bottled Water
CDC	Centre for Disease Control
CFU	Colony Forming Units
d-ALAD	d-aminolaevulinic acid dehydratase
DNA	Deoxyribonucleic Acid
FAAS	Flame atomic absorption spectrometry
FAO	Food Agricultural Organisation
FDA	Food and Drug Administration
Hb	Haemoglobin
HUS	Hemolytic-uremic syndrome
ICP	Inductive coupled plasma
IARC	International Agency for Research on Cancer
IAEA	International Atomic Energy Agency
IPCS	International Programme on Chemical Safety
ISO	International Organization for Standardization
JECFA	Joint FAO/WHO Expert Committee on Food Additives
KEBS	Kenya Bureau of Standards
metHB	Methaemoglobin
MS	mass spectrometry
pH	Hydrogen ions potentiometric
ppm	Parts Per Million
PMTDI	Provisional maximum tolerable daily intake
PTWI	Provisional tolerable weekly intake
PVC	Polyvinyl chloride
RFW	Rain Roof Water
RVW	River Water
SAS	Statistical analysis for science
SPADNS	Sulfo Phenyl Azo Dihydroxy Naphthalene Disulfonic Acid
SPSS	Statistical Package for Social Scientists
STW	Stream Water
TPC	Total Plate Count
TPW	Tapped Water
UN	United Nations

UNEP	United Nations Environment Programme
USA	United States of America
USEPA	United States Environmental Protection Agency
VRBGA	Violet-red Bile Glucose Agar
WHO	World Health Organisation
WRI	World Resource Institute

ABSTRACT

Poor accessibility to safe water is a major cause of morbidity and mortality in developing countries where mechanisms to monitor and enforce regulations for quality water are inadequate or lacking. The aim of this study is to determine the microbial and chemical quality of water in Nyeri Town and assess the health risks associated with the water used and the preferred water. Water supply system in Nyeri Town consists of Municipal piped water, natural river and stream water running down some parts of town, roof catchment water and commercially available bottled water. The Town was divided into five study regions (Upper Town, Lower Town, Ruringu, Kin'gon'go and Majengo) on the basis of the social-economic conditions and in terms of the source of water supply. Basic information was obtained through a pre-tested questionnaire administered to the relevant personnel at the municipal water and health departments. Randomly selected adult members of community in each of the five study regions were interviewed to assess the levels of awareness on the health risks associated with the local water supply. Quality and safety of water was assessed following WHO established methods for determining microbial and chemical concentrations in the water. Water samples collected from each water source in the five study regions and samples of different brands of commercially bottled water purchased from the local markets were subjected to laboratory tests in the university food and water laboratories. Study on the health risks in the drinking water was based on environmental sanitation conditions including open field excreta disposal and disinfection toilets; water quality and the occurrence of water related diseases.

Municipal piped water supply was widely distributed in all five regions and it was the most used source of drinking and the preferred water. It was least used in Ruringu (78%) whereas this was above 90% in other regions. Water from roof catchment was also commonly used in the region. Majengo recorded the highest rate (97%) but this was the preferred source by only 79% of the residents. Microbial concentration in the tap water was within the WHO limits but the river and stream water samples collected after the slum exceeded the recommended levels of *E. coli* concentration. Some brands of the commercially bottled water (20%) exceeded the WHO recommended Zero count of *E. coli*. Chemical concentration exceeded the KEBS and WHO standards for cadmium and iron. Fluoride was significantly high in the stream water. In regard to health risks in the drinking water, environmental contamination through poor excreta disposal especially by children was reported by 53% of respondents in Majengo and 45% in Ruringu, 39% in lower town, 37% in Upper Town and Kingongo. These were the same regions who reported significantly high occurrence of water related illnesses Majengo 60%, Lower Town 33%.

Municipal piped water was mostly used and preferred water in all regions. Though river water was used should be encouraged to use municipal water instead of river or stream water which were found to contain faecal contaminant bacteria. Microbial contamination observed in commercially bottled water shows the need to enforce and enhance KEBS regulations to the bottling companies.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Water is a vehicle for bacteria some of which are harmful to health. Water can also be a vehicle for other hazards that include chemicals and radiations that are environmental toxicants, all of which are harmful to human health. Access to safe water supply and basic sanitation is a fundamental need and a human right. It is vital for the dignity and health of all people. Lack of clean water and sanitation, leads to a wide range of potential diseases like diarrhoea, cholera, typhoid, malaria, yellow fever, filariasis, bilharzias, trachoma, scabies among others (WHO, 2003). Of importance, dirty water is often the cause of ordinary childhood diarrhoea, mainly due to poor sanitation and poor access to safe water. Over 80% of the households in Africa survive on less than US \$ 1 per day; hence buying water may not be visible. As a result, poor children in Africa are 10 times more likely to die before their 5th birthday, and 9 times more likely to die of water and sanitation related infectious diseases than children from richer families'. Disease pattern in East Africa hospitals indicate that 75% of the problems are water related (<http://www.amref.org>).

The microbiological quality of drinking water is of the highest priority and must never be compromised thus it should be free of all bacteria indicative of pollution (WHO, 2003). Provision of sufficient water is a critical intervention to enhance public health. Though quantity is important, quality remains top in attempt to provide people with potable water. Sufficient and quality water will therefore not only improve people's health but it will also have an economic impact in the community and country in general.

Chemical water poisoning of domestic water is another health hazard. For example, health problem associated with heavy metals contaminations related to long industrial discard were first highlighted in the industrially advanced countries especially in the, incidents of mercury and cadmium pollution in Sweden and Japan (Riemann and Bryan, 1979).

For these reasons water quality must be assured, by confirming the absence of microbial and environmental risks/hazards. In connection to this WHO has set guidelines for potable water for human/community consumption. Each country is expected to develop its standards for potable water to rule out hazards and assure population health.

The maintenance of water quality is best done by systematic surveillance which includes bacteriological and chemical analysis. In Kenya the systematic water surveillance system is lacking. Water availability to most communities in Kenya is not ascertained in terms of bacterial and chemical quality. Importance of systematic surveillance is to prevent water-borne disease outbreaks.

Community awareness is important in terms of assuring that the water is potable. If the communities are aware of the health risks associated with water, they can make the water potable and hence prevent diseases, disabilities and death from occurring. In Nyeri the community is mixed, urban and semi-rural with various types of water

supplies; tapped water, borehole water, stored rain water, river/spring water. Bottled water is stocked in local shops and supermarkets. Nyeri municipal water goes through treatment and testing at the treatment plant. Physical, chemical and biological parameters are tested before the water is released for consumption. River and stream water are not tested for those parameters and it is consumed as it is. Roof water is collected from the roof and stored in tanks for use as need be, and there are no tests done. Bottled water is supposed to be ascertained by Kenya Bureau of Standards (KEBS) before marketing, but the quality is never ascertained at the level of consumers.

1.2 Problem Statement

Water quality, personal hygiene and sanitation are very crucial in reducing water related diseases in populations (Wood, 2008 and WHO, 2006). Nyeri is a mixed set-up community with urban and semi-urban population using different types of water sources (tapped water, river and spring water, borehole water, stored rain water and bottled water). Apart from tapped municipal water which is controlled by the municipal council, and some of the bottled water by the KEBS, the others are not. Diarrhoea and gastroenteritis is number four in the top 10(ten) leading causes of outpatient morbidity in Kenya (2007). They are number four in top 20 (twenty) causes of mortality and number two for infants in Kenya. The same trend is seen in Nyeri town for adults while for infants respiratory diseases are number one. Personal hygiene, sanitation, and waste disposal largely contribute to safety of drinking water

and may also causes of diarrhoea diseases in adults, especially those with low immunity (children, elderly, pregnant women and immune compromised).

Cases of water-borne diseases are on the increase and hence there is need to put an end or control to this effect. Issues of quality control are scanty and hence there is need to delineate water quality control in terms of microbial and chemical aspects. When water related diseases occur it means the water available is not fit for human consumption. To some people, tapped water and other locally available waters are no longer safe and hence there is increased confidence in bottled waters. This has created ready market for bottled water and this puts the consumer at a risk of taking contaminated waters from the manufacturers who may opt not follow the set up standards.

Bottled water has its own economical implications notwithstanding and is accessible to only a small percentage in the community. Easy accessibility to stream and river water may make it more available especially to majority in the community. Enhancement of the safety of this water source is important for improvement of health of the people. It is therefore important to obtain the necessary data on quality of the water from these sources in the community.

In Kenya regulations on heavy metals concentrations and microbial levels in drinking waters have been established, but monitoring and enforcement of the regulations is not rigorous. Moreover the community leaves the responsibility of monitoring the quality and standards of water to the KEBS and other government

authorities. The result is that there is no ownership for the quality standards by the community and the levels of awareness about health risks associated with un-potable water may be low.

1.3 Justification

Water can be a major health hazard if proper hygiene/sanitation, manufacturing practices, storage and eventual consumption are not properly observed. Epidemics from water-borne diseases to food poisoning, food infection or even spoilage to the prepared food may occur through contamination of water. The numbers of cases of diarrhoea and other water-related diseases have shown an increase recently at Nyeri General Hospital and other health facilities in Nyeri Town. The cost of buying bottled water is an extra expense that can be avoided if quality of waters available locally is guaranteed. Some companies declare presence of certain nutrients which may not be present and hence there is need to establish if compliance is adhered to. Environmental contamination concern is raising fears to the community about safety of natural sources of water. There is a change of community behaviour in favour of bottled water. It is common for parents to package drinking water from home to school for children, but many others may prefer to buy commercially packed water. Working and travelling category find it convenient to purchase bottled water to carry on journey or to workplaces. Many people opt to buy bottled water other than use tap water or other locally available waters, which is free in belief of its safety. Determination of general quality of drinking waters and monitoring of standards are important for public health interventions to be put in place. Since drinking waters are

consumed by even the susceptible population: elderly, pregnant women and immune-compromised it should be safe.

Qualities of water consumed can be contaminated during the handling and the processing. This then calls for the community as well, to participate actively in maintaining quality water by good practical standards. Having the knowledge, good behaviour and the right attitude is necessary for maintaining safe water. The study also provided a base line data for future studies.

1.4 Objective

1.4.1 Main Objective

To determine the suitability of drinking waters and the levels of community awareness of health risks related to using unsafe water in Nyeri Town.

1.4.2 Specific Objectives

1. To identify the Preferred and Used Water.
2. To determine the health risk awareness of unsafe water among the community.
3. To determine the bacterial and chemical levels of drinking waters.

1.5 Hypothesis

Various water sources used by communities in Nyeri Town do not meet the recommended standards of water safety. The community is not aware of the quality and health risks associated with different types of drinking waters in Nyeri Town.

Bottled water may not be as presented in the bottle.

1.6 Research Questions

1. There are various sources of domestic water in Nyeri Town but which one is the source of choice to the larger community?
2. Water sources may present various health risks to the community. What is the level of health risks awareness of using unsafe water among the community in Nyeri town?
3. Are the different types of water sources bacteriologically and chemically safe for use in the community?

1.7 Significance of the Study

The study will inform policy makers about the quality and health risk of drinking waters available in the community. This will lead to advocacy for regular, rigorous tests and practices for better quality of drinking waters. Measures can be put in place to reduce the prevalence of water-borne diseases through drinking waters available to the community. The information will be useful to the consumers as informed choice of the drinking waters can be done. The findings of this study will also help the consumer to understand the quality of bottled water and other drinking waters in Nyeri town. This information will also be significant to the quality controllers and researchers in Nyeri town.

CHAPTER TWO: LITERATURE REVIEW

2.1 Water

Water is a vital necessity for life and for industrial development. For example human being needs a minimum of 20 litres per day. It is essential for blood and other liquid as well as cells of the body. To sustain life, a satisfactory quality and quantity supply of water must be available to all. On the other hand, water may be also be responsible for the spread of many diseases, (Stanfield *et al.*, 2005). According to the UN secretary general's address during the 5th session on commission on sustainable development, 1997, water availability continues to dwindle, with records of 2/3 of world's population experiencing periods of water stress. Apart from scarcity, pollution is affecting the quality of many surface and ground water resources. Other data indicates that despite safe water and sanitation being essential human needs (WRI *et al.*, 1996), 20% of the world's population still lacks access to safe water, 70% of the people living in developing countries notably Asia, Africa and Latin America do not have adequate sanitation. This record has stood since 1970's, the people most critically affected are the poor, particularly women and children, 10 million person years of effort are put into waste fetching water each year, 3.3 million death per year, mainly children under 5 years of age, are caused by water related diseases- i.e. water-borne, water washed, insect vector related or water-based diseases.

The suitability of water for drinking is now a matter of local, national and international concern. Provision of safe drinking water and sanitation for all, the reduction of water related diseases and greater food security all seem a pipe dream going by above statistics. There is need therefore to a certain sustainable management of water resources

in all uses; including both water quality and quantity aspects (Meybeck *et al.*, 1990). Microbiological examination of water samples is done to determine its portability. Bacteria found in water are mainly of three types: (a) the autochthonous (natural aquatic) bacteria; (b) soil-dwelling organisms and (c) organs that normally inhabit the intestines of human and other animals. Upstream of unpolluted rivers may have low counts as opposed to downstream of towns due to discharge of sewage and industrial effluents into the rivers (Harrigan, 1998). Water pollution results from sewage, industrial and agricultural runoff wastes. Combinations of biological, chemical and physical qualities are compromised reducing the wholesomeness of water (Afullo, 2006). Pollution control decisions and measures are not always rational. For instance to please an aroused but ill-informed public opinion, an institution or government may act in a way to please- just to be seen to be active- spending resources that may be better spent elsewhere. Increased awareness of possible dangers steaming from polluting a water body has encouraged the view that nothing should be discharged or dumped into it (Afullo, 2006).

Water can affect health in many ways: a) lack of personal hygiene may transmit illnesses known as water-washed diseases like diarrhoea, bacillary dysentery, skin diseases like scabies, eye diseases like trachoma. b) it may carry the organisms of specific conditions called water-borne diseases like typhoid, cholera, poliomyelitis, amoebiasis, hepatitis A. c) it may be necessary in the life cycle of a vector of water-related diseases such as malaria, schistosomiasis, onchocerciasis (river blindness), trypanosomiasis (sleeping sickness). In addition water can have less mineral elements and lead to deficiency diseases (goitre) or excess and lead to other diseases (fluorosis).

