ASSESSMENT OF BACTERIOLOGICAL QUALITY OF DRINKING WATER IN KIBERA SUBLOCATION OF NAIROBI CITY, KENYA.

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DECLARATION

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

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DEDICATION

TO MY PARENTS

ISAAC CHEMULITI AND RACHEL NAN'GINDA.

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ABSTRACT

Water is essential to man, animals and plants and without water, life on earth would not exist. However, the way it is handled may pose a great risk to the health of man and animals. Water has been associated with disease outbreaks particularly in communities living in areas with poor hygiene and sanitation. Generally there are three ways by which water can cause diseases, namely drinking contaminated water, contact with contaminated water and lack of water for proper hygiene. Such diseases are caused by the presence of certain pathogenic bacteria, viruses, helminths and protozoa which gain entry into water supplies. Safe and adequate supplies of water with proper sanitation are therefore one of the essential measures in the management of these diseases.

This study was designed with the objective of assessing the physical and bacteriological quality of in-house and out-house (tanks/standpipes) drinking water in Kibera sublocation of Nairobi and to determine risk factors that could affect the quality of water.

Water samples from twenty out-house tanks/standpipes from which residents drew their water for daily use were collected. An additional sixty samples were collected from in-house containers supplied by the same tanks/standpipes. All these were analyzed for total bacterial count, coliforms, faecal coliforms, faecal streptococci, and chlorine and pH levels. A questionnaire was administered at the time of sampling to determine risk factors that could affect the "quality" of water.

Total bacterial count was assessed using the pour plate method. These ranged form between 1 to 302 and 8 to 4200 per ml of water for out-house and in-house water respectively. The Most Probable Number of coliform was determined using the multiple tube technique and computed from statistical tables. Out-house

water had a coliform count range of between 0 to 92 while in-house coliform count range was between 0 to 161. Faecal coliform were enumerated on the basis of positive or negative production of acid and or gas at 44.5°C. Out of the eighty samples screened, 32 (40%) were positive. Among these, 2 (6.25%) were from out-house tanks/standpipe while the remaining 30 (93.75%) were from in-house containers. Faecal contamination was further confirmed by isolation of faecal streptococci using the multiple tube technique and growth on MacConkey agar. Thirty nine (48.75%) of all samples were contaminated with faecal streptococci with counts ranging from between 2 to 542. Of these, 2 (5.13%) were from out-house tanks/standpipe while the remaining 37 (94.87%) were from in-house containers.

Serotyping of *E.coli* isolates showed that 28 (87.5%) were non-enteropathogenic while 4 (12.5%) were enteropathogenic. These came from one out-house tank and three in-house containers. The chlorine content in all water samples was 0.5mg/l.

Members of sixty households were interviewed in this study. It was revealed that all households stored their water in containers of which, 54 (90%) used containers made of plastic, 4 (6.67%) used earthenware and 2 (3.33%) metal containers. Fifty eight (96.7%) households covered their containers while, 2 (3.3%) did not. Stored water took an average of 2.28 days to replenish with the containers taking an average of 4.43 days before they were cleaned. Forty two (70%) of the households boiled water, while 18 (30%) did not. A cup/mug was used to scoop drinking water from the containers in 26 (43.3%) of the households, while 34 (56.7%), poured drinking water out of the containers. In this study, the method used to draw drinking water from the containers (scooping verses pouring out) was the only questionnaire derived variable that was significantly (P =

0.0202 for total bacterial count and P = 0.0082 for faecal streptococci) related to the bacteriological quality of water. Members in 42 (70%) of the households interviewed were aware that water could act as a vehicle for disease transmission. Of these, 34 (81%) said they knew measures they could institute to ensure water was safe while the remaining 8 (20%) did not. The prevailing environmental conditions within Kibera at the time of sampling were such that they increased the risk of water contamination. For example, there was no provision of proper and effective sewage, waste water and garbage disposal facilities. Bacteriological contamination of stored water in the study area could be attributed to the drawing of water using contaminated scoops as well as touching of water with "contaminated hands".

These results indicate that upto 35% of water at distribution level (out-house tanks/standpipe) in Kibera sublocation were contaminated. Further bacteriological deterioration of water occurred in the house, a factor which could be attributed to certain unhygienic behaviours. In conclusion, water contamination at the distribution level in Kibera should be prevented to ensure that it is safe. In addition, educational programmes on environmental and personal hygiene should be instituted to prevent water contamination at the distribution and domestic levels

CHAPTER ONE

INTRODUCTION

Water is fundamental to maintaining life and is critical to development and civilization. It plays great roles for example, personal uses (hygiene, drinking, cooking, swimming, washing), supporting growth of crops, and provision of transport and power. The chief aim of management of water resources throughout the world is to provide adequate and quality water for human functions. The World Health Organisation (1985) defines access to safe drinking water as provision of piped water to housing units or to public standpipes within 200m of each household. However, the supply of safe drinking water to any community is a major problem in many developing countries. The WHO (1983) estimated that nearly 60% of rural people in developing countries did not have access to safe water. In Kenya, WHO (1985) estimated that about 80% of urban population and only 15% of rural people had access to safe drinking water.

Water plays important roles in the transmission of major enteric diseases. These are diseases such as cholera, typhoid, paratyphoid, infectious hepatitis, amoebic and bacillary dysentery. It has been estimated that 80% of all diseases in the world are associated with the use of "unsafe" water (IRC, 1988). "Unsafe" water combined with inadequate sewage disposal and low levels of personal hygiene result in very high morbidities of water-associated diseases in developing countries. The use of "safe" drinking water is one of the measures in the management of these enteric infections (Henry *et al., 1990*). A study by Esrey (1990) indicated that major preventive measures such as proper sewage disposal, personal and domestic hygiene, food and water hygiene, effective waste water disposal and efficient drainage are useful tactics in combating water-associated

diseases.