Water-washed diseases are transmitted by faecal-oral route due to lack of washing hands, eating utensils and vegetables, and lack of personal hygiene- washing the face, eyes and body. These can be prevented by washing as the main cause is lack of water. There may inadequate water because there is very little water available or because it has to be carried a long way, requiring time and energy.

To prevent an increase in water-washed diseases, the quantity of water need to be increased. The water-borne diseases are due to dirty water, contaminated with the organism causing the disease. To prevent an increase in water-borne diseases the quality of water needs to be improved. Quantity may be improved or available but quality may be poor, hence the need to ensure that a large quantity (Wood, 2008).

A holistic approach to drinking water supply risk assessment and risk management increases confidence in the safety of drinking water. This entails a systematic assessment of risks throughout a drinking water supply - from the catchment and its source water through to the consumer – to identification of the ways in which these risks can be managed, including methods to ensure that control measures are working effectively. It incorporates strategies to deal with day-to-day management of water quality, including upsets and failures, (WHO guidelines for drinking water, 2006).

Water should be free of tastes and odours that are objectionable to majority of consumers. In assessment of quality of drinking water, consumers rely on their senses.

Microbial, chemical and physical constituents may affect the appearance, odour and taste of the water and the consumer will evaluate the quality and acceptability of the water on the basis of these criteria. Though turbidity may not have direct health effects, highly coloured nor has an objectionable taste or odour may be regarded by consumer as unsafe and may be rejected. It is therefore important to be aware of consumer perceptions and to take into account both health-related and aesthetic criteria in assessing drinking water supplies and development of regulations and standards.

2.1.1 Bottled Water

Bottled water is defined as water that is sealed in food grade bottles and intended for human consumption (World Health Organisation (WHO) and Kenya Bureau of Standards (KS 05-459: PART 1: 1996). There are several types of bottled waters, depending on the source of the water. These types are split into two distinct groups:- mineral water and drinking water. Mineral waters are sometimes sparkling (carbonated) and are mainly used as an alternative to soft drinks or cocktails. Bottled drinking water is consumed as an alternative to tap water, and is also used for cooking. It is obtained from a variety of sources including springs, artesian wells, drilled wells and public water supplies. It is globally and internationally regulated as a “Food” by the Food and Drug Administration (FDA). Kenya Bureau of Standards is the local regulatory body in Kenya which is charge with the duty of ensuring that products manufacturers comply with the set standards.

Bottled water is perceived that it is healthier than other drinking waters. However in some countries bottled water may be no safer, or healthier, than tap water while it sells up to 1000 times more in price. The sales are increasing because people are worried about pollution and safety of municipal water. The attitudes towards tap water are being shaped by the pollution which is choking the rivers and streams (<http://www.usatoday.com>). The consumption of bottled water is becoming more and more popular in Kenya as can be seen in the market the number of companies manufacturing bottled water. Some consumers may have lost confidence in their tap water because of outbreaks of water borne diseases. Studies conducted by University of Geneva said that there is little difference between the bottled water and tap water. The difference between some bottled water and tap water is that it is distributed in bottles rather than pipes. While it is true that bottled water may be safer in areas where tap water may be contaminated, may be boiling or filtering tap water may be a better option for people on a lower income. Buying bottled water is not a long term sustainable solution to securing access to healthy water. Protecting rivers will help ensure that tap water remains a service which delivers good quality drinking water to everyone at a fair price. Plastic bottles release toxic chemicals which can pollute the environment during manufacture and disposal of bottles (<http://www.usatoday.com>)

Under Food and Drug Administration (FDA) manufacturers are responsible for producing safe, wholesome and truthfully labelled food products, including bottled water products. It is a violation of the law to introduce into market adulterated or misbranded products that violate the various provisions of the Act. The FDA has also

established regulations specifically for bottled water, including standard of identity regulations which define different types of bottled water, and standard of quality regulations, which set maximum levels of contaminants (chemical, physical, microbial and radiological) allowed in bottled water. FDA describes bottled water as water that is intended for human consumption and that is sealed in bottles or other containers with no added ingredients, except that it may contain a safe and suitable antimicrobial agent. Fluoride may be added within the limits set by the FDA.

Bottled water may be used as an ingredient in beverages, such as diluted juices or flavoured bottled waters. However, beverages labelled as containing “sparkling water”, “seltzer water”, “soda water”, “tonic water”, or “club soda” are not included as bottled water under the FDA’s regulations, because these beverages have historically been considered soft drinks. Some bottled water also comes from municipal sources—in other words—the tap. Municipal water is usually treated before it is bottled (www.fda.gov).

Under Kenya Bureau of Standards (KEBS) manufacturers are responsible for producing safe, wholesome and truthfully labelled food products, including bottled water products. It is a violation of the law to introduce into market adulterated or misbranded products that violate the various provisions of the Act. The KEBS has also established regulations specifically for bottled water, including standard of identity regulations which define different types of bottled water, and standard of quality regulations, which set maximum levels of contaminants (chemical, physical, microbial and radiological) allowed in bottled water. Bottled water may be used as an ingredient in beverages, such as diluted

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2.2 Water Related Diseases

Water can be a good vehicle of various forms of bacterial and parasitic diarrhoeal diseases associated with poor sanitation and hygiene. It is also associated with other waterborne diseases like malaria, schistosomiasis, trypanosomiasis, dracunculosis and onchocerciasis (Wood *et al.*, 2008). Diarrhoeal diseases are very common in Africa, with children at higher risk infection. Spread of diarrhoea is by the faecal-oral transmission route, by ingestion of contaminated food, water or by contaminated hands. Sparkling clear water may be dangerously polluted. For example, spring water may contain *Giardia lamblia* cysts from contamination upstream (Stanfield *et al.*, 2005). Assessment of public health hazards of water in terms of the presence of pathogens, and toxins and in conformity with the established and legal standards specifications are of paramount importance (Harrigan, 1998). Such requirements give criteria for acceptance or un-acceptance of water. Tolerance of contaminative given pathogen by human depends on: minimum dose required to cause infection and susceptibility of the individual consumer, the survival of the pathogen in the consumer body and storage of water before consumption.

2.2.1 Infections, Morbidity and Mortality

The incidence and prevalence of disease is determined from statistical analysis of illness and deaths. From these data a picture of the public health in a population can be obtained. The population might be total global population of humans or the population of a localised region, such as a city, state, or country. Worldwide infectious diseases are still major killers. Diarrhoea is among the five major killers and it has no vaccine available. In Africa infectious diseases account for 61% deaths as compared to 11% in America, where primary health care system is good. Lack of resources in developing regions limits access to health care, safe food and water, and effective immunisation programs (Madigan, *et al.*, 2003).

Infectious diseases are global health problems and the scope and focus of these problems are constantly changing. Some of the factors that contribute to changes are (1) human demographic behaviour; (2) economic development and land use; (3) technology and industry; (4) international travel and commerce; (5) microbiological adaptation and change; (6) breakdown of public health measures; and (7) abnormal natural occurrences that upset the usual host-pathogen balance. Such changes may affect natural water conditions rendering it more favourable for transmission of water related diseases (Nordberg *et al.*, 1999).

2.3 Contaminants

2.3.1 Chemical Contaminants

Chemical contaminants are hazardous mainly not from a single exposure, but prolonged periods of exposure. In most cases, water becomes undrinkable due to unacceptable taste, odour and appearance. Chemical contaminants will include those that are of

importance and those that are very harmful even in small quantities and cause diarrhoea. Heavy metals include lead, cadmium, chromium, manganese, zinc, copper, mercury among others. They have serious health hazards resulting directly from their cumulative effects. They have a tendency of being deposited on surfaces of some soft and bone tissues and organs such as liver, kidney, lungs and heart. Some cross the blood-brain barrier and cause some levels of madness and coordination, hence associated with nervous disorders. Thus the mad-hatters' disease associated with lead poisoning of painters and mercury poisoning of Napoleon the great resulted from this. The madness exhibited by 'matatu' (minibus) conductors and touts in Kenya and Zambian bus stages/ranks is attributable to their heavy and regular exposure to lead from the leaded petrol that their vehicles use (Afullo, 2006).

2.3.1.1 Iron

Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/litre. Iron may also be present in drinking-water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50mg/day. As a precaution against storage in the body of excessive iron, in 1983 JECFA established a PMTDI of 0.8 mg/kg of body weight, which applies to iron from all sources except for iron oxides used as colouring agents and iron supplements taken during pregnancy and lactation or for specific clinical requirements. An allocation of 10% of this PMTDI to drinking-water gives a value of about 2 mg/litre, which does not present a hazard to health. The taste

and appearance of drinking-water will usually be affected below this level. No guideline value for iron in drinking-water is proposed. The 1958 WHO *International Standards for Drinking-water* suggested that concentrations of iron greater than 1.0 mg/litre would markedly impair the potability of the water. The 1963 and 1971 International Standards retained this value as a maximum allowable or permissible concentration. In the first edition of the *Guidelines for Drinking-water Quality*, published in 1984, a guideline value of 0.3 mg/litre was established, as a compromise between iron's use in water treatment and aesthetic considerations. No health-based guideline value for iron in drinking-water was proposed in the 1993 Guidelines, but it was mentioned that a value of about 2mg/litre can be derived from the PMTDI established in 1983 by JECFA as a precaution against storage in the body of excessive iron. Iron stains laundry and plumbing fixtures at levels above 0.3 mg/litre; there is usually no noticeable taste at iron concentrations below 0.3 mg/litre, and concentrations of 1–3 mg/litre can be acceptable for people drinking anaerobic well water.

2.3.1.2 Lead

Lead is the commonest of the heavy elements, accounting for 13 mg/kg of the earth's crust. Several stable isotopes of lead exist in nature, including, in order of abundance, ^{208}Pb , ^{206}Pb , ^{207}Pb , and ^{204}Pb . It is a soft metal with a melting point of 327 °C (WHO, 2003). Lead is used in the production of lead acid batteries, solder, alloys, cable sheathing, pigments, rust inhibitors, ammunition, glazes, and plastic stabilizers (WHO, 1989). Tetraethyl and tetramethyl lead are important because of their extensive use as antiknock compounds in petrol, but their use for this purpose has been almost completely phased out in North America and Western Europe, though not in Eastern

Europe or many developing countries including Kenya (WHO, 2003). From a drinking-water perspective, the almost universal use of lead compounds in plumbing fittings and as solder in water-distribution systems is important. Lead pipes may be used in older distribution systems and plumbing (Quinn and Sherlock, 1990). Atomic absorption spectrometry and anodic stripping voltammetry are the methods most frequently used for determining the levels of lead in environmental and biological materials. Detection limits of less than 1 µg/litre can be achieved by means of atomic absorption spectrometry (ISO, 1986).

With the decline in atmospheric emissions of lead since the introduction of legislation restricting its use in fuels, water has assumed new importance as the largest controllable source of lead exposure in the USA (Levin *et al.*, 1989). Lead is present in tap water to some extent as a result of its dissolution from natural sources but primarily from household plumbing systems in which the pipes solder, fittings, or service connections to homes contain lead. PVC pipes also contain lead compounds that can be leached from them and result in high lead concentrations in drinking-water. The amount of lead dissolved from the plumbing system depends on several factors, including the presence of chloride and dissolved oxygen, pH, temperature, water softness, and standing time of the water, soft, acidic water being the most plumbosolvent (Schock, 1989; 1990). Although lead can be leached from lead piping indefinitely, it appears that the leaching of lead from soldered joints and brass taps decreases with time (Levin *et al.*, 1989). Prepared food contains small but significant amounts of lead. Lead content is increased when the water used for cooking or the cooking utensils contain lead, or the food,

especially if acidic, has been stored in lead-ceramic pottery ware or lead-soldered cans (Quinn and Sherlock, 1990; Galal-Gorchev, 1991).

Lead is a cumulative general poison, infants, children up to 6 years of age, the foetus, and pregnant women being the most susceptible to adverse health effects. Its effects on the central nervous system can be particularly serious (WHO, 2003). Overt signs of acute intoxication include dullness, restlessness, irritability, poor attention span, headaches, muscle tremor, abdominal cramps, kidney damage, hallucinations, and loss of memory, encephalopathy occurring at blood lead levels of 100–120 $\mu\text{g}/\text{dl}$ in adults and 80–100 $\mu\text{g}/\text{dl}$ in children. Signs of chronic lead toxicity, including tiredness, sleeplessness, irritability, headaches, joint pain, and gastrointestinal symptoms, may appear in adults at blood lead levels of 50–80 $\mu\text{g}/\text{dl}$. After 1–2 years of exposure, muscle weakness, gastrointestinal symptoms, lower scores on psychometric tests, disturbances in mood, and symptoms of peripheral neuropathy were observed in occupationally exposed populations at blood lead levels of 40–60 $\mu\text{g}/\text{dl}$ (USEPA, 1986). Lead interferes with the activity of several of the major enzymes involved in the biosynthesis of haem (USEPA, 1986). The only clinically well-defined symptom associated with the inhibition of haem biosynthesis is anaemia (Moore, 1988), which occurs only at blood lead levels in excess of 40 $\mu\text{g}/\text{dl}$ in children and 50 $\mu\text{g}/\text{dl}$ in adults (FAO, 1987). Lead-induced anaemia is the result of two separate processes: the inhibition of haem synthesis and an acceleration of erythrocyte destruction (Moore, 1988). Enzymes involved in the synthesis of haem include d-aminolaevulinate synthetase (whose activity is indirectly induced by feedback inhibition, resulting in accumulation of daminolaevulinate, a

neurotoxin) and d-aminolaevulinic acid dehydratase (d-ALAD), coproporphyrinogen oxidase, and ferrochelatase, all of whose activities are inhibited (USEPA 1986; Moore, 1988). Reproductive dysfunction may also occur in females occupationally exposed to lead (USEPA, 1986; IARC, 1980).

In 1986, JECFA established a provisional tolerable weekly intake (PTWI) of 25 µg of lead per kg of body weight (equivalent to 3.5 µg/kg of body weight per day) for infants and children (FAO, 1987). This PTWI was reconfirmed by JECFA in 1993 and extended to all age groups (WHO, 1993). On the assumption of a 50% allocation to drinking-water for a 5-kg bottle-fed infant consuming 0.75 litres of drinking-water per day, the guideline value is 0.01 mg/litre (WHO, 2003). As infants are considered to be the most sensitive subgroup of the population, this guideline value will also be protective for other age groups.