In developing countries, more and more people are crowding into squatter settlements in every major city. The steady upward trends in urbanization in Kenya in the last two decades, has led to 6-8% annual growth in the urban population (Obudho, 1986). However, the provision of adequate and quality water supplies and good sanitation facilities have not kept pace with this human growth. It is estimated that about one third of the Nairobi city population does not have access to clean water (Karingi, 1993). This is mainly in the slums and squatter settlements. Although some of these areas may be served by a water distribution system, crowding, low water pressures, leaks, lack of sewerage and inadequate waste water disposal systems have often resulted in frequent outbreaks of water associated diseases in these areas (WHO, 1976).

Approximately two-thirds of households obtain their daily water from sources outside the house and get it in containers. In East Africa, this proportion is about 90% (White *et al.*, 1972). In slum areas, which lack piped water supplies to houses, water is drawn from public standpipes and carried to houses. The possibility of contamination of such water between the standpipes and houses has been recognized (Wagner and Lanoix, 1959). It is worthy noting that Lindskog and Lindskog (1985) found out that such ferried water became easily contaminated between the collection points and consumption at home.

Ferried water is subject to contamination during collection and storage. A study in Khubestone village in Lesotho, showed that in households where water was kept in large containers (from which water was frequently added and removed) the water was more prone to increasing pollution than in households in which water was stored in a bucket used to collect it. In addition, Burgers *et al.*, (1988) confirmed the risk of water contamination between collection and use in

houses. They found out that collection and storage of drinking water in open vessels which are not cleaned regularly, use of communal cups to draw water and hands touching the water during collection were risk factors associated with pollution of household water.

Among the drinking water quality parameters, the bacteriological quality is the most important and hence routinely evaluated in all domestic and public water sources. Commonly, water is examined for bacterial indicators of faecal contamination (WHO, 1996). Indicator microorganisms used to detect faecal contamination of water are coliforms (typified by *Escherichia coli)* and faecal streptococci (typified by *Streptococcus faecalis).* The presence of *Escherichia coli* and or *Streptococcus faecalis* in water indicates contamination by faeces of human and non-human origin (Dukta, 1973; Feachem, 1974, 1975; Mara, 1974). With the rapidly increasing population in Nairobi coupled with deteriorating water supplies and sanitation systems, water quality is bound to be affected significantly.

This study was therefore designed with the following objectives:

1. To assess the bacteriological quality of out-house and in-house drinking water in Kibera area.
2. To determine the levels of pH and residual chlorine in drinking water in the same area.
3. To determine the risk factors that could affect the bacteriological quality of water.

CHAPTER TWO

LITERATURE REVIEW

2.1. WATER SOURCES AND USES

Water covers three quarters of the earths surface. The greater part of this water is found as surface water mass which includes oceans, seas, lakes, dams and rivers. It is also found as ground water within the earths crust. This form is available through springs, wells, tubewells and boreholes. All water bodies are interconnected through the atmosphere via the hydrological cycle.

Underground water, surface water and often rainwater are major sources for community water supplies. Ground water is that portion of precipitation, mostly rainfall, which has percolated into earth to form underground deposits called aquifers. Underground water can be tapped by various means such as springs, wells and boreholes. In most cases, water from underground sources can be used without further treatment for individual and community uses. Ground water serves the majority of people who live in rural areas and is by far the most practical and safe in nature (Wagner and Lanoix, 1959).

Surface water originates from rainfall and is mainly a mixture of run-off. The quantity of run-off depends upon a large number of factors. The most important include the amount and intensity of rainfall, the climate, vegetation and geographical, geological and topographical features of the area. Rainwater is usually tapped from the roofs of buildings or from surface run-off areas (WHO, 1972).

In it's natural state, water is one of the purest compounds known. However it is not easy to find a source of fresh water that has not been disturbed (Schwabe, 1969). Industrialization, increasing populations and several human activities have indirect and undesirable effects on the aquatic environment

(Deborah, 1992). Examples of human activities which have deleterious effects on surface water are uncontrolled land use for urbanization, deforestation, accidental (or unauthorized) release of chemical substances and discharge of untreated wastes or leaching of noxious liquids from solid waste deposits. Similarly, the uncontrolled and excessive use of fertilizers and pesticides have long term adverse effects on ground and surface water sources.

Pollution of water is becoming one of the major problems confronting public health authorities all over the world, particularly the expanding industrial world. The most important of these pollutants are those which negatively affect human health. Two main categories of water associated health hazards are biological agents that may affect man following ingestion of water or other forms of water contacts, chemical and radioactive pollutants which usually result from discharges of industrial wastes (Schwabe, 1969; WHO, 1972). Biological hazards are of major public health importance. According to Sanders and Warford (1976) about 80% of all human diseases in the world are attributed to water-borne agents. Such diseases include cholera, typhoid and paratyphoid fever, infectious hepatitis, amoebic dysentery and bacillary dysentery. Drinking of safe water is therefore important in controlling such diseases.

2.2. CHARACTERISTICS OF WATER.

2.2.1. PHYSICAL AND CHEMICAL PROPERTIES.

2.2.1.2 pH VALUE

The pH value or hydrogen ion concentration is a measurement of the acidity or alkalinity of water. Pure water is slightly ionized into positive hydrogen ions and negative hydroxyl ions.

Acidity of water is it's quantitative capacity to react with a base at

designated pH levels (APHA, 1989). An acid water is one which has a pH value of less than 7.0. Acidity in unpolluted water is usually due to carbonic acid from dissolved carbon dioxide. Decomposing vegetation can also give rise to acid water with a pH value of above 3.7. Water contaminated with industrial effluent can contain mineral acids, with pH values of below 3.7. The WHO Standards (1971), give the lowest desirable level of pH as 7.0 and the minimum permissible level as 6.5.

Alkalinity is entirely due to the bicarbonate, carbonate and hydroxide ions in water. The highest desirable level according to WHO standards (1971) is pH 8.5 with the maximum permissible being 7.2.

2.2.1.2. COLOUR, TASTE AND ODOUR

Colour in drinking water may be due to the presence of humic material, naturally occurring metallic ions or highly coloured industrial wastes. The WHO (1985) standards for drinking water, states that the desirable limits for drinking water colour should be 5 units with highest permissible level of 50 units.

Taste is the combined perception of substances detected by the senses of taste and smell. Generally, the taste buds in the oral cavity detect inorganic compounds of metals such as magnesium, calcium, sodium, copper, iron and zinc.

Water odour is mainly due to the presence of organic substances. Some odours are indicative of biological activity, while others may originate from industrial pollution. Water should be free of objectionable taste and odour (WHO, 1985).

2.2.1.3. TEMPERATURE

Cool water is generally more palatable. Low water temperatures tend to decrease the efficiency of treatment processes, including disinfection and may thus have a deleterious effect on drinking water quality. High water temperatures enhance the growth of microorganisms and may also increase taste, odour,colour and corrosion problems.

No guideline value is recommended for temperature, since its control is usually impracticable (WHO, 1984)

2.2.1.4. FLUORIDES AND CHLORIDES

Fluorides may occur naturally in water or may be added in controlled amounts during the treatment process. In areas rich in fluoride, well-water may contain up to 10mg/l of it. The highest natural level so far reported is 2800mg/l. Low levels of 0.5-2mg/l provide protection against dental caries especially in children (Hutton, 1990). However, for fluoride, the margin between beneficial and toxic effects is rather small (Gorchev, 1988). High levels in water may lead to adverse health effects. These may include dental fluorosis at concentration levels of between 0.9-1.2mg/l (Dean, 1942). In warmer seasons, dental fluorosis may occur at low levels because of high amounts of water consumed. In hot climates, an average consumption of 5 litres/day is not unusual and, in such cases, fluoride levels in drinking water should be decreased accordingly. Skeletal fluorosis is observed when drinking water contains 3-6mg/l of fluoride, while crippling fluorosis may occur at fluoride water concentration of over 10mg/l (WHO, 1984). The Kenya Bureau of Standards (1985) recommend water fluoride level of 1.5mg/l.

Chlorides are present in nearly all natural waters giving rise to salty

raste. Chloride in surface and ground water originates from both natural and anthropogenic sources. Chloride levels in unpolluted waters are often below 10mg/l and sometimes below 1mg/l (DNHW, 1978). The recommended level of chloride according to WHO (1983) is 250mg/l for drinking water.

Chlorine remains the most widely used water disinfectant for community water supplies due to it's germicidal properties, the comparatively low cost and the ease of application. Chlorine gas or chlorine compounds are very strong oxidising agents which kill organisms in water by destroying the enzymes essential for their metabolic processes. In addition, they also react with ammonia, iron, manganese sulphide and some organic substances. Thus, chlorine residual of 1 mg/l kills Schistosoma cercaria (WHO, 1965) and 2 mg/l kills amoebic cyst within a period of 30 minutes.

In Kenya, the Bureau of Standards (KBS, 1985) recommends chlorine residual level of between 0.2-0.5mg/l of drinking water, but under conditions of epidemic diseases, the Bureau recommends temporary increase of the residual chlorine in water.

2.2.2. BIOLOGICAL PROPERTIES

Natural and waste waters contain a variety of living organisms, forming a balanced ecological system. The types and numbers of various groups of organisms are related to water quality, and the environmental factors in the surrounding water mass. Living microorganisms of public health importance found in water include, bacteria, viruses and parasites.

2.2.2.1. BACTERIA

Most microorganisms found in water are harmless although sometimes pathogenic ones are accidentally introduced into water. Pathogenic bacteria which have been found in drinking water and incriminated as causative agents of human diseases include: Faecal streptococci, *S. typhi*, *S. paratyphi*, *S. typhimurium*, *Shigella spp.*,*Campylobacter jejuni*, *Vibrio cholerae*, *Yersinia enterocolitica* (Mohammed and Morrison, 1975; WHO, 1985; Thona et al., 1988; Pinfold, 1990; WHO, 1996). Table 1 summarizes the common waterborne bacterial pathogens and their significance in water supplies.

Some microorganisms, naturally present in the environment and not normally regarded as pathogens, may cause disease opportunistically when present in drinking water. Those at risk include the very young, the very old and patients in hospital e.g those suffering from acquired immunodeficiency syndrome (AIDS) and patients undergoing immunosuppressive therapy. Water used by such patients may produce a variety of infections. *Pseudomonas* spp, *Flavobacterium*, *Acinetobacter*, *Klebsiella* and *Serratia* are examples of such opportunistic microorganisms (WHO, 1996).

2.2.2.2. VIRUSES

Discharges of sewage and human excreta constitute the main sources of viruses in aquatic environment. Viruses of greatest significance are essentially those that multiply in the intestines of humans and are excreted in large numbers in faeces of infected individuals (WHO, 1979). Viruses which are pathogenic to humans and which may occur in polluted water include, Picornaviruses, Adenoviruses, Parvoviruses, Caliciviruses and Papovaviruses (WHO, 1996). Table 2 lists viruses infective to humans that are found in sewage polluted water and their significance.

TABLE 1: WATERBORNE BACTERIAL PATHOGENS AND THEIR SIGNIFICANCE IN WATER SUPPLIES

Pathogen	Health significance	Main route of exposure (a)	Persistence in water supplies (b)	Resistance to chlorine (c)	Relative infective dose (d)
Campylo. jejuni, C.coli	High	O	Moderate	Low	moderate
Pathogenic *E.coli*	High	O	Moderate	Low	High
Salmonella typhi	High	O	Moderate	Low	High
Other *Salmonella*	High	O	Long	Low	High
Shigella spp.	High	O	Short	Low	Moderate
Vibrio cholerae	High	O	Short	Low	High
Yersinia enterocolitica	High	O	Long	Low	High(*)
Legionella	Moderate	I	May multiply	Moderate	High
Pseudo. aeruginosa	Moderate	C,IN	May multiply	Moderate	High(*)
Aeromonas spp.	Moderate	O,C	May Multiply	Low	High(*)
Mycobacterium	Moderate	I,C	May multiply	High	*

* = Not known or uncertain
(a) O = oral ingestion; I = inhalation in aerosal; C = contact with skin; IN = ingestion in immunosuppressed patients.
(b) Detection period for infective stage in water at 20°C: short = upto 1 week; moderate = 1 week to 1 month; long = over 1 month.
(c) When the infective stage is freely suspended in water treated at conventional doses and contact times: resistance moderate, agent may not be completely destroyed; resistance low, agent completely destroyed.
(d) Dose required to cause infection in 50% of healty volunteers.