2.3.1.3 Cadmium

Cadmium is a metal with an oxidation state of +2. It is chemically similar to zinc and it occurs naturally with zinc and lead in sulphide ores. Cadmium metal is used mainly as an anticorrosive, electroplated onto steel. Cadmium sulphide and selenide are commonly used as pigments in plastics. Cadmium compounds are used in electric batteries, electronic components and nuclear reactors (Friberg *et al.*, 1986; Ros & Slooff, 1987). Fertilizers produced from phosphate ores constitute a major source of diffuse cadmium pollution. The solubility of cadmium in water is influenced to a large degree by its acidity; suspended or sediment-bound cadmium may dissolve when there is an increase in acidity (Ros & Slooff, 1987). In natural waters, cadmium is found mainly in bottom

sediments and suspended particles (Friberg *et al.*, 1986). Cadmium can be determined by atomic absorption spectroscopy using either direct aspiration into a flame or a furnace spectrometric technique. The detection limit is 5 µg/litre with the flame method and 0.1 µg/litre with the furnace procedure (ISO, 1985, 1986; Ware, 1989).

Cadmium concentrations in unpolluted natural waters are usually below 1 µg/litre (Friberg *et al.*, 1986). Median concentrations of dissolved cadmium measured at 110 stations around the world were <1 µg/litre, the maximum value recorded being 100 µg/litre in the Rio Rimao in Peru (WHO/UNEP, 1989). Average levels in the Rhine and Danube in 1988 were 0.1 µg/litre (range 0.02–0.3 µg/litre) (ARW, 1988) and 0.025 µg/litre (AWBR, 1988), respectively. In the sediments near Rotterdam harbour, levels in mud ranged from 1 to 10 mg/kg dry weight in 1985–1986, down from 5–19 mg/kg dry weight in 1981 (Ros & Slooff, 1987). Contamination of drinking-water may occur as a result of the presence of cadmium as an impurity in the zinc of galvanized pipes or cadmium-containing solders in fittings, water heaters, water coolers and taps. Drinking-water from shallow wells of areas in Sweden where the soil had been acidified contained concentrations of cadmium approaching 5 µg/litre (Friberg *et al.*, 1986). In Saudi Arabia, mean concentrations of 1–26 µg/litre were found in samples of potable water, some of which were taken from private wells or cold corroded pipes (Mustafa *et al.*, 1988). Levels of cadmium could be higher in areas supplied with soft water of low pH, as this would tend to be more corrosive in plumbing systems containing cadmium. In the Netherlands, in a survey of 256 drinking-water plants in 1982, cadmium (0.1–0.2 µg/litre) was detected in only 1% of the drinking-water samples (Ros & Slooff, 1987).

A number of new studies of cadmium exposure and health impact in human populations have been carried out and reviewed by Jarup *et al.* (1998). These include studies of kidney dysfunction and osteoporosis. Some data indicate that adverse effects may occur at lower exposures than was previously thought. Although these data indicate that a proportion of the general population may be at increased risk for tubular dysfunction when exposed to cadmium at the PTWI, the risk estimates that can be made with current information are imprecise. JECFA (2000a, b) considered all of the new data but decided that, in view of the uncertainties, the existing PTWI of 7 µg/kg of body weight should be retained. A guideline value for cadmium of 0.003 mg/litre is retained, based on an allocation of 10% of the PTWI to drinking-water.

2.3.1.4 Fluoride

Fluoride accounts for about 0.3 g/kg of the Earth's crust and exists in the form of fluorides in a number of minerals. The most important source of fluoride in drinking water is naturally occurring. Inorganic fluoride-containing minerals are used widely in industry for a wide range of purposes, including aluminium production. Fluorides can be released to the environment from the phosphate-containing rock used to produce phosphate fertilizers; these phosphate deposits contain about 4% fluorine. Fluorosilicic acid, sodium hexafluorosilicate and sodium fluoride are used in municipal water fluoridation schemes. Daily exposure to fluoride depends mainly on the geographical area. In most circumstances, food seems to be the primary source of fluoride intake, with lesser contributions from drinking-water and from toothpaste. In areas with relatively high concentrations, particularly in groundwater, drinking-water becomes increasingly

important as a source of fluoride. Intakes in areas where high fluoride coal is used indoors may also be significant. Guideline value is 1.5 mg/litre.

In groundwater, concentrations vary with the type of rock the water flows through but do not usually exceed 10 mg/litre; the highest natural level reported is 2800 mg/litre. Basis of guideline Epidemiological evidence that concentrations above this value carry derivation an increasing risk of dental fluorosis, and progressively higher concentrations lead to increasing risks of skeletal fluorosis. The value is higher than that recommended for artificial fluoridation of water supplies, which is usually 0.5–1.0 mg/litre. Limit of detection 0.01 mg/litre by ion chromatography; 0.1 mg/litre by ion- selective electrodes or the SPADNS (sulfo phenyl azo dihydroxy naphthalene disulfonic acid) colorimetric method. Treatment achievability of 1 mg/litre should be achievable using activated alumina (not a “conventional” treatment process, but relatively simple to install filters).

Many epidemiological studies of possible adverse effects of the long-term ingestion of fluoride via drinking-water have been carried out. These studies clearly establish that fluoride primarily produces effects on skeletal tissues (bones and teeth). In many regions with high fluoride exposure, fluoride is a significant cause of morbidity. Low concentrations provide protection against dental caries, especially in children. The pre- and post-eruptive protective effects of fluoride (involving the incorporation of fluoride into the matrix of the tooth during its formation, the development of shallower tooth grooves, which are consequently less prone to decay, and surface contact with enamel) increase with fluoride concentration up to about 2mg/litre of drinking water; the

minimum concentration of fluoride in drinking-water required to produce it is approximately 0.5 mg/litre. However, fluoride can also have an adverse effect on tooth enamel and may give rise to mild dental fluorosis at drinking-water concentrations between 0.9 and 1.2 mg/litre, depending on intake. Elevated fluoride intakes can also have more serious effects on skeletal tissues. It has been concluded that there is a clear excess risk of adverse skeletal effects for a total intake of 14mg/day and suggestive evidence of an increased risk of effects on the skeleton at total fluoride intakes above about 6mg/day.

The 1958 and 1963 WHO *International Standards for Drinking-water* referred to fluoride, stating that concentrations in drinking-water in excess of 1.0–1.5 mg of fluorine per litre may give rise to dental fluorosis in some children, and much higher concentrations may eventually result in skeletal damage in both children and adults. To prevent the development of dental caries in children, a number of communal water supplies are fluoridated to bring the fluorine concentration to 1.0mg/litre. The 1971 *International Standards* recommended control limits for fluorides in drinking-water for various ranges of the annual average of maximum daily air temperatures; control limits ranged from 0.6–0.8 mg/litre for temperatures of 26.3–32.6 °C to 0.9–1.7 mg/litre for temperatures of 10–12 °C. In the first edition of the *Guidelines for Drinking water Quality*, published in 1984, a guideline value of 1.5 mg/litre was established for fluoride, as mottling of teeth has been reported very occasionally at higher levels. It was also noted that local application of the guideline value must take into account climatic conditions and higher levels of water intake. The 1993 *Guidelines* concluded that there

was no evidence to suggest that the guideline value of 1.5 mg/litre set in 1984 needed to be revised. It was also recognized that in areas with high natural fluoride levels, the guideline value may be difficult to achieve in some circumstances with the treatment technology available. It was also emphasized that in setting national standards for fluoride, it is particularly important to consider climatic conditions, volume of water intake and intake of fluoride from other sources.

2.3.1.5 Nitrates

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrate is used mainly in inorganic fertilizers, and sodium nitrite is used as a food preservative, especially in cured meats. The nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of leaching or runoff from agricultural land or contamination from human or animal wastes as a consequence of the oxidation of ammonia and similar sources. Anaerobic conditions may result in the formation and persistence of nitrite. Chloramination may give rise to the formation of nitrite within the distribution system if the formation of chloramine is not sufficiently controlled. The formation of nitrite is as a consequence of microbial activity and may be intermittent. Nitrification in distribution systems can increase nitrite levels, usually by 0.2–1.5 mg/litre.

Guideline value for 50 mg/litre to protect against methaemoglobinaemia in bottle-fed nitrate infants (short-term exposure) Guideline value is 3 mg/litre for methaemoglobinaemia in infants (short-term Provisional guideline exposure) value for nitrite is 0.2 mg/litre (provisional) (long-term exposure). The guideline value for chronic effects of nitrite is considered provisional owing to uncertainty surrounding the

relevance of the observed adverse health effects for humans and the susceptibility of humans compared with animals. The occurrence of nitrite in distribution as a consequence of chloramine use will be intermittent, and average exposures over time should not exceed the provisional guideline value. Occurrence In most countries, nitrate levels in drinking-water derived from surface water do not exceed 10 mg/litre, although nitrate levels in well water often exceed 50 mg/litre; nitrite levels are normally lower, less than a few milligrams per litre.

The primary health concern regarding nitrate and nitrite is the formation of methaemoglobinaemia, so-called “blue-baby syndrome.” Nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidize haemoglobin (Hb) to methaemoglobin (metHb), which is unable to transport oxygen around the body. The reduced oxygen transport becomes clinically manifest when metHb concentrations reach 10% or more of normal Hb concentrations; the condition, called methaemoglobinaemia, causes cyanosis and, at higher concentrations, asphyxia. The normal metHb level in infants under 3 months of age is less than 3%. The Hb of young infants is more susceptible to metHb formation than that of older children and adults; this is believed to be the result of the large proportion of fetal Hb, which is more easily oxidized to metHb, still present in the blood of infants. In addition, there is a deficiency in infants of metHb reductase, the enzyme responsible for the reduction of metHb to Hb. The reduction of nitrate to nitrite by gastric bacteria is also higher in infants because of low gastric acidity. The level of nitrate in breast milk is relatively low; when bottle-fed; however, these young infants are at risk because of the potential for exposure to nitrate/nitrite in

drinking-water and the relatively high intake of water in relation to body weight. The higher reduction of nitrate to nitrite in young infants is not very well quantified, but it appears that gastrointestinal infections exacerbate the conversion from nitrate to nitrite. The weight of evidence is strongly against there being an association between nitrite and nitrate exposure in humans and the risk of cancer.

Studies with nitrite in laboratory rats have reported hypertrophy of the adrenal zone glomerulosa. The mechanism of induction of this effect and whether it occurs in other species is unclear. JECFA developed an ADI of 5 mg of potassium nitrite per kg of body weight based on the NOAEL in these studies. The 1958 WHO *International Standards for Drinking-water* referred to nitrates, stating that the ingestion of water containing nitrates in excess of 50–100 mg/litre may give rise to methaemoglobinaemia in infants under 1 year of age. In the 1963 International Standards, this value was lowered to 45 mg/litre, which was retained in the 1971 International Standards. The 1971 International Standards first mentioned concern over the possibility of nitrosamine formation *in vivo*; as nitrosamines are a possible hazard to human health, the 1971 Standards stated that it may eventually become necessary to reduce the level of nitrates in water if it is found that this source makes a significant contribution to the hazard to human health arising from nitrosamines. In the first edition of the *Guidelines for Drinking-water Quality*, published in 1984, a guideline value of 10 mg/litre for nitrate-nitrogen was recommended. It was also recommended that the guideline value for nitrite must be correspondingly lower than that for nitrate, and it was noted that the nitrite-nitrogen level should be considerably lower than 1 mg/litre where drinking-water is correctly

treated. The 1993 Guidelines concluded that extensive epidemiological data support the current guideline value for nitrate-nitrogen of 10 mg/litre, but stated that this value should be expressed not on the basis of nitrate-nitrogen but on the basis of nitrate itself, which is the chemical entity of concern to health. The guideline value for nitrate is therefore 50 mg/litre. This guideline value for methaemoglobinaemia in infants, an acute effect, was confirmed in the addendum to the Guidelines, published in 1998. It was also concluded in the 1993 Guidelines that a guideline value for nitrite should be proposed, although no suitable animal studies of methaemoglobinaemia were available. A provisional guideline value for nitrite of 3 mg/litre was therefore proposed by accepting a relative potency for nitrite and nitrate with respect to methaemoglobin formation of 10:1 (on a molar basis). In the addendum to the Guidelines, published in 1998, it was concluded that human data on nitrite reviewed by JECFA supported the current provisional guideline value of 3mg/litre, based on induction of methaemoglobinaemia in infants. In addition, a guideline value of 0.2 mg/litre for nitrate ion associated with long-term exposure was derived in the addendum to the Guidelines, based on JECFA's ADI derived in 1995. However, because of the uncertainty surrounding the relevance of the observed adverse health effects for humans and the susceptibility of humans compared with animals, this guideline value was considered provisional. Because of the possibility of simultaneous occurrence of nitrite and nitrate in drinking-water, it was recommended in the 1993 and 1998 Guidelines that the sum of the ratios of the concentration of each to its guideline value should not exceed 1.

2.3.1.6 PH

No health-based guideline value is proposed for pH. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters, the optimum pH required being in the range of 6.5-9.5. The 1958 WHO *International Standards for Drinking-water* suggested that pH less than 6.5 or greater than 9.2 would markedly impair the potability of the water. The 1963 and 1971 International Standards retained the pH range 6.5–9.2 as the allowable or permissible range. In the first edition of the *Guidelines for Drinking-water Quality*, published in 1984, a guideline value pH range of 6.5–8.5 was established for pH, based on aesthetic considerations. It was noted that the acceptable range of pH may be broader in the absence of a distribution system. No health-based guideline value was proposed for pH in the 1993 guidelines. The pH of water in distribution system must be controlled to minimise the corrosion of water mains and pipes in the household water system.

2.3.1.7 Copper

Copper is both an essential nutrient and a drinking-water contaminant. It has many commercial uses. It is used to make pipes, valves and fittings and is present in alloys and coatings. Copper sulphate pent hydrate is sometimes added to surface water for the control of algae. Copper concentrations in drinking-water vary widely, with the primary source most often being the corrosion of interior copper plumbing. Levels in running or fully flushed water tend to be low, whereas those in standing or partially flushed water samples are more variable and can be substantially higher (frequently > 1mg/litre). Copper concentrations in treated water often increase during distribution, especially in systems with an acid pH or high-carbonate waters with an alkaline pH. Food and water are the primary sources of copper exposure in developed countries. Consumption of

standing or partially flushed water from a distribution system that includes copper pipes or fittings can considerably increase total daily copper exposure, especially for infants fed formula reconstituted with tap water.