(Source WHO, 1996)

TABLE 2. WATERBORNE VIRAL PATHOGENS AND THEIR SIGNIFICANCE IN WATER SUPPLIES

Pathogen	Health significance	Main route of exposure (a)	Persistence in water supplies (b)	Resistance to chlorine (c)	Relative infective dose(d)
Adenoviruses	High	O, I, C	*	Moderate	Low
Enteroviruses	High	O	Long	Moderate	Low
Hepatitis A	High	O	Long	Moderate	Low
Hepatitis E	High	O	*	*	Low
Norwalk virus	High	O	*	*	Low
Rotavirus	High	O	*	*	Moderate

* = Not known or uncertain

(a) O = oral ingestion; I = inhalation in aerosal; C = contact with skin;

(b) Detection period for infective stage in water at 20°C: short = unto 1 week; moderate = 1 week to 1 month; long = over 1 month.

(c) When the infective stage is freely suspended in water treated at conventional doses and contact times: resistance moderate, agent may not be completely destroyed; resistance low, agent completely destroyed.

(d) Dose required to cause infection in 50% of healty volunteers.

(Source WHO, 1996)

2.2.2.3. PARASITES

Parasites of public health importance include protozoa and helminths. Intestinal protozoa pathogenic to humans which are waterborne include *Giardia intestinalis*, *Cryptosporidium parvum*, *Entamoeba histolytica* and *Balantidium coli* (WHO, 1996). These microorganisms have a worldwide distribution, although *Balantidium coli* is uncommon. Contamination of water supplies by sewage can lead to the transmission of these organisms.

Chang and Kabler (1956) reported outbreaks of waterborne amoebic dysentery associated with consumption of contaminated tap water. Outbreaks of giardiasis have been associated with untreated drinking water or water receiving disinfection only (Craun, 1979). Coliform microorganisms are not a good indicator for *Giardia* or *E. histolytica* in treated water because of the increased resistance of these protozoa to inactivation by disinfection. Thus in situations where disease outbreaks occur from drinking contaminated water, boiling of water may provide effective control of the intestinal protozoa.

Helminths potentially transmitted by drinking water are *Dracunculus medinensis*, *Ascaris spp.*, *Fasciola spp.*, *Trichuris spp.*, *Echinococcus spp.*, *Schistosoma spp.*, *Strongyloides spp.* and hookworms (WHO, 1972). Waiyaki (1987) estimated a 90% prevalence of schistosomiasis among Pokomo and Orma school children in Tana River District. Except for guinea worm, *Dracunculus medinensis* which is solely transmitted by drinking water, the vast majority of helminths are not primarily waterborne and therefore, not routinely examined for in water (WHO, 1996).

The major water associated vectors of disease causing agents are *Simulium spp.* (black flies), mosquitoes and tsetseflies (WHO, 1972).

2.2.2.4. FREE-LIVING MICROORGANISMS

Free-living organisms generally considered significant in water include phytoplankton (free-living bacteria, fungi and algae), zooplankton (free-living protozoa, rotifers, cladocera and worms) and macroinvertebrates (aquatic insect larvae, crustacea and gastropods). These microorganisms when present in water supplies may cause adverse effects on health, aesthetic problems, objectionable odours and taste, and can also interfere with water treatment (Palmer, 1977).

A relationship between high concentration of blue-green algae and outbreaks of gastroenteritis in humans have been reported in India (Gupta and Dashora, 1977) and in the Philippines (Dean and Jones, 1972). These microorganisms should be removed from drinking water reservoirs (WHO, 1984). This may be achieved by protection of the source, implementing good treatment practices, periodic and systematic swabbing and flushing of pipelines as well as monitoring water quality (WHO, 1996).

2.3. MICROBIAL QUALITY OF WATER

Microorganisms are widely distributed in nature and often find their way into most sources of natural waters. Examination of the microbial flora from different sources of natural waters has shown that underground water contains mainly soil microorganisms, whilst surface waters have a much more diverse flora (Watt, 1986). Surface water is subject to frequent changes in microbial contents caused by a variety of activities (Geldreich, 1990).

In rural areas, water from small streams draining isolated or uninhabited watersheds may possess acceptable bacteriological, physical and chemical quality for human consumption in its natural state (Wagner and Lanoix, 1959). However, in most instances, surface water is subject to pollution and contamination by

pathogenic microorganisms and cannot be considered safe without treatment. Berrel and Rowland (1979), in their study found out that during onset of rains, rural water was highly contaminated with coliforms and faecal streptococci.

Ground waters have for a long time been considered free of pathogenic microorganisms and therefore consumed without treatment. However, human activities such as discharge of untreated wastes, uncontrolled and excessive use of fertilizers have made ground water susceptible to contamination. In addition, ground waters are also subject to contamination from natural sources because of changes in hydrologic regimen due to such activities as pumping, drilling, excavating or dredging (Morris, 1965). Biological activities apart from being sources of organic wastes, can also be potential sources of pathogenic microorganisms to ground water (FAO, 1979). Kaba (1990) in his study of the microbiological quality of borehole water around Nairobi, found that out of 71 boreholes sampled, thirty (42%) were contaminated with coliforms and 18 (25%) with faecal coliforms. Contamination of ground water in the United States of America, has been reported to cause disease outbreaks (Fradkin *et al.*, 1989). It is therefore recommended that, where contamination is suspected, ground water should be treated before consumption.

In areas where there is no ground water or where the quality of such water is objectionable for domestic use, rainwater is collected in tanks or cisterns. The quality of rainwater is affected by the nature and the maintenance of the collecting surfaces. Water running off roofs into domestic tanks may contain wind blown dust, bird and animal droppings. In some parts of the world, it is common practice for the users to hold the down pipe away from the tank to allow the first polluted flush to run to waste. Storing water for several weeks at temperatures of between 10-15°C destroys most of the disease causing pathogens.