Guideline value for WHO is 2 mg/litre while the occurrence concentrations in drinking-water range from 0.005 to >30 mg/litre, primarily as a result of the corrosion of interior copper plumbing. Basis of guideline to be protective against acute gastrointestinal effects of copper and derivation provide an adequate margin of safety in populations with normal copper homeostasis. Limit of detection 0.02–0.1 mg/litre by ICP/MS; 0.3 mg/litre by ICP/optical emission spectroscopy; 0.5 mg/litre by FAAS. Copper is not removed by conventional treatment processes. However, copper is not normally a raw water contaminant. For adults with normal copper homeostasis, the guideline value should permit consumption of 2 or 3 litres of water per day, use of a nutritional supplement and copper from foods without exceeding the tolerable upper intake level of 10 mg/day or eliciting an adverse gastrointestinal response. At levels above 2.5 mg/litre, copper imparts an undesirable bitter taste to water; at higher levels, the colour of water is also impacted. In most instances where copper tubing is used as a plumbing material, concentrations of copper will be below the guideline value. However, there are some conditions, such as highly acidic or aggressive waters, that will give rise to much higher copper concentrations, and the use of copper tubing may not be appropriate in such circumstances.

IPCS concluded that the upper limit of the acceptable range of oral intake in adults is uncertain but is most likely in the range of several (more than 2 or 3) but not many milligrams per day in adults. This evaluation was based solely on studies of gastrointestinal effects of copper-contaminated drinking-water. The available data on toxicity in animals were not considered helpful in establishing the upper limit of the acceptable range of oral intake due to uncertainty about an appropriate model for humans, but they help to establish a mode of action for the response. The data on the gastrointestinal effects of copper must be used with caution, since the effects observed are influenced by the concentration of ingested copper to a greater extent than the total mass or dose ingested in a 24-h period. Recent studies have delineated the threshold for the effects of copper in drinking-water on the gastrointestinal tract, but there is still some uncertainty regarding the long-term effects of copper on sensitive populations, such as carriers of the gene for Wilson disease and other metabolic disorders of copper homeostasis.

The 1958 WHO *International Standards for Drinking-water* suggested that concentrations of copper greater than 1.5 mg/litre would markedly impair the potability of the water. The 1963 and 1971 International Standards retained this value as a maximum allowable or permissible concentration. In the first edition of the *Guidelines for Drinking-water Quality*, published in 1984, a guideline value of 1.0 mg/litre was established for copper, based on its laundry and other staining properties. The 1993 Guidelines derived a provisional health-based guideline value of 2mg/litre for copper from the PMTDI proposed by JECFA, based on a rather old study in dogs that did not

take into account differences in copper metabolism between infants and adults. The guideline value was considered provisional because of the uncertainties regarding copper toxicity in humans. This guideline value was retained in the addendum to the Guidelines published in 1998 and remained provisional as a result of uncertainties in the dose–response relationship between copper in drinking-water and acute gastrointestinal effects in humans. It was stressed that the outcome of epidemiological studies in progress in Chile, Sweden and the USA may permit more accurate quantification of effect levels for copper-induced toxicity in humans, including sensitive subpopulations. Copper can also give rise to taste problems at concentrations above 5mg/litre.

2.3.2 Microbial Contaminants

Drinking water shall be free from any pathogenic organisms and it shall comply with the microbiological limits. Contaminated water with human/animal excreta can be a source of pathogenic bacteria, viruses, protozoa and helminths. By the time microbial contaminants is detected many people may have been exposed. Hence reliance cannot be placed solely on end-product testing even when the tests are performed frequently to ensure microbial safety of drinking water. A systematic assessment is necessary in order to determine potential hazards that can affect the water system, identify control measures needed to reduce or eliminate such hazards. Operational monitoring system is also needed to ensure that barriers within the system are functioning and also to develop a management plan to determine actions taken under both normal and incident conditions, (WHO guidelines for drinking water, 2006).

2.3.2.1 Coliforms

They are indicator organisms and their presence signals that a given water source is contaminated with pathogens. They commonly inhabit the intestinal tract of humans and other animals. Their presence in water makes the water unsafe for human consumption. When excreted into water they eventually die, but not as quickly as some pathogens. The *coli* forms and the pathogens behave similarly during water purification, (Madigan *et al.*, 2003). Coliforms are not themselves pathogenic under normal conditions, but some strains cause diarrhoea. The coliform test procedures are commonly used to test for coliforms in water samples. The most-probable number (MPN) procedure and membrane filter (MF) procedure are commonly used. In well regulated water supply systems, coliform test should be negative. If the test is positive, a breakdown in the system has occurred in purification procedures or distribution systems (Madigan *et al.*, 2003.)

2.3.2.2 Escherichia coli

Escherichia coli, commonly referred to as *E. coli*; is named after its discoverer, is a Gram negative bacterium that is commonly found in the lower intestine of warm-blooded organisms (endotherms). Most *E. coli* strains are harmless, but some, such as serotype O157:H7, can cause serious food poisoning in humans and are occasionally responsible for costly product recalls (CDC, 2007; Vogt and Dippold, 2005). The harmless strains are part of the normal flora of the gut, and can benefit their hosts by producing vitamin K₂, (Bentley and Meganathan, 1992) or by preventing the establishment of pathogenic bacteria within the intestine (Hudault *et al.*, 2001). *E. coli* are not always confined to the intestine, and their ability to survive for brief periods

outside the body makes them an ideal indicator organism to test for faecal contamination of water in the environment (Feng *et al.*, 2007).

Certain strains of *E. coli*, such as O157:H7, O121 and O104:H21, produce toxins. Food poisoning caused by *E. coli* is usually associated with eating unwashed vegetables and meat contaminated post-slaughter. O157:H7 is further notorious for causing serious and even life-threatening complications like hemolytic-uremic syndrome (HUS). This particular strain is linked to the 2006 United States *E. coli* outbreak of fresh spinach. Severity of the illness varies considerably; it can be fatal, particularly in young children, the elderly or the immune-compromised. The infection is more often mild than severe in most cases. *Escherichia coli* can harbour both heat-stable and heat-labile enterotoxins. The latter, termed LT, contains one 'A' subunit and five 'B' subunits arranged into one holotoxin, and is highly similar in structure and function to Cholera toxins. The B subunits assist in adherence and entry of the toxin into host intestinal cells, while the A subunit is cleaved and prevents cells from absorbing water, causing diarrhoea. LT is secreted by the Type 2 secretion pathway (Wong *et al.*, 2000).

Transmission of pathogenic *E. coli* often occurs via faecal-oral transmission (Heaton and Jones, 2008). Common routes of transmission include: unhygienic food preparation (Sabin, 2006), farm contamination due to manure fertilization (Thomas, 2007), irrigation of crops with contaminated grey-water or raw sewage (Chalmers *et al.*, 2007), feral pigs on cropland (Bach *et al.*, 2002) or direct consumption of sewage-contaminated water (Institute of Medicine of the National Academies, 2002). Dairy and beef cattle are primary reservoirs of *E. coli* O157:H7 (Szalanski, 2004) and they can carry it

asymptotically and shed it in their faeces (Szalanski, 2004). Food products associated with *E. coli* outbreaks include raw ground beef, raw seed sprouts or spinach raw milk, unpasteurized juice, and foods contaminated by infected food workers via faecal-oral route (Alam and Zurek, 2004).

2.4 Wastewater and Sewage

Wastewater is liquid effluent derived from domestic sewage or industrial sources that cannot be discarded in untreated form into the lakes or streams due to public health, economic, and aesthetic considerations. Sewage is liquid effluent contaminated with human or animal faecal materials. Wastewater commonly contains harmful inorganic or organic compounds as well as pathogenic micro organism. Wastewater treatment involves chemical and biological (microbial) treatments to remove or neutralise contaminants. Industrial waste may contain toxic substances that must be pre-treated before they are released for wastewater treatment (Madigan *et al.*, 2003).

2.5 Cost and Significance of Food borne diseases to Society

Food borne disease as defined by WHO is a disease of an infectious or toxic nature caused by, or thought to be caused by the consumption of contaminated by the disease agent. The WHO Expert Committee summarised this as: the agent is mostly of microbial origin and the most widespread problem in the world and an important cause of reduced economic productivity. It was also estimated that the risk of becoming ill as a result of such microbial contamination of food was 100,000 times greater than the risk from pesticide contamination. Besides the extremely important but unquantifiable cost in terms of human pain and suffering, an addition reason for being concerned about

diseases spreading by foods is their economic impact and their burden in the national budget (Adams and Moss, 1995).

CHAPTER THREE: METHODOLOGY

3.1 Study Area

Nyeri Town in Central Kenya with a population of about 200,000 persons was chosen as the site for this study on the basis of funds available and proximity to my study institution. It is semi-urban and with various types of sources of drinking water. Population is estimated to be about 200,000, 110,550 adults, 8945 children and density of 654. Five different study areas were taken as Kingogo, Upper Town, Lower Town, Majengo and Ruringu (see appendix 5: Map of Nyeri Town).

Majengo is situated along Chania River; houses are mixed types- constructed with various types of materials mud, timber and stone. Sources of water are the Municipal water on stand points and water kiosks and the river water just a few metres away and it is free. They have communal toilets and garbage bins are placed at various points, for waste disposal and collection.

Ruringu has mixed type of houses, less densely populated and agricultural practices both livestock and horticultural. Sources of water are the Municipal tap water and stored rain water, for domestic and drinking use. Garbage collection/disposal is mainly managed by private companies and Municipal council. Most of the houses have toilet in the house or within the compound shared amongst few people.

Kin'gon'go area has mixed type of houses, less densely populated with little agricultural practices, mainly livestock. Sources of water available are the Municipal water river

water, stored rain water and river water though it is far. Garbage collection/disposal is managed by private companies and the Municipal council. Most house have toilet within the house in the compound shared by few persons.

Lower Town has mixed types of houses, moderate density and practicing agriculture both livestock and horticultural. Sources of water are Municipal water, stored rain water and river/stream water though available it is far. Garbage collection and management is by the Municipal council and private companies. In some houses toilets are communal while others are in the house or within the compound

Upper Town has mixed types of houses, low density and practicing agriculture. It is more of rural setup with well constructed houses. Sources of water are Municipal water, stored rain water, and river/stream water, but it is far for the majority of people. Garbage collection/management is by the Municipal council and private companies. Toilets are in most of the houses or within the compound shared within the family members.

3.2 Research Design

The study area was a cross-sectional one adopted from the social survey design described by Orodho (2008). This involved a systematic gathering data on demographic characteristics, the social environment, activities, opinion or attitudes on the sample population. Water samples comprised bottled water from the local shops-supermarkets, small shops and 'kiosks'; Tap water from commercial points and households; Stored rain water and water from local stream and river. A pilot study was initially done and the

data analysed before embarking on the main investigation. Community awareness of quality and health risks was determined by administering a questionnaire to the community.

3.3 Study Population

The study population was drawn selected localities, Health care providers, water department officials and community leaders. A questionnaire was administered to these groups. Water samples were drawn from the river, stream, stored rain water, municipal tapped water and bottled water from supermarkets, shops, and kiosks.

3.4 Sample size determination

3.4.1 Respondents

The sample size for the questionnaire was determined using the formula used by Kiragu, K., (1991):

$$N = \frac{z^2 pqD}{d^2}$$

Where; N= the desired sample size, Z= Normal deviate which corresponds to 95% confidence interval, p= Proportion of the study population estimated to have utilised water, q=1-p, d=degrees of freedom=0.05, and D=Design effect=1

Thus, $N = \frac{1.96^2 * 0.2 * 0.8 * 1}{0.05^2}$, this is approximately equal to 246.

Key informants: Health care providers and water and administrative officials were selected with the help of the Public health officer based on the willingness and availability.

3.4.2 Key Informants

Health care providers (14), administrators, water officials and community leaders (12) were selected to give key information about the Nyeri Town community on incidences of disease outbreaks, water safety, sanitation and waste disposal.

3.4.3 Water samples

Bottled water samples were bought from ten (10) leading supermarkets, shops and kiosks in Nyeri Town. Nineteen (19) different brands of bottled water found in the market were sampled. Tapped water samples were sampled from the five (5) study sites namely: Ruringu, Majengo, Lower Town, Upper Town and Kin'gon'go.

3.5 Inclusion/exclusion criteria

Mature residents of Nyeri Town both male and female were included in the interviews on health awareness on suitability of drinking water. Children and none resident of Nyeri Town were excluded in the study.

3.6 Data Collection Tools/Instruments

Structured questionnaire administered to the residents, raw data forms prepared by investigator, observation forms used to collect information. Equipments and chemicals/reagents were used to carry out laboratory chemical and microbial analyses. Standard tests were used to determine various variables for water quality.

3.7 Sampling Procedures

3.7.1 Study sites

The five study areas were categorised based on their environmental and social unique characteristic for each area.

3.7.2 Respondents

Self and assistant interviewers administered the questionnaire to residents from the residence and work places. A questionnaire was administered to the Nyeri Town community to establish the awareness, knowledge, perception of quality, and implications of the community behaviours (Appendix 1). Preferred drinking water as well as opinion of the quality of bottled water was determined too.

3.7.3 Key Informants

Health care providers, administrators, water officials and community leaders were identified with the help of the Public Health Officer and requested to give information using various questionnaires. Consent and confidentiality were observed accordingly.

3.7.4 Water

3.7.4.1 Bottled water

Samples of different brands of bottled water were purchased from supermarkets, shops and kiosks in Nyeri town. Samples were bought in 1.5 litres each brand from all major ten Supermarkets. Other brands not sold in the supermarkets were bought from the shops and kiosks at various points at the bus station, along the major streets, and places of residence (Kigongo, Ruringu, Majengo, Lower and Upper Town). The samples were placed into cool box for transportation to the laboratory for both microbial and chemical analysis.

3.7.4.2 Tapped water

Tapped water from municipal council was collected in sterile bottles at five (5) different points in Nyeri Town. Upper Town at the Provincial Offices, Lower Town at the bus station, Majengo at a standpoint tap, Kigongo at a hotel and Ruringu at petrol station. The taps were cleaned with alcohol to remove dirt. Taps were opened for three minutes to clear the lines. Sterilisations of the taps were done by burning cotton soaked in alcohol until red hot. Taps were opened before sampling once more and water allowed to flow for about one minute. Water was filled into sterile 1.5 litre bottles to the shoulders, avoiding contamination of the tops. Caps were replaced and labelled accordingly with the point of sampling and placed into cool box for transportation to the laboratory for analysis.