In addition, the sediment and organic matter settle out with time (Watt, 1986).

Some piped supplies of drinking water are chlorinated or disinfected. Efficient chlorination yields water that is free from coliforms. If piped supplies are distributed without chlorination, the water must be disinfected before consumption. Water which enters the distribution system may become contaminated before it reaches the consumers tap. Coliform microorganisms may gain access to water in the distribution system from booster pumps, packing used in jointing of mains or from washers on service taps. In addition, contamination from outside the distribution system may gain access, for example through cross-connections, back siphonage, defective reservoirs and water tanks and inefficient repairs to domestic plumbing systems. In Canada, a large outbreak of *Campylobacter jejuni* gastroenteritis was attributed to the contamination of unchlorinated municipal water supply by the meltwater entering the municipal wells. Stool specimens from 29 patients yielded 8 unknown serotypes and one previously known serotype of *Campylobacter jejuni* (Millson *et al.*, 1991).

Inadequate water-supply facilities have made water storage a common practice in urban areas of Kenya. The microbial quality of water stored in tanks depends on the original quality of water put in the tank. If the tank was not open to contamination, the stored water would over time purify itself of most of the harmful bacteria by natural processes (Watt, 1986). Khalid Mohammed (1993) observed that 93% and 78.3% of stored water sampled out of 60 home tanks in Kikuyu Division of Kiambu, were contaminated with faecal coliforms and faecal streptococci respectively. Of the faecal coliforms, 56.7% were non-enteropathogenic *E. coli* and 16.7% were enteropathogenic *E. coli*.

The possibility of pollution of water occurring between collection and use especially where public standpipes are used has long been recognised (Wagner and

Lanoix, 1959). Lindskog and Lindskog (1985) found out that water becomes easily contaminated between tap and consumption at homesteads. A study carried in Guatemala, showed that, 97% of the water samples collected from piped distribution systems were free of coliforms, but 65% of the samples from home containers had acceptable levels (Torun, 1982). Risks of water contamination between collection and use as a result of various reasons, such as collection and storage of drinking water in open vessels which are not regularly cleaned, use of communal cups to draw water as well as touching the water during collection, storage and use have been confirmed by Burgers *et al.*, (1988).

The association between water contamination and human diseases is not clear. This is because Kirchhoff (1982) found that disinfection of heavily contaminated water stored in the home had no impact on the morbidities of diarrhoea, where as Deb (1986) found out that the use of long-necked water storage jars which prevented contamination of the stored water protected families from cholera. Yeager (1991) reported that diarrhoeal incidence in children was lower in households using water reservoirs with a tap but higher when a bucket had been used to retrieve the water from the storage containers.

2.4. WATER-ASSOCIATED HUMAN INFECTIONS

Water plays an essential role in supporting human health. However, it also has a great potential for transmitting a wide variety of diseases. Poor quality water supplies are associated with high morbidities of infectious diseases. Water-associated diseases can be caused by pathogenic bacteria, worms, viruses and protozoa. According to WHO (1980), 30,000 people die daily worldwide from water-related diseases. In developing countries, 80 percent of all health problems are water-associated. In addition, a quarter of children born in those

developing countries die before the age of five from water-associated diseases.

The categorization of water-related diseases may be based on their modes of transmission as water-borne, water-washed, water-based and water-related insect vectored diseases (Hofkes, 1983).

2.4.1.WATER-BORNE DISEASES

The water-borne diseases are the most prevalent of the water-associated diseases. These include diseases whose causative agents are spread through the contamination of water with either human and animal faeces or urine. For example, cholera, infectious hepatitis, leptospirosis, gastroenteritis, amoebic dysentery, bacillary dysentery, paratyphoid, typhoid, and tularaemia. In these diseases water acts as a passive vehicle for each of the causative agent. It is worthy noting that all waterborne diseases can also be transmitted by any routes which provide opportunities for the ingestion of faecal material. Thus, cholera may be spread by contaminated food. Control of such diseases can be achieved by improving the quality of water by treatment.

It has been demonstrated that there is a close association between inadequate environmental sanitation and high morbidities of water-borne diarrhoea and enteric pathogens (Henry, 1981). Thus in Chogoria, access to safe water was associated with a 40% drop in occurrences of diarrhoeal cases among the people who used safe water as compared to those who used unsafe water (Goldberg *et al.*, 1987).

2.4.2. WATER-WASHED DISEASES

These are infections of the intestinal tract and skin which could significantly be reduced following improvements in domestic and personal hygiene.

improvements in hygiene are highly related to availability of adequate quality water. Examples of such diseases are ascariasis, taeniasis, hydatidosis, conjunctivitis, myiasis, leprosy, scabies, skin sepsis, ulcers and trachoma.

Poor hygiene, inadequate water supply and low water quality increase the rate of spread of water-washed diseases. Results from a cross-sectional survey of dermal conditions in a representative sample of school children in the Ankole District in Uganda gave a prevalence of 49.6% and 42.3% for scabies and skin sepsis respectively (Cook, 1967). Epidemiological studies have shown that eye infections associated with water availability are a major problem in semi-arid areas. Prost and Negrel (1989) indicated that daily face-washing reduced both the prevalence and intensity of trachoma in children. In areas with plenty of good quality water supply cases of trachoma are low (Bradley, 1977).

2.4.3. WATER-BASED DISEASES

A water-based disease is one which the pathogen spends a part of its life cycle in an intermediate aquatic host(s). All these diseases are due to infection by parasitic worms which depend on the presence of aquatic intermediate hosts to complete their life cycles. The larvae of these worms are directly ingested with water or indirectly on foods. The most important diseases in this group are guinea-worm and schistosomiasis. The schistosomes bore their way directly into human skin and are therefore a hazard to those in constant contact with infective water, whether for domestic use or not (WHO, 1972).

2.4.4. WATER ASSOCIATED INSECT VECTORED DISEASES

These are diseases which are transmitted by insects which either breed in water or bite "near water". For example, malaria, onchocerciasis, yellow fever,

and dengue are transmitted by insects which breed in water while trypanosomiasis is transmitted by riverine tsetsefly which bites "near water".