3.7.4.3 River and streams water

There is one main river and one stream. River and stream water was sampled by taking three samples at any sample point. Samples were obtained from downstream and upstream at distance of 1 kilometre upstream and downstream each. Sterile bottles 1.5 litres each were filled with the water capped and placed into cool box for transportation to the laboratory for analysis.

3.7.4.4 Stored Rain water

Stored rain water was sampled using the same procedure as for tapped water.

3.8 Water Samples Processing

3.8.1 Chemical

According to the International Atomic Energy Agency (IAEA) protocols, (1992) on drinking waters, samples were kept at cold-rooms temperature prior to analysis. Sample

pre-treatment was done as described in the International Atomic Energy Agency (1992) protocols. In this method, 100 ml of each of the water samples were put into a 250 ml beaker and placed on hot plate. When about to boil, 2 ml of nitric acid-water mixture (50:50) and 10 ml hydrochloric acid-water mixture (50:50) were added. The samples were then evaporated until the mixture reduced to approximately 10 ml. The 10 ml residues were then transferred into 100 ml volumetric flasks and topped up to the mark with distilled water and digested using concentrated acids (wet-ashing). Nitric acid, sulphuric acid and hypochloric acid was used in the ratio of 2:1:1.

3.8.1.1 Lead, cadmium, copper and iron analysis using Atomic Absorption Spectrophotometer (AAS)

The lead was determined using a Shimadzu Atomic Absorption Flame Emission Spectrophotometer Model AA-6200 (AAS), (Osborne and Voogt, 1978). Commercial lead, cadmium, copper, and iron standards were used as reference (Wako Pure Chemical Industries Ltd., Japan).

3.8.1.2 Analysis of Fluoride

Determination of fluoride was done according to the method of Greenberg *et al.*, 1998. The samples were analysed by sodium 2-(parasulphophenylazo)-1,8-dihydroxy-3,6-naphthalene disulphonate (SPADNS) method. The SPADNS calorimetric method is based on the reaction between fluoride and zirconium-Dye Lake. The method relies on the fact that when fluoride reacts with certain zirconium dyes, a colourless complex anion and a dye are formed. The complex is proportional to fluoride concentration and it tends to bleach the dye which gets lighter as concentration increases. The resulting

complex is measured in a spectrophotometer at 750 nm. A spectrophotometer (Shimadzu UV mini 1240) was used.

3.8.1.3 Analysis of Nitrate

Ultraviolet Spectrophotometric Screening Method was used to determine nitrate in drinking waters. 50 ml of all the water samples were added 1 ml of 1N hydrochloric solution and mixed thoroughly. Standards of nitrate solutions ranging from 0 to 7 milligram nitrate per litre were done for a standard curve. Absorbance reading at 220 nm for nitrate and 275 nm wavelengths for interference due to dissolved matter were done for the samples and standards.

3.8.1.4 PH Value

The pH of the water was determined using a pH/conductivity meter (Denver Instruments model 20) located in the Food Biochemistry Laboratory in Jomo Kenyatta University of Agriculture and Technology following the AOAC method.

3.8.2 Microbial

3.8.2.1 General Evaluation

Total microbial counts were done using AOAC method for drinking waters (bottled water, tapped water, river/stream water, and stored rain water).

3.8.2.2 Specific evaluation

Enumeration *Escherichia coli* (*E. coli*) was done according to the AOAC methods. Serial dilutions were made with 0.1% Tryptone water to four dilutions each of the water samples. Duplicate plates of each of dilution were done using spread plate technique onto sterile plates of Violet-red bile glucose agar (VRBGA). The plates were inverted and incubated at 37⁰C for 24-48 hours. *E. coli* colonies were identified as those that were

pink in colour and they were counted and multiplied by the dilution factor. The results were expressed as colony- forming-unit per millilitre (CFU/ml).

3. 9 Data Storage and Analysis

3.9.1 Data Storage

Filled in questionnaires were sorted out, and the coded information fed into the computer. Results from the laboratory tests were also fed into the computer. The resultant data were stored in hard and backed up in software disks.

3.9.2 Analysis of Data

Descriptive indices such as frequencies, means, percentages and standard deviations were calculated for water quality and water related health risks. Comparison was done between the microbial counts and metal concentrations from the samples and the maximum permissible level and concentrations by WHO guidelines, (2006) and KEBS Standards, (2007). WHO guidelines are the umbrella quality standards all over the world while KEBS are the local quality standards for the country of Kenya. Statistical Package for Social Sciences (SPSS) was used to analyse questionnaires on community awareness. Bar charts, line graphs, pie charts and themes were used to present data and qualitative information. SAS package was used to analyse the results obtained from the laboratory on microbial and chemical quality for differentiation of water samples.

3.10 Ethical Considerations

Permission to carry out the research was sought from the appropriate institutions and authorities, Kenyatta University, Ministry of water, and administrators. Consent to

question the respondent was sought from the participants. Water samples bought from the market were coded for confidentiality.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Socio-Demographic Characteristics

4.1.1 Place of Residence

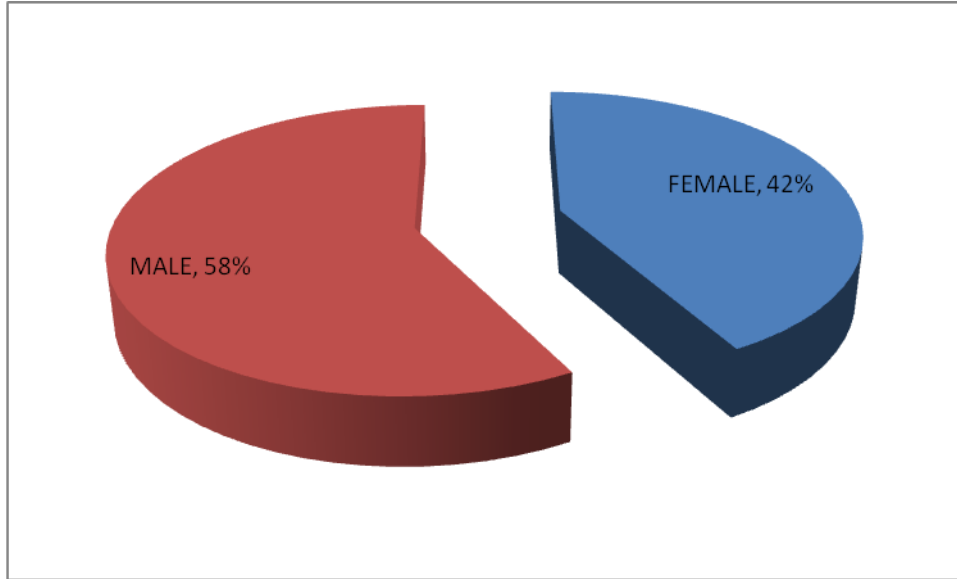
With regards to the place of residence of the respondents, the majority (24%) were from lower town while up to 22% were from Majengo area (Table 4.1). Ruringu area was represented by 21% of the respondent while 19% were residents of King'ong'o and 14% were from Upper Town. The presence of representatives from various parts of Nyeri Town was important since some water quality related risks of interest to the study were site unique to the areas studied.

Table 4.1: Place of Residence

	Ruringu	Lower Town	Upper Town	Majengo	King'ong'o
Percentage of total respondents	21	24	14	22	19

N= 246

With regards to the gender of the respondents, up to 58% of the respondents were males while the remaining 42% were females (Figure 4.1). This was because the majority of house heads who the study targeted as respondents were males. Female house heads were largely from female headed households or where the husbands worked and lived away from home.



N= 246

Figure 4.1: Gender of the Respondents

The majority of the respondents were between the age of 37 to 54 years (Figure 4.2), followed by age group 18 to 36 years (26%). Only 10% of the respondents were at the age of above 55 years and above. The majority of the respondents were therefore in their middle age and thus the most economically active group. The exposure of this group to water quality related risks can have a serious adverse effect to the whole community.

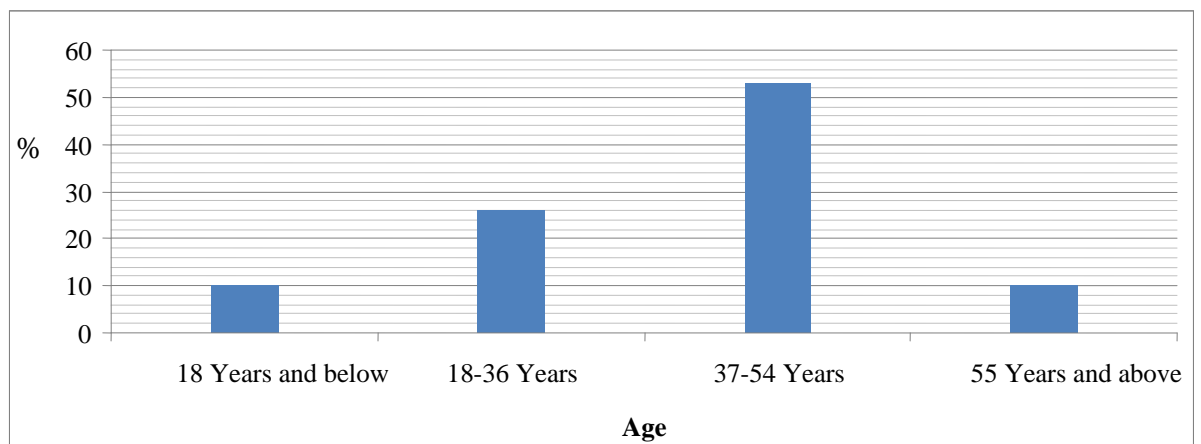


Figure 4.2: Age distribution of the Respondents

4.1.2: Socio-Demographic Information

Over 70% of the respondents had stayed in the area for over 5 years and thus conversant with the water quality issues affecting the community in the area (Table 4.2). Up to 68% of the respondents were married while the rest 32% were single. Respondents with secondary school education were 58% while 22% had primary school education. Only 13% had university education. Education level of an individual determines the awareness of health risks and propels one to take mitigation measures. The majority of the respondents (96%) were Christians by faith while only 2% Muslims. The rest had traditional religious beliefs.

The study revealed that up to 54% of the respondents were living in permanent houses while 28% lived in semi permanent structures. While permanent housing indicated economic empowerment and thus access to sanitation facilities such as good toilets and sewerage system, residents in semi permanent areas were largely from slums like Majengo lacking such facilities. Further to these only 34% of the respondents owned their houses. These were largely from the town outskirts like Ruringu. Those in the town centre were largely tenants. About 60% of the respondents were semi-skilled workers while 25% were professionals and the remaining 15% were unskilled. In addition, only 51% earned regular income.

Table 4.2: Socio-Demographic Information

Variable	Per Cent
Length of stay in the area	
Over 5 Years	70
< 5 Years	30
Marital status	
Married	68
Single	25
Widowed	7
Education level	
Secondary	65
Primary	22
University	13
Religion	
Muslim	2
Christian	96
Others	2
Type of housing	
Permanent	54
No response	18
Semi Permanent	28
Ownership	
Owned	34
Rented	62
Others	4
Occupation	
Professional	25
Skilled Worker	60
None	15
Income regular	
No	49
Yes	51

N=246

4.1.3: Household Characteristics

The household sizes ranged from one to six with an average of four persons (Table 4.3).

The majority of the households (30.5%) had four members followed by one member at

24.6%. About 21.7% the households had six members. The number of household members per household determines its water needs and consumption levels. Majority of households (83.3%) had two adults in most cases a husband and a wife. Although the respondents were skewed towards households without children (57.4%), vulnerability of children to water related diseases is well documented. Children die of water related diseases in developing countries. This study, however did not examine the disease pattern in the study area. This emphasizes the need for quality water in the area.

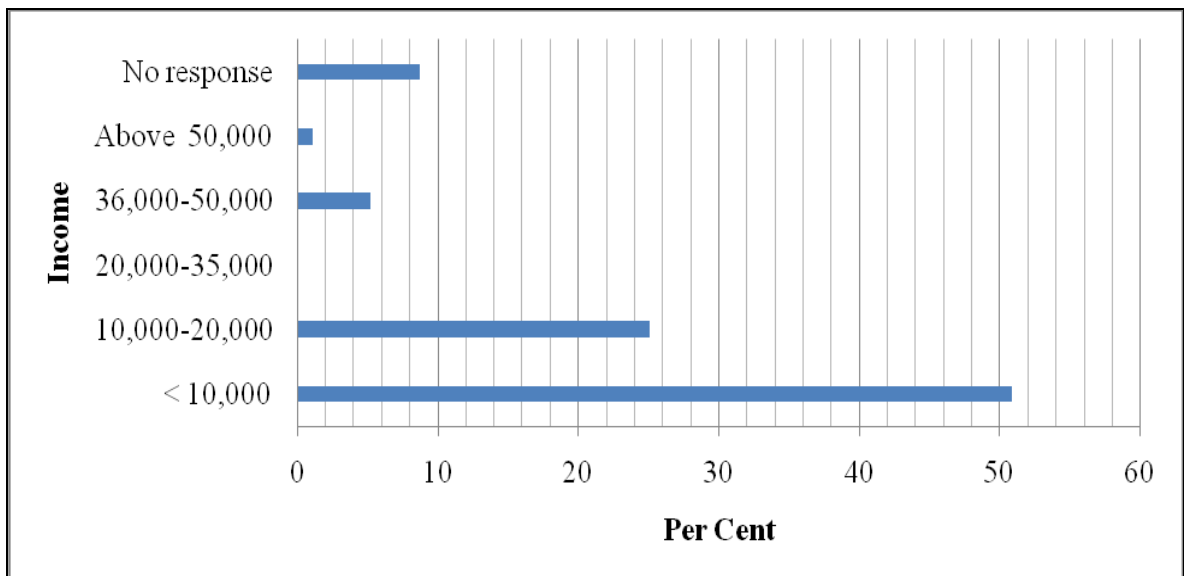
Table 4.3: Household Characteristics

Variable	Per Cent
Household size	
One	24.6
Two	14.5
Four	30.5
Six	21.7
No response	8.7
Adults	
One	11.1
Two	83.3
Four	2.8
Five	1.4
Six	1.4
Children	
None	57.4
One	19.4
Three	7.4
Four	13.9
Five	1.9

N=246

4.1.4: Household Income

Half of the respondents interviewed (51%) earned less than Kenya shillings 10,000 per month per household (Figure 4.3). In addition, up to 25% of the respondents earned between 10,000 and 20,000 per household. Education level and/or the income level of the residents may better explain the differences in pollution levels. Majority of the respondents had 65% secondary school level of education while in income majority earn less than Kenya shillings 10,000. In general, those residents with higher education and greater income are more likely to take actions to protect and ensure the quality of their drinking water.



N= 246

Figure 4.3: Household Income Ranges

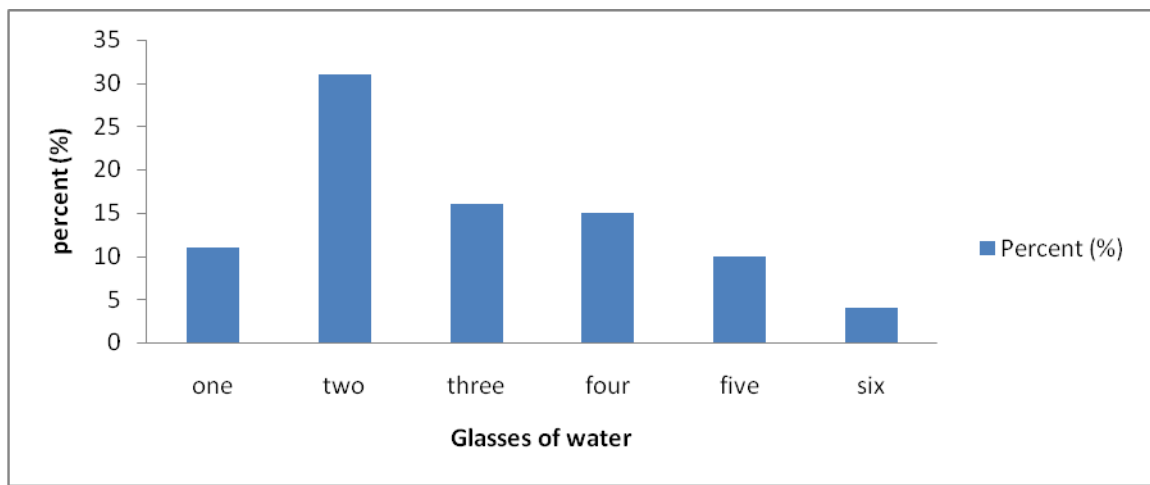
4.2: Water Source and Health Risks

4.2.1 Water Intake

Figure 4.4 is the pattern of rate of water consumption by the respondents. About 91% of the respondents reported to drink one or more glasses per day, only 9% of the

respondents did not. This includes water from various sources such as rain/stream water, municipal tapped water, roof catchments water and bottled water.

The majority of the respondents (31%) consumed two glasses of water per day while 17% of the respondents took three glasses (Figure 4.4). Up to 16% of the respondents took four glasses while 11% took one and 9% took five. The risks of acquiring infection due to contaminated water may increase according to the number of glasses taken. Although WHO recommends eight glasses of water per day, none reported to consume the same (WHO, 2006).



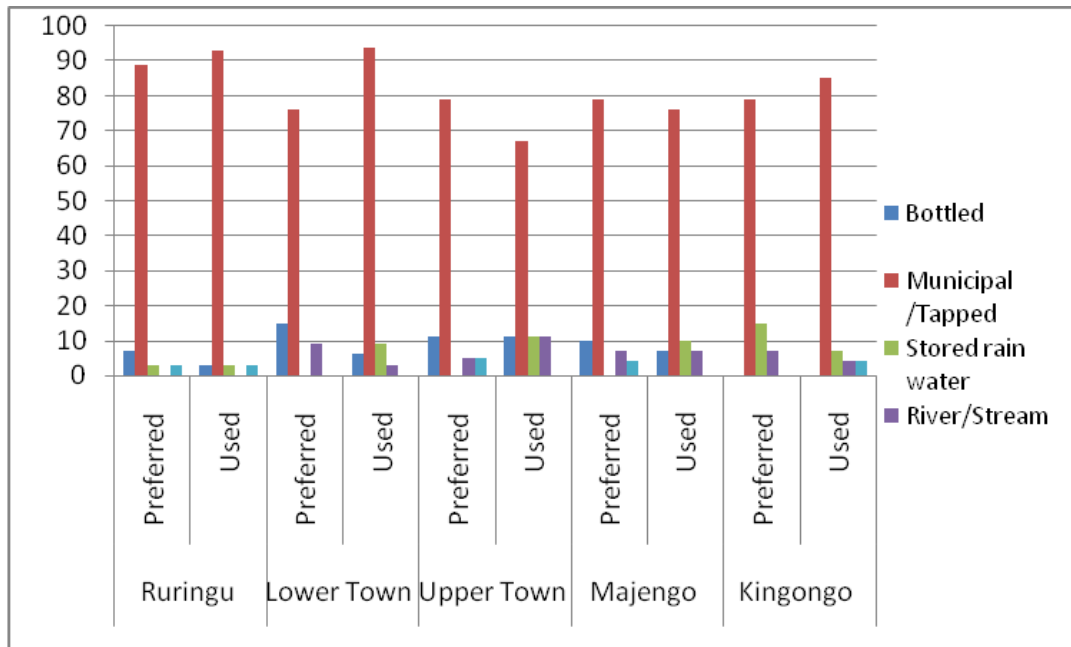
N=246

Figure 4.4: Glasses Taken Per Day by the Respondents

4.2.2 Preferred Versus Household Water Sources in the Study Area

Figure 4.5 is the usage of water as per source. Highest number of consumers used municipal Council Tap water. This source of water was used by residents of Ruringu (93%), Lower Town (94%), Upper Town (89%), Kingongo (78%), and Majengo (97%). At Kin'gon'go 1% of residents reportedly used rain water and 2% at Ruringu. In

addition, river/stream water was largely used at Kin'gon'go by 19% of the respondents, 11% at Upper Town and 6% in Lower Town. At Majengo river water is just a few metres away, less than 500metres, hence an alternative source to the Municipal water. The stand points and water kiosks are few and queuing may also discourage usage of Municipal water. On the other hand river water is free and residents may opt to use to compensate for the low income in the area.



N= 246

Figure 4.5: Preferred Versus Household Water Sources in the Study Area

With regards to preferred water sources, the municipal tapped water source was also the most preferred by residents in Nyeri Town. This source of water was preferred by residents of Ruringu (89%), Lower Town (76%), Upper Town (79%), Kingongo (79%), and Majengo (79%). In lower town, residents used municipal water despite having less

preference for it. This indicates that with alternatives available, these community members would shift from their main source of water which is municipal tapped.

4.2.3: Preference and Rating of Bottled Water by the Respondents

Up to 42% of the respondents took bottled water (Table 4.4). The majority of community members (63%) perceptions regarding bottle water were that it was fairly safe. Only 28% of the respondents thought that the water was safe. It was not surprising that the majority of the respondents (54%) only had partial confidence while 36% had confidence. Up to 9% of the respondents did not have any confidence in the quality of bottled water. As will be discussed later, bottle water had fairly high levels of Total Viable Counts and *Escherichia coli* and thus unfit for consumption. This explains the community's partial confidence in bottled water possibly from their health experience after using it.

Table 4.4: Preference and Rating of Bottled Water by the Respondents

Variable	Per Cent
Drink bottled water	
Yes	42
No	58
Rating	
Very safe	28
Fairly safe	63
Unsafe	9
User opinion on bottled water	
Have confidence	36
Partial confidence	54
No confidence	10

N= 246

4.2.4 Water Related Health Risks

For the majority of the respondents, the source of water was less than 500 m from their residence (Table 4.5). This was less than 500 metres 86% of residents of Ruringu, Lower Town (88%), Upper Town (89%), Kin'gon'go (74%), and Majengo (77%). This means that water was fairly within reach. Treatment of water was not practiced by 66% of residents of Ruringu, Lower Town (73%), Upper Town (74%), Kin'gon'go (52%), and Majengo (77%). This indicates that the residence had confidence in the quality of their source of water which was largely municipal tapped water.

Table 4.5: Water Related Health Risks

	Response	Ruringu (%)	Lower Town (%)	Upper Town (%)	Majengo (%)	Kingongo (%)	Average
Distance from water sources	<500m	86	88	89	77	74	82.8
	500m-1km	0	6	0	16	22	8.8
	Over 1km	14	6	11	7	4	8.4
Treat Drinking Water	Yes	34	27	26	23	48	31.6
	No	66	73	74	77	52	68.4
Method Used	Boiling	46.7	87.5	63.4	79.4	82.2	71.8
	Chemical additives	15.6	12.5	12.2	10.3	8.9	11.9
	Others	37.8	0	24.4	10.3	8.9	16.3
Storage Method	Bottle	7	9	12	7	7	8.4
	Closed Jar	83	88	66	57	78	74.4
	Open Jerry can	10	3	11	33	0	11.4
	Open Container	0	0	11	0	4	3.0
	Others	0	0	5	3	11	3.8
Water meets Household Needs	Yes	93	97	95	60	89	86.8
	No	7	3	5	40	11	13.2

N=246

For the residents treating water, boiling was the most used method being practiced by 46.7% of residents of Ruringu, Lower Town (87.5%), Upper Town (63.4%), Kin'gon'go (82.2%), and Majengo (79.3%). Water was largely stored in closed jars by the respondents which reduce contamination from bacterial and other contaminants. The water used met household needs for the majority of the respondents. This was reported by 93% of the residents of Ruringu, Lower Town (97%), Upper Town (95%) and Kingongo (89%). Water was least adequate in Majengo (60%) which is a slum with no access to municipal tapped water. Table 4.5 above, shows that more than 50% in all the areas do not treat drinking water, thus Nyeri Town community would be at risk as some of the water sources are of poor quality.

4.2.5 Household Experiences with Water Related Health Risks

The community interviewed was largely aware of waterborne illnesses (Table 4.6). This was reported by 86% of the residents of Ruringu, Lower Town (97%), Upper Town (84%), Majengo (83%) and Kingongo (75%). Though not very common, a significant proportion of respondents had experienced the illnesses related to water. This was reported by 21% of the residents of Ruringu, Lower Town (9%), Upper Town (16%), Majengo (13%) and Kin'gon'go (41%). On average 14.5% of the respondents had experienced the water related illnesses.

Table 4.6: Family Experiences with Water Related Health Risks

		Ruringu	Lower Town	Upper Town	Majengo	Kingongo
Variable	Response	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Awareness of Illnesses Related To Water	Yes	86	97	84	83	74
	No	14	3	16	17	26
Experienced The Illnesses	Yes	21	12	16	13	41
	No	79	88	84	87	59
Family Member Experienced Illnesses	Yes	14	15	21	47	30
	No	86	85	79	53	70
Members Affected	Children	58	65	45.6	7.5	63.4
	Adult	7	12	8.2	12.5	9.7
	All	37	23	45.2	12.5	26.9
Knowledge On Prevention	Yes	90	91	95	77	81
	No	10	9	5	23	19

N= 246

The household members most affected by water related illnesses were children as reported by 28% of the residents of Ruringu, Lower Town (33%), Upper Town (26%), Majengo (60%) and Kin'gon'go (26%). The high incidences of water related illnesses in Majengo can be attributed to its slum nature associated with poor sanitation condition and little access to clean water. Unfortunately knowledge on prevention of water related diseases was least (77%) in majengo, where the cases of diseases were highest. Among the residents of Ruringu, knowledge on prevention of water related diseases was reported by 90% Lower Town (91%), Upper Town (95%), and Kingongo (81%).

4.3: Risk Awareness of Unsafe Water among the Community

4.3.1 Community Perceptions Regarding Water Quality

With regards to respondents perceptions on water quality the majority 53% perceived that there was need to improve household water quality while 62% felt the need to improve community water quality (Table 4.7). This is evidence that the majority of the community felt that water quality in the study area needed to be improved. Community awareness on water quality is the key to community empowerment as a reminder of the need for a clean environment and sustainable source of clean water.

Table 4.7: Respondents Perceptions Regarding Water Quality

Variable	Per Cent
Need to improve household water quality	
Yes	53
No	47
Need to improve community water quality	
Yes	62
No	38

N= 246

4.3.2 Parameters Used by the respondents to Know Water Quality

The majority of respondents had no parameter for testing the water quality in the study area (Table 4.8). For example, 27% of the respondents trusted the municipal water quality thus did not inspect it at all, 40% for river/stream water, 49% for rain water and 53% for well water. Colour was largely used to test the quality of municipal tapped water by 25% of the respondents. This was because treated water bore a white colour of chlorine which residents interpreted as a sign of quality.

Table 4.8: Parameters Used by the respondents to Know Water Quality

Water Source	Parameters							
	Boil	Chemical	Colour	Sight	Smell	Taste	Others	None
Municipal (%)	3	25	25	2	1	9	8	27
River/ Stream (%)	8	1	18	6	1	12	14	40
Rain (%)	5	0	17	3	3	6	17	49
Well (%)	8	2	15	0	6	9	7	53

N= 246

For rain and stream water colour was used by 25% and 18% respectively to determine quality. This was largely because contaminated water changed from colourless to various other colours depending on the contaminant. Despite the value of good quality drinking water, many respondents are unaware of contamination issues and associated health risks. The community often neglected to determine the quality of their own drinking water for various reasons. Therefore, a prediction method for contamination risk of a specific source of water supply situation, in addition to increasing awareness, could provide the community with a rationale for further investigating the possibility of contamination.

4.4: Sanitation, Waste Disposal and Water related Health Risks

4.4.1 Toilet Facility Characteristics

Table 4.9: Toilet Facilities Characteristics

Variable	Category	Ruringu	Lower Town	Upper Town	Majengo	Kingongo
		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Type of Toilet Facility	None	3	0	0	0	0
	Pit Latrine	45	73	47	73	56
	VIP Latrine	7	0	0	10	4
	Flash Toilet	45	27	53	17	41
	Others	0	0	0	0	0
Distance of Toilet to Water Facility	<300m	97	94	95	77	81
	300m-1KM	0	6	5	23	11
	1KM-1.5KM	0	0	0	0	7
	>1.5KM	3	0	0	0	4
Frequency of Washing Hands after Toilet	Always	62	55	58	57	63
	Often	10	36	42	30	22
	Sometimes	24	6	0	10	15
	Rarely	3	3	0	3	0
	Not At All	0	0	0	0	0
Frequency of Disinfecting Toilet Facility	Not At All	17	9	5	43	33
	Once	14	18	11	20	7
	Twice	17	18	16	13	15
	3- 6 Times	17	27	42	17	11
	7 And Above	34	27	26	7	33
Use Toilet	Yes	90	97	95	100	96
	No	10	3	5	0	4
Frequency of Use	Always	86	88	84	100	89
	Most Times	7	9	16	0	11
	Sometimes	7	3	5	0	0
	Rarely	0	0	0	0	0
	Not At All	0	0	0	0	0

N= 246

The most common type of toilet facilities in the study area were toilets and pit latrines (Table 4.9). Flash toilets were reported by 45% of the residents of Ruringu, Lower Town (27%), Upper Town (53%), Majengo (17%) and Kin'gon'go (41%). High use of flash toilets was reported within the town centre where the facilities are available. Pit latrines were used by 45% of the residents of Ruringu, Lower Town (73%), Upper Town (47%), Majengo (73%) and Kingongo (56%).