2.5. QUALITY OF DRINKING WATER.

Water quality examination is based on the determination of certain microorganisms, minerals and organic compounds contained in water. The basic requirements for drinking water are that it should be free of pathogenic microorganisms, compounds that have adverse health effects, and should be fairly clear, not saline, have no compounds that cause offensive taste nor smell and cause no encrustation nor corrosion of the water supply system and not stain clothes washed with it (Hofkes, 1983).

In 1985, the WHO published "Guidelines for drinking water quality" which gave the tolerable levels for bacteriological, physical and chemical constituents of drinking water (WHO, 1985). With the aid of these guidelines, individual countries are expected to formulate their own national standards for water quality based on prevailing local conditions.

The most important parameter of drinking water quality is the bacteriological condition. Standards for bacteriological water quality are based on microorganisms that are non-pathogenic but their presence serves as indicators of contamination. The levels of certain intestinal indicator microorganisms are used to determine the degree of health risks which may result from consuming the contaminated water. In addition, they are used to monitor the effectiveness of the water treatment in reducing microbial numbers so that the risks are reduced to acceptable levels.

According to WHO (1985) guidelines chlorinated or otherwise disinfected water supplies should not contain coliforms in any 100ml-sample of water entering

the distribution system. In non-disinfected supplies there should be no (faecal) *E. coli* in 100ml-sample of water. In principle, all samples taken from the distribution system (including consumers premises) should be free from coliforms (WHO, 1972). In Kenya, the Kenya Bureau of Standards (KBS) requires that treated water entering the distribution systems should have 0/100 ml faecal coliforms. For untreated water entering the distribution systems, the faecal coliforms should be 0/100 ml and 3 coliform microorganism from other sources in any one sample or 0 in any 2 consecutive samples or 0 in 98% of yearly samples (KBS, 1985).

2.6. MICROBIAL INDICATORS OF FAECAL POLLUTION OF WATER

Contamination of drinking water by human or animal excrement or by sewage are dangerous especially if among the contributing population there are cases of carriers of infectious enteric diseases which are waterborne. The recognition that polluted water is responsible for spread of waterborne infections has led to the development of sensitive methods for evaluating the quality of drinking water to ensure that it is free from faecal pollution (WHO, 1985). However they are relatively expensive and time consuming. As a result of this, water is routinely examined only for specific types of bacteria which originate in large numbers from human and animal excreta and whose presence in water is indicative of faecal pollution. According to Bonde (1977), microorganisms indicative of faecal pollution should be present whenever pathogens are present, occur in greater numbers than the pathogens, be more resistant to disinfectants and to aqueous environments than the pathogens and grow readily on relatively simple media.

In the late 1800's, Houston proposed the use of three groups of bacteria

(coliforms, faecal streptococci and gas-producing clostridia which are commonly found in the faeces of warm-blooded animals) as indicators of faecal pollution of water (Hutchinson and Ridgway, 1977). He argued that since these groups could only come from faecal sources, their presence would indicate faecal pollution.

The use of these normal intestinal flora rather than the pathogens themselves is universally accepted for monitoring and assessing the bacteriological quality of water. The criteria to be satisfied by an ideal indicator cannot be met by any one microorganism. However, many of them are best fulfilled by *E.coli* and to, a lesser extent by thermo-tolerant coliform bacteria. Thus, *E.coli* is the indicator used universally to assess bacteriological contamination of water in both tropical and temperate countries (Barbaras, 1986).

E.coli and coliform microorganisms are however not good indicators for enteroviruses and cysts of some parasites in treated water. This is because they are resistant to inactivation by the commonly used disinfectants (WHO, 1984). In non-disinfected water, the presence of indicator bacteria could suggest the presence of pathogenic protozoa.

Other microorganisms, for example faecal streptococci, enterococci and spores of sulfite-reducing clostridia, typified by *Clostridium perfringens* are not routinely used as indicators but have useful properties which enable them to be used for particular purposes. Although these microorganisms are less numerous than coliforms in faecally polluted waters, they however have long survival periods and so they may be used to confirm the presence of faecal contamination when *E.coli* is not found.

2.6.1. ESCHERICHIA COLI

E.coli is found in large numbers in the faeces of humans and of nearly all

warm-blooded animals. It is found in sewage, effluent, all natural waters and soils subjected to recent faecal contamination. The presence of *E.coli* in water indicates the need for immediate action. This is a gram negative, non-spore forming and rod-shaped bacterium which can either be motile or non-motile (motile ones are peritrichous). Growth is aerobic or facultatively anaerobic. Metabolism is both respiratory and fermentative. Acid is produced by the fermentation of glucose and lactose. Catalase is produced but not oxidase, and nitrates are reduced to nitrites.

Serological typing is based on the somatic O-antigens, the capsular K-antigens and the flagellar H-antigens. Serological identification of *E.coli* is too complicated for routine use, hence certain tests are used which identify this microorganism with high degree of specificity.

2.6.1.1. PATHOGENIC ESCHERICHIA COLI

Most of the strains of *E.coli* are non-pathogenic although some pathogenic ones are known to occur. Four strains of pathogenic *E.coli* are recognised namely enteropathogenic, enteroinvasive, enterotoxigenic and enterohemorrhagic.

Enteropathogenic (EPEC) subtypes of *E.coli* are capable of producing diarrhoea without producing enterotoxins and are not invasive (Levine *et al.*, 1983). These subtypes have been associated with outbreaks of infantile gastroenteritis although their exact pathogenic mechanisms are not fully understood (Scotland, 1989). Enteroinvasive strains of *E.coli* (EIEC) produce dysentery by a mechanism similar to that of *Shigella spp.* The microorganisms invade the colonic mucosa and cause bloody diarrhoea. This invasive property is demonstrated by the guinea pig keratoconjunctivitis test (Sereny, 1955).