The distance of toilet to water facility was generally less than 300m as indicated by 97% of the residents of Ruringu, Lower Town (94%), Upper Town (95%), Majengo (77%) and Kingongo (81%). Closeness of toilet facilities to water sources may pose risk of water contamination. The frequency of washing hands after toilet was rated as always by most of the respondents as indicated by 62% of the residents of Ruringu, Lower Town (55%), Upper Town (58%), Majengo (57%) and Kin'gon'go (63%). With regards to the frequency of disinfecting toilet facility a significant proportion of respondents never disinfected their toilets. This was reported by 17% of the residents of Ruringu, Lower Town (9%), Upper Town (5%), Majengo (43%) and Kingongo (33%). Failure to disinfect toilet facilities exposes underground and surface water to the risk of contamination with human waste. The frequency of toilet use was reported as always by most respondents. This was reported by up to 86% of the residents of Ruringu, Lower Town (88%), Upper Town (84%), Majengo (100%) and Kin'gon'go (89%).

4.4.2 Alternative Methods of Waste Disposal by Households

The study indicated that alternative methods of waste disposal by households included children using open places to help themselves (Table 4.10). This was reported by up to 45% of the residents of Ruringu, Lower Town (39%), Upper Town (37%), Majengo

(53%) and Kin'gon'go (37%). Open field method of excreta disposal is a major source of water contaminator. The frequency for this practice was rated as sometimes by up to 31% of the residents of Ruringu, Lower Town (39%), Upper Town (21%), Majengo (7%) and Kin'gon'go (52%).

Table 4.10: Alternative Methods of Waste Disposal by Households

		Ruringu	Lower Town	Upper Town	Majengo	Kingongo
Variable	Category	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Children Use Open Places as Toilets	Yes	45	39	37	53	37
	No	55	61	63	47	63
Frequency	Always	7	12	0	43	37
	Sometimes	31	39	21	7	52
	Rarely	62	48	79	50	11
Baby Waste Just as Harmful	Yes	90	85	89	83	81
	No	10	15	11	17	19
Disposal of Other Waste	Open Bush	34	30	47	27	22
	Composite Pit	59	67	37	60	63
	Burying	0	0	0	0	4
	Others	7	3	16	13	11

N=246

Majengo and Kin'gon'go 43% and 37% of children used open places as toilets always. Baby waste was reported by the majority of respondents to be just as harmful as adult waste. This was reported by up to 90% of the residents of Ruringu, Lower Town (85%), Upper Town (89%), Majengo (83%) and Kin'gon'go (81%). Disposal of other waste was done in the bushes as reported by up to 34% of the residents of Ruringu, Lower

Town (30%), Upper Town (47%), Majengo (27%) and Kin'gon'go (22%). This waste was washed to the river beds contaminating water and endangering the health of its consumers.

4.4.3 Respondent's Opinions Regarding the State of Sanitation Condition

Up to 61% of the respondents expressed the need to improve household sanitation conditions while up to 76% thought there is need to improve community sanitation conditions (Table 4.11). Solid waste management practices throughout Nyeri Town are largely poor. Management is limited to organized collection from the more affluent urban areas and dumping took place on the outskirts of urban centre. In the majority of cases, garbage of all types accumulated close to its point of origin and was periodically burnt. Waste was also commonly dumped directly into seasonal watercourses or rivers, thereby contributing to water pollution and waterborne diseases.

Table 4.11: Respondent's Opinions Regarding the State of Sanitation Condition

Variable	Per Cent
Need to improve household sanitation conditions	
Yes	61
No	39
Need to improve community sanitation conditions	
Yes	76
No	24

N=246

4.4.4 Responses from Health Care Providers

Reported incidence of disease out breaks were given as diarrhoea and vomiting, amoebic dysentery, intestinal worms, skin diseases and eye infections. Reported infections included water and sanitation related diseases, brought about by environmental

pollution, contamination of water, use of unsafe water, lack of toilet facilities, living in unhygienic conditions, poor waste disposal and lack of funds to put up water and sanitation facilities in place. Ways of improving water and sanitation were boiling of water, digging of pit latrines and rubbish pits, installation of piped water in villages, education on safe water usage and proper sanitation, inspection of schools, hotels and food handlers, and city council to modify ways of disposing waste.

4.4.5 Responses from Administrators, Water Officials and Community Leaders

From Water and sewage super-intendants and technicians there is not enough water in all households, water disconnections with high fines for some people due to non-payments of water bills.

They recommended having more frequent barazas to be in touch with the community and give necessary education on safe water use and sanitation. Women as well, to be involved in sanitation and water sources projects and activities. Ownership of water sources, sanitation and waste disposal. Local authority needs to source for funds, to promote water kiosks in low in-come areas with lower water costs and water-reconnection fines.

4.4.6 Environmental Observation

At Majengo area, there is waste disposal site at open yard though few disposal bins are available. River water is used mainly for washing clothes and cleaning. There are domestic animals (cows, goats and chicken), few water points/water kiosks and waste disposal is poor and communal toilets are poorly maintained. Lower Town the

conditions are better, but have very few water points and toilet facilities for the public. Upper Town needs to have water points and toilet facilities for the public to be improved. Some parts of Upper Town are rural setup with individual house toilets and garbage collection by the Council. Some areas have agricultural practices both livestock and domestic animals. Ruringu and King'ong'o have domestic animals and horticultural products in some households. Most of the toilets are clean as they are individual for household or for a few homesteads.

4.5: Bacterial Levels of Drinking Water in Nyeri Town.

The results of the *E. coli* content of the water from Nyeri Town are shown in Table 4.12. From the results obtained, there were no significant differences in *E. coli* content between the roof and tap waters ($p < 0.05$). There were significant differences in *E. coli* content between the river water and stream waters ($p > 0.05$), however, there were no significant differences between the stream and bottled waters ($p < 0.05$).

Table 4.12: Bacterial levels of drinking water in Nyeri town.

Sample	Total Plate Counts (TPC) (counts/ml)	Coliforms (counts/ml)
Bottled water	653±168 ^b	250±115 ^b
Tap water	1194±708 ^{ab}	Nil ^c
River water	1781±647 ^a	1017±507 ^a
Roof water	1525±25 ^a	Nil ^c
Stream water	1510±10 ^a	374±4 ^{ab}
WHO limits	20	0
KEBS limit	20	0

Each value is a mean ±SE of three analyses done in triplicates.

Means within columns followed by different superscripts (letters **a**, **b**, **c**) are significantly different from each other ($p < 0.05$).

The roof and tap waters had nil *E. coli* counts. There are about 200 known pathogenic *E. coli* that cause diarrhoeal diseases and urinary tract infections. It is a leading cause of kidney failure in children (Madigan, 2003). The WHO limit for *E. coli* in drinking water is nil (0) counts per millilitre. The roof and tap waters met this limit as they had nil *E. coli* counts. The river water after the Majengo and stream waters had high counts of *E. coli* thus did not meet these limits. Five brands out nineteen analysed bottled water had counts of *E. coli*, thus indicating that some of the bottled waters in the market are not safe for human consumption as far as the microbial quality is concerned.

The results of total plate counts (TPC) in the Nyeri Town waters are shown in Table 4.12. From the results, there were no significant differences between the roof, river, tap and stream waters in terms of total plate counts ($p < 0.05$). Food borne disease as defined by WHO is a disease of an infectious or toxic nature caused by, or thought to be caused

by the consumption of food or water. The WHO Expert Committee summarised it as, most of it is of microbial origin and it is the most widespread problem in the world. It is an important cause of reduced economic productivity. It was also estimated that the risk of becoming ill as a result of microbial contamination of food was 100,000 times greater than the risk from pesticide contamination. Besides the extremely important but unquantifiable cost in terms of human pain and suffering, an addition reason for being concerned about diseases spreading by foods is their economic impact (Adams and Moss, 1995). The WHO limit for total plate count in drinking water is 500 colony forming units (CFU). All the waters contained higher microbial levels than the WHO limit.

4.6: Chemical Levels of Drinking Water in Nyeri Town.

The results of the nitrates content in the Nyeri Town waters are shown in Table 4.13. The roof waters were not significantly different from the tap waters ($p < 0.05$); however, they were significantly lower ($p < 0.05$) in nitrates content from the bottled, river and stream waters. The nitrate contents of the bottled, river and stream waters were not significantly different from each other ($p < 0.05$). Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. The nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of leaching or runoff from agricultural land or contamination from human or animal wastes as a consequence of the oxidation of ammonia and similar sources. Anaerobic conditions may result in the formation and persistence of nitrite. Chloramination may give rise to the formation of nitrite within the distribution system if the formation of chloramines is not sufficiently controlled. In most countries, nitrate levels in drinking-water derived

from surface water do not exceed 10 mg/litre, although nitrate levels in well water often exceed 50 mg/litre. All the waters analyzed in this study had nitrates content lower than this range.

Table 4.13: Chemical levels of drinking water in Nyeri town.

Sample	Nitrates (mg/l)	Fluorides (mg/l)	Copper (mg/l)	Iron (mg/l)	Cadmium (mg/l)	Lead (mg/l)	pH (mg/l)
Bottled water	1.11±0.27 ^a	3.53±0.76 ^c	0.70±0.08 ^b	0.67±0.76 ^c	0.69±0.11 ^b	0.60±0.10 ^c	7.08±0.16 ^a
Tap water	0.44±0.02 ^b	1.60±0.40 ^d	0.98±0.18 ^{ab}	0.98±0.18 ^b	1.54±0.07 ^a	0.77±0.23 ^c	7.67±0.07 ^a
River water	1.16±0.52 ^a	1.07±0.06 ^d	1.54±0.46 ^{ab}	1.15±0.46 ^b	0.32±0.14 ^{a^c}	2.14±1.04 ^b	7.20±0.17 ^a
Roof water	0.38±0.01 ^b	8.22±0.02 ^b	1.44±0.00 ^{ab}	1.43±0.00 ^b	0.30±0.00 ^c	2.33±0.03 ^b	6.05±0.01 ^b
Stream water	1.12±0.02 ^a	1.75±0.02 ^a	1.77±0.01 ^a	1.78±0.01 ^a	0.37±0.01 ^c	4.46±0.04 ^a	7.63±0.03 ^a
WHO limits	50	1.5	2	0.3	0.003	0.01	6.5-8.5
KEBS limit	10	1.5	0.1	0.3	0.005	0.5	6.5-8.5

Each value is a mean ±SE of three analyses done in triplicates.

Means within columns followed by different superscripts (letters **a**, **b**, **c**) are significantly different ($p < 0.05$) from each other.

The WHO limit for nitrates in drinking water is 50 mg/litre. All the waters analyzed contained lower levels of nitrates than stipulated by the WHO. The Kenyan standard for drinking water specified the nitrates to be below 10 mg/litre. This limit was also not exceeded by any of the water samples.

The results of fluoride content in water from Nyeri Town are shown in table 4.13. No significant differences ($p < 0.05$) in the fluoride content between the tap and river waters.

The fluoride content of the stream water was significantly higher ($P < 0.05$) than the other waters sources. The roof water contained significantly higher levels of fluoride than the river and tap waters ($p < 0.05$), may be due to storage. The most important source of fluoride in drinking water is naturally occurring. Inorganic fluoride-containing minerals are used widely in industry for a wide range of purposes, including aluminium production. Fluorosilicic acid, sodium hexafluorosilicate and sodium fluoride are used in municipal water fluoridation schemes. Daily exposure to fluoride depends mainly on the geographical area. In areas with relatively high concentrations, particularly in groundwater, drinking-water becomes increasingly important as a source of fluoride. WHO Water Guideline value is 1.5 mg/litre, the same as KEBS. In groundwater, concentrations vary with the type of rock the water flows through but do not usually exceed 10 mg/litre. Fluoride can also have an adverse effect on tooth enamel and may give rise to mild dental fluorosis at drinking-water concentrations between 0.9 and 1.2 mg/litre, depending on intake (WHO guidelines, 2006). Elevated fluoride intakes can also have serious effects on skeletal tissues. It has been concluded that there is a clear excess risk of adverse skeletal effects for a total intake of 14mg/day and suggestive evidence of an increased risk of effects on the skeleton at total fluoride intakes above about 6mg/day. The river waters were within this limit with the tap water falling within this range. The fluoride content of the bottled water and roof stored rain water were significantly higher than the limit.

The results of lead content in the waters analyzed are shown in Table 4.13. From the results, there were no significant differences in lead content between the river water and

roof water ($p < 0.05$). No significant differences in lead content between the bottles water and the tap waters ($p < 0.05$). However, the lead content of the stream waters were significantly higher than the other waters ($p < 0.05$). The bottled and tap waters had significantly lower levels of lead as compared to the other waters ($p < 0.05$). Sources of lead in surface water or sediment include deposits of lead containing dust from the atmosphere, wastewater from the industries that handle lead, urban run-off and mining piles (UNEP, 2000). During the rainy season, lead may be leached from soils that are found next to busy highways into the water system posing a serious health problem (USEPA, 2003). Once lead falls onto the soil, it usually sticks to the soil, depending on the particulate matter size, from where small amounts may enter rivers and lakes and streams as the soil particles are moved by rainwater (Mahaffey, *et al.*, 1982). In general, very little lead is found in lakes, rivers, or ground water (WHO, 1989). Man's exposure to lead through water is low compared to exposure through air and food (WHO/FAO, 1995).

The water lead concentrations in most American cities as determined in 1962, ranged from trace to $6.2 \mu\text{g}/100 \text{ ml}$ (Duggan and Inskip, 1985). McBe (1970) found lead concentrations of more than $5.0 \mu\text{g}/100 \text{ ml}$ in 41 of 2595 samples and 25% contained no measurable amount of lead. The lead content in the tap water analyzed during the current study was 1.0 to $1.9 \mu\text{g}/100 \text{ ml}$. This is much lower than the lead content reported in the two earlier studies in the American Cities. The American cities studied were more likely to have had lead plumbing thus contributing to the high lead levels in the tap waters. The water supply systems in Kenya are relatively new and thus are mostly free of lead thus

explaining the low lead content in the Nyeri waters as compared to the American Cities waters. The WHO limit for lead in drinking water is 5 mg/litre. All the bottled water samples were within this limit. The tap, river, roof and stream waters were also within this limit.

The results of the cadmium content of the water from Nyeri town are shown in Table 4.13. From the results, there were no significant differences between the roof, stream and river waters in cadmium content ($p < 0.05$). The tap water cadmium content was however significantly higher than the cadmium content in the other waters ($p < 0.05$). The bottled waters had significantly lower levels of cadmium than tap waters but significantly higher than the river, stream and roof waters ($p < 0.05$). Much of the cadmium entering fresh waters from industrial sources may be rapidly adsorbed by particulate matter, and thus sediment may be a significant sink for cadmium emitted to the aquatic environment (WHO, 1992). Great variations are quoted for the cadmium contents of rainwater, fresh waters, and surface waters in urban and industrialized areas. Levels from 0.01 mg/litre to 4.0 mg/litre have been quoted in the literature depending on specific location and whether or not cadmium total or dissolved cadmium is measured (Elinder, 1985; WHO, 1992; OECD, 1994). The results of this study fall within this range being 0.30 to 1.54 mg/litre. The WHO limit for cadmium in drinking water is 5 mg/litre. The entire bottled, tap, river, stream and roof waters were within this limit.

The results of the iron content of the water from Nyeri Town is shown in Table 4.13. From the results obtained, there were no significant differences between the tap, river and roof waters ($p < 0.05$) in iron content. The stream waters were significantly higher

than the other waters ($p < 0.05$). The bottled waters had significantly lower levels of iron as compared to other waters ($p < 0.05$). It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/litre. The iron levels in the waters in the current study fell within the lower scale of this limit ranging from 0.67 to 1.78 mg/litre. Iron may also be present in drinking-water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. As a precaution against storage in the body of excessive iron, in 1983 JECFA established a PMTDI of 0.8 mg/kg of body weight, which applies to iron from all sources except for iron oxides used as colouring agents and iron supplements taken during pregnancy and lactation or for specific clinical requirements. An allocation of 10% of this PMTDI to drinking-water gives a value of about 2 mg/litre, which does not present a hazard to health. The taste and appearance of drinking-water will usually be affected below this level. The WHO limit for iron in drinking water is 10 mg/litre. The iron contents of the waters were significantly lower than the WHO limit ($p < 0.05$).

The results of the pH levels of waters from Nyeri Town are shown in Table 4.13. From the roof waters had significantly lower pH levels as compared to the others ($p < 0.05$). There were no significant difference in pH between the tap, river, bottled and stream waters ($p < 0.05$). Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters, the optimum pH required often being in the range 6.5–9.5. The pH of water in distribution system must be controlled to minimise the corrosion of water mains and pipes in the household water system. The WHO limits for pH in drinking water is 6.5-9.5. The bottled, river, tap and stream waters

were within this limit, however, the roof waters had slightly lower pH than given in these limits.

The results of the copper content in the Nyeri waters are shown in Table 4.13. Although there were significant differences in copper content among brands of bottled waters ($p < 0.05$), some did not have any detectable levels. There were no significant differences in copper content in the tap, river, roof and stream waters ($p < 0.05$). Generally the copper contents were not significantly different between the bottled, tap, river, and roof waters ($p < 0.05$). Consumption of water from a distribution system that includes copper pipes or fittings can considerably increase total daily copper exposure, especially for infants fed formula reconstituted with tap water. Farming activities and copper usage are of importance in the contamination of water sources, especially river/stream waters. The WHO limit for copper in drinking water is 10 mg/litre. All the water samples analysed were significantly lower ($p < 0.05$) than this limit.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS.

5.1 Conclusion

Most preferred drinking water is tap water followed by bottled water. However these sources need to be managed well to improve on quality and maintain good health. Some brands of bottled water in the market present various health risks though they look clean. Bottled water though perceived to be safe, is not safe as 20% of the brands had *E. coli*, hence do not meet the WHO and KEBS limits in bacterial levels. Bottled water stocked at the local shops, supermarkets and kiosks is available for everybody, even non-residents where municipal council water and others are not.

Majengo area reported highest usage of Municipal and they also reported the highest rate of infections. Though municipal water usage is high, there are health risks associated with usage of toilets- disinfection and washing of hands. Hence personal hygiene and sanitation needs to be enhanced so as to reduce the disease burden. Garbage collection and waste disposal needs to be enhanced and prevent waste contaminating the river.

Samples of river water collected before entering the slum (Majengo) area had low bacterial and *E. coli* as compared to those collected after leaving the area which had very high counts of bacteria and *E. coli*. The river water is heavily contaminated and hence no longer fit for consumption by the people within and after the Majengo area.

5.2 Recommendations

This study elicited the following recommendations: -

- i. Continuous enforcement of regulations and monitoring system are necessary to increase understanding of the specific characteristics of individual water supply systems. Such a system could include detailed analysis of temporal and spatial variations in source water quality parameters.

- ii. It is recommended that the local authority should enhance the waste management system in Nyeri town. These may include improvement of sewerage facilities, and solid waste management; intensive water quality monitoring and information sharing; awareness campaigns on conservation of water resources, ecosystem and environment sanitation and basic hygiene and health care.
- iii. Promotion of local awareness on pollution, health risks and water intake in collaboration with the authority and the community.
- iv. Make the municipal tapped water more accessible in the community by electing centrally located pay water stand pipes and an improved water billing system that could reduce constant water meter disconnections.
- v. Authorities need to control settlement at Majengo area located near the river, improvement of environmental sanitation and housing especially toilets/latrines garbage collection and management. Health awareness education campaigns also need to be enhanced in the area and probably poverty eradication programmes.

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B) How much do you earn per month?

1=<10,000 2=10,001-20,000 3=20,001-35,000

4=35,001-50,000 5=50,001-100,000 6=>100,000

8. Is your income regular?

1=Yes 2=No

If no, specify _____

9. A) How many members live in the house? _____

B) 1=Adults _____ 2= Children _____

c) Water Source and Health Risks

10. What is your main source of water for domestic use?

1=Rain 2=Well 3=River/stream 4=Municipal Tapped

5=others specify _____

11. How far is your home from the water source?

1=< 500m 2=500m-1 Km 3=others specify _____

12. A) Do you treat your drinking water?

1=Yes 2=No

B) If yes, what method do you use?

1=Boiling 2=filtering 3=chemical additives

3=others specify _____

13. How do you store your drinking water?

1=In a bottle 2=Closed jar 3=Open jerry can 4=Open container 5=Others

specify _____

River/stream water _____

Rain water _____

Well water _____

Others, specify _____

21. A) In your own assessment is there need to improve on the water quality in your household? 1=Yes 2=No

B) If yes, suggest ways of doing so _____

22. A) In your own assessment is there need to improve on the water quality in the community you live in? 1=Yes 2=N0

B) If yes, suggest ways in which to do so _____

d) Sanitation and Waste Disposal Practice

23. What toilet facility do you have in your household?

1=None 2=Pit latrine 3=VIP latrine 4=Flash toilet (with water closer)

5=others, specify _____

24. What is the distance between your water source and toilet facility?

1=<300m 2=300m-1Km 3=1KM-1.5Km 4=>1.5Km

25. How often do you wash your hands after toilet?

1=Always 2=Often 3=Sometimes 4=Rarely 5=Not at all

26. Are there times that you do not use the toilet?

(i) To urinate _____ (ii) For long call _____

27. How often do you clean and disinfect your toilet facility in a week?

1=Not at all 2=Once 3=Twice 4=Thrice to six 5=Seven and above

28. A) Do your household members use the toilet facility?

1=Yes 2=No

B) If yes, how often do they use the toilet facility?

1=Always 2=Most of the times 3=Some times 4=Rarely 5=Not at all

29. A) Do you train your young children to wash their hands after toilet use?

1=Yes 2=No

B) If yes, how often do they wash their hands?

1=Always 2=Sometimes 3=Rarely

30. A) Do your young children use open places as toilet facility? 1=Yes

2=No

B) If yes, how often?

1=Always 2=Sometimes 3=Rarely

31. Do you think the baby waste is just as harmful to health as adult waste is?

1=Yes 2=No

32. How do you dispose other waste from the household?

1=Open yard/bush 2=Composite pit 3=Burying 4=Others,

specify_____

33. What methods do you use to dispose your other sanitary

waste?_____

34. A) In your own assessment is there any need to improve sanitation conditions in your household? 1=Yes 2=No

B) If yes, give ways that are possible_____

35. A) In own assessment is there any need to improve sanitation conditions in the community you live in? 1=Yes 2=No

B) If yes, suggest ways_____

e) Water Intake

36. A) Do you take water other than from foods and drinks?

1=Yes 2=No

B) What quantity (glasses) per day?_____

37. What source do you drink from?

1=Bottled 2=Municipal Tap 3=Well 4=Stored rain water

5=River/stream 6=others specify_____

38. What source of water do you prefer to drink? _____

Give reasons_____

39. A) Do you drink bottled water?

1=Yes 2=No

B) If yes, what is your preferred brand?_____

40. How do you rate bottled water?

1=very safe 2=Fairly safe 3=Unsafe

41. What is your opinion of bottled water? _____

1=Have confidence 2=Partial confidence 3=No confidence

APPENDIX 2: QUESTIONNAIRE FOR HEALTH CARE PROVIDERS

Respondent Personal Data

Name (Optional) _____

Sex: 1=Male 2=Female

Age: 1=18-30years 2=30-50years 3=>50years

Name of clinic/hospital _____

1. List down the common water and sanitation related diseases that are reported to you by the community

Water RelatedSanitation related

2. Which of the diseases listed above have the highest

incidence/outbreaks _____

3. In your view, what are the direct causes of water and sanitation related diseases? _____

4. Do the patients you handle relate their ill health to:

a) Their use of water 1=Yes 2=No

b) Their poor use of sanitation facilities 1=Y 2=N

c) Inadequate availability of water 1=Y 2=N

d) Inadequate sanitation facilities 1=Y 2=N

5. How do you make your patients aware of the need to proper use and

management water and sanitation facilities? _____

6. Propose additional ways through which use of water and sanitation can be improved _____

APPENDIX 3: QUESTIONNAIRE FOR ADMINISTRATOR /WATER OFFICIALS

Respondent Personal Data

Date: _____

Name (Optional) _____

Sex: 1=Male 2=Female

Age: 1=18-29years 2=30-50years 3=>50years

Name of Organisation _____

Designation _____

1. What services does your office provide to ensure that water source and sanitation facilities are available to the residents/community?

(i) _____

(ii) _____

(iii) _____

2. What measures do you put in place to ensure that the residents/community have adequate knowledge about water practices?

(i) _____

(ii) _____

(iii) _____

3. What measure do you put in place to ensure that the residents/community have positive perceptions about water practices?

(i) _____

(ii) _____

(iii) _____

4. A). How do you empower your residents/community to ensure responsibilities for their water source?

(i) _____

(ii) _____

(iii) _____

B) How do you empower your residents/community to ensure responsibilities for their sanitation facilities?

(i) _____

(ii) _____

(iii) _____

5. A) Do you give your residents/community relevant information on how they can properly manage their water sources?

1=Yes 2=No

B) If yes, how often do you provide the information?

1=once a week 2=twice a week 3=three or more times in a week
4=once in 2 weeks 5=once/month 6=others_____

6. A) Do you give your residents/community relevant information on how they can properly manage their sanitation facilities?

1=Yes 2=No

B) If yes, how often do you provide the information?

1=once /week 2=twice/ week 3=thrice/ week 4=thrice or more/week
5=once/two weeks 6=once /month 7=others, specify_____

7. What type of information do you provide? (e.g.) verbal, pamphlets, etc

8. (A) Are the cases of misuse of water and poor sanitation?

1=Yes 2=No

(B) How do you deal with those members of the community who destroy water sources/sanitation facilities?

9. In which of the following aspects do you involve the community you serve in matters concerning water/sanitation provision? (Tick appropriately)

- a. Planning
- b. Implementing
- c. Evaluation/Monitoring
- d. Management/Administration

10. In those activities that you do not involve them, what are the reasons?

- (i) _____
- (ii) _____
- (iii) _____

11. Compared to men how would you rate women's involvement in the following aspects of handling water in the community you serve?

- (i) Increasing sources of water _____
- (ii) Maintenance of water quality _____
- Give reasons _____

12. Compared to men how would you rate women's involvement in the following aspects of sanitation facilities in the community you serve?

(i) Increasing sanitation facilities _____

(ii) Maintenance of sanitation facilities _____

Give reasons _____

APPENDIX 4: ENVIROMENTAL AUDIT**a) Water Use**

Area _____

1. Water source:

Municipal tap water; Bore hole/well; River/stream; Rain water

Others, specify _____

2. Method used to store water

Covered water tank; Jerry can; Uncovered container;

Others, specify _____

3. Method of water treatment

None; Boiling; Filtering; Chemicals;

Others, specify _____

4. Water source condition

Very safe; Fairly safe; Unsafe; Very unsafe

b) Sanitation Use and Practice

5. Availability of toilet facility: None; Pit latrine; VIP latrine; Flash toilet; Other, specify

6. Condition of toilet:

Very clean; Clean; Not clean; Very dirty

7. Other methods of domestic waste disposal

Open yard/bush; Composite pit; Burying; Others, specify _____

8. Distance between water source and toilet facility

Less than 300m; 300m-1Km; 1-1.5Km >1.5Km

9. Type of waste: 1=Solid 2=Liquid 3=Emissions
10. Domestic animals: Cows, goats, dogs, chicken, cats, rabbits, donkeys,
others_____
11. Signs of vermin/rodents: faeces, smell, dead ones,
12. Cockroaches
13. General parasites: jiggers, lice, fleas
14. Drainage: stagnant waters, ponds, dams, ditches,
15. Education facilities: Primary school, secondary, churches
16. General environment: Grass, bushes, cleanliness
17. Waste collection and disposal

APPENDIX 5: NYERI TOWN MAP