Enterotoxigenic (ETEC) *E.coli* cause a cholera-like syndrome in infants,

children and adults. From an epidemiological point of view it is responsible for most episodes of *E.coli* diarrhoeal cases especially in developing countries. The ETEC strains produce either heat-labile enterotoxin (LT), or heat-stable (ST) enterotoxin (Clements and Finkelstein, 1979). Some strains produce both toxins. The production of toxins is controlled by plasmids. The production of both LT and ST is encoded for by transferable plasmid DNA, with different plasmids governing production of LT alone, LT and ST and ST alone (Gyles *et al.*, 1974: Wachsmuth *et al.*, 1976). The action of LT enterotoxin is the same as cholera toxin.

The ability of ETEC to cause disease depends not only on the production of enterotoxin, but also the ability to colonize the small intestines. Various colonization or adherence factors have been described which enable the bacteria to attach themselves to intestinal mucosa (Smith and Linggood, 1972: Jones and Rutter, 1972; Naggy *et al.*, 1977) permitting the release of enterotoxin close to the reactive sites. The disease caused by ETEC is clinically indistinguishable from clinical cholera (Dopont *et al.*, 1971; Mundell *et al.*, 1976; Field, 1979).

Enterohemorrhagic *E.coli* produce a cytotoxin referred to as verocytotoxin (VT) or shiga-like toxin (Konowalchuk *et al.*, 1986). This microorganism belongs to the serogroup O157:H7 and has been associated with outbreaks of haemorrhagic colitis in the United States (Riley *et al.*, 1983). The disease is characterized by blood-stained diarrhoea which is usually without fever but accompanied by abdominal pains. There is a strong incrimination of VT-producing *E.coli* (VTEC) as a cause of haemolytic uraemic syndrome (HUS) (Spika *et al.*, 1986).

2.6.2. THERMOTOLERANT (FAECAL) COLIFORMS

These coliforms are characterized by their ability to ferment lactose at 44-45°C and comprise of those belonging to genus *Escherichia*, *Citrobacter*,

Enterobacter and Klebsiella (WHO, 1984). The *E.coli* is the only specific coliform of faecal origin which is always present in the faeces of man and animals in large numbers and rarely found in water and soil which have not been subjected to faecal pollution.

Thermotolerant coliforms other than *E.coli* have also been found to occur naturally on vegetation in tropical rainforests, decaying plant material and soils (Rivera, 1988). This therefore means their occurrence in water does not necessarily indicate faecal contamination of human origin. Thermotolerant coliforms are less reliable indicators of faecal contamination than *E.coli* (WHO, 1996). However, their presence should not be ignored, as the basic assumption that pathogens may be present and treatment has been inadequate still holds. Their use in assessing the water-quality is acceptable and methods of detecting them are relatively simple and widely available.

2.6.3. COLIFORM GROUP

Coliforms have for a long time been recognised as suitable microbial indicators of drinking water quality, because these microorganisms are easy to detect and enumerate in water. Coliforms are defined as microorganisms which display B-galactosidase activity (WHO, 1996). These are Gram-negative non-spore forming bacteria capable of growing in the presence of bile salts and ferment lactose at 35-37°C with production of acid, gas and aldehyde within 24-48 hours. They are oxidase negative and when the Membrane Filter Method is used, produce a dark colony on filter and a metallic sheen on an endotype medium containing lactose when incubated for 48 hours at 37°C (APHA, 1989). This group comprises of *Escherichia coli, Citrobacter, Enterobacter and Klebsiella* species. In modern taxonomical groupings, other lactose fermenting bacteria found both in faeces and

the environment such as *Enterobacter cloacae* and *Citrobacter freundii* are included in the coliform group.

The coliform group also contains species rarely found in faeces and which can multiply in good quality drinking water namely *Serratia fonticola*, *Rahnella quatilis* and *Buttiauxella* (WHO, 1996). Several species of *Serratia* and *Yersinia* have also been isolated from faecally uncontaminated water and soil.

The existence of non-faecal bacteria that fit the definition of coliforms limits the use of this group as indicators of faecal pollution. Gordon (1990) indicated that coliforms do not fit most of the underlying assumptions of a good indicator of faecal pollution in tropical waters. He suggested the use of anaerobes or their phages, primarily due to their ability to survive outside the intestinal tract. Coliform bacteria should not be detectable in treated water supplies and if found, they suggest inadequate treatment or post-treatment contamination (Kabler, 1954).

Although coliforms may not always be directly related to the presence of faecal contamination or pathogens in drinking water, their test is still useful for monitoring microbial quality of public water supplies (Akin, 1975). When coliforms are found in the absence of "faecal" coliforms and *E.coli*, secondary indicator microorganisms such as faecal streptococci and sulfite-reducing clostridia especially *Clostridium perfringens* may be used to determine the presence of faecal contamination.

2.6.4. FAECAL STREPTOCOCCI GROUP

This group consists of microorganisms belonging to the genera *Enterococcus* and *Streptococcus*. They occur in the intestinal tracts of man and animals and are regarded as specific indicators of faecal pollution of water under many practical

conditions. The main problem encountered using these microorganisms as indicators of water contamination is that they are short-lived as compared to coliforms, and they may give a wrong impression that the water is safe although other pathogens are still surviving. However, they can be used to assess the significance of doubtful coliform results of a test.

The ratio of faecal coliforms to faecal streptococci could provide information about the source of contamination (APHA, 1989; Geldreich, 1966, 1970; Feachem, 1973). A ratio greater than four indicates human faecal contamination whereas a ratio of less than 0.7 suggest contamination of non-human sources.

The isolation and identification of faecal streptococci using conventional media such as M-enterococcus, KF-streptococci agar and azide glucose broth are relatively simple and in-expensive, and known to be highly specific for faecal pollution (Grabow, 1986).

2.6.5. SULFITE REDUCING CLOSTRIDIA

These are anaerobic, spore-forming microorganisms. Of these, the most characteristic, *Clostridium perfringens* is normally present in faeces of man and animals but occur in smaller numbers than *E. coli*. Nevertheless, *Cl. perfringens* survives much longer than either coliform bacteria or streptococci and resist disinfection. Its presence in disinfected waters may indicate inadequate treatments (Kool, 1979).

According to Gordon (1990), *Cl. perfringens* satisfies most but not all of the criteria for an ideal indicator (Bonde, 1977) than faecal coliforms or faecal streptococci. The inability of this bacterium to proliferate in waters makes it a suitable indicator of recent faecal pollution. Unfortunately, techniques for the isolation and identification of *Cl.perfringens* are sophisticated and

expensive.

The use of *Cl. perfringens* as water quality indicator has been rarely used due to the fact the spores are known to survive for a long time in water even after all the other contaminants have been eliminated. The long survival of *Cl. perfringens* spores might lead to confusion when they are detected in water. Dolman and Iida (1963) indicated that *Cl. botulinum* type E spores found in coastal areas have their origin from land masses and are carried down by water sources. Similarly, the same may apply to *Cl. perfringens*, so that when they are found in streams it may be far removed from the point of entry, and any other vegetative bacteria associated with it might long have ceased to exist (Muhammed, 1971). The endospores have high specific gravity and tend to settle at the bottom of the water thus they can be missed during testing. Therefore, these organisms are not efficient indicators of water pollution.

World Health Organisation regards the presence of *Cl. perfringens* as confirmatory of pollution of faecal origin, and in the absence of faecal coliforms, a reflection of a distant pollution (WHO, 1963). Detection of *Cl. perfringens* by Membrane Filtration Technique (MF) depends upon the development of large black halos as read from the reverse side of the plate. Enumeration is only possible in water samples with very low microorganism density.

2.6.6. MISCELLANEOUS INDICATORS OF WATER QUALITY

Feachem and Geldreich (1981) indicated that microorganisms like *Aeromonas* and *Pseudomonas* may be used in assessing the hygienic quality of drinking water. However, examination of these microorganisms is not essential for routine monitoring (WHO, 1996). They are only valuable in certain circumstances in giving an indication of the general cleanliness of the water distribution system and in

assessing the quality of bottled water.

Bacteriophages have been proposed as indicators of water quality, particularly with respect to human enteric viruses. This is because of their simple nature and their relative ease of detection in water samples (Havelaar, 1991). Borrego *et al.*, (1987) examined specific *E. coli* bacteriophage to see whether it might serve as an effective and reliable indicator of faecal pollution of water. Two groups of bacteriophages namely somatic coliphage and F-specific RNA bacteriophages, although they do not occur in large numbers in faeces are invariably found in sewage. They are therefore primarily used as an index of sewage contamination of water and as an additional indicator of the efficacy of water treatment because of their high persistence as compared to bacterial indicators.

Bifidobacteria and the *Bacteroides fragilis* are anaerobes which are faeces-specific and do not survive or multiply in waters. They have been seen as alternative to coliform group in tropical and semitropical areas (Allsop *et al.*, 1985). However, their rate of decay in polluted water is greater than that of bacterial indicators hence unreliable.

2.7. STANDARD TECHNIQUES FOR TESTING BACTERIOLOGICAL WATER QUALITY

Bacteriological examination of water is aimed at detecting recent faecal pollution. The following techniques are used in bacteriological examination of water.

2.7.1. MULTIPLE TUBE FERMENTATION TECHNIQUE

This method is described in APHA (1989). Briefly, this technique involves adding measured volumes of water samples to sets of sterile tubes/bottles

containing lactose. After incubation at 37°C for 48 hours, the tubes are checked for positive reactions. The technique utilises the ability of coliform to ferment lactose with the production of acid and gas. The gas is detected by its appearance in a Durham tube inserted into every tube or bottle. The acid is detected by using various indicators. The number of tubes showing positive reaction are recorded and an estimate of the Most Probable Number (MPN) of microorganisms present in the original sample is obtained by using McCradys statistical tables. This technique, however only gives a statistical estimate of the Most Probable Number (MPN) of the coliforms (APHA, 1989).

False positive reactions have been reported to occur which are thought to be dependent on the bacterial flora of water and the medium used (Thompson, 1927: Bossong *et al.*, 1981). In addition, false negative reactions when using the Standard Most Probable Number (S-MPN) technique have also been reported by Evans *et al.*, (1981). However, when they used Modified Most Probable Number (M-MPN), they managed to observe different species of coliforms, including *Citrobacter, Enterobacter, Klebsiella and Escherichia.* Despite all these drawbacks, the technique is still in use until there is development of more sensitive and specific methods.

2.7.2. MEMBRANE FILTRATION TECHNIQUE

Membrane filters (MF) made up of cellulose, first described by Zsigmondy and Bachmann (1918), were patented in the United States in 1922 (Zsigmondy and Bachmann, 1922). Membrane Filtration Technique involves filtering a measured volume of water sample (usually 100ml) through a membrane which has 0.45um pore sizes. Microorganisms are retained on the filter surface which is then incubated face upwards on a suitable selective medium containing lactose. Microbial

colonies developing on the membrane are counted as presumptive number of coliforms of faecal origin. The visible colonies are counted and expressed in terms of the number in 100ml of the original water sample (WHO, 1983).

The technique is advantageous over the others because of its ability to concentrate and localize the bacteria from large sample volumes. Therefore, this increases the sensitivity of quantifying bacteria.

When using various brands of filters, Dukta (1973) encountered a number of problems. For instance, he observed that Sartorius membranes showed hydrophobic areas that limit the true filtering areas. Upon autoclaving both Sartorius and Millipore membrane filters, they became distorted and a bit fragile. Moreover, while testing for faecal coliform density, he also found out that Millipore membrane filters frequently produced beige-yellow background which made counting very difficult. In case of high colony concentration the recovery of microorganisms by the membrane filters decreased due to increased probability of overlapping by the colonies.

Kabler (1954) compared Membrane Filtration Technique (MF) with Most Probable Number procedure in the recovery of coliforms from water samples. Using the two procedures, Kabler examined 1706 water samples and achieved an agreement of 73.8% between them in the recovery of coliforms. He however thought that the two methods were not measuring the same type of organisms. Presnell *et al.*, (1954) obtained 87.1% agreement between the two methods when they applied to coliform detection from sea water. Jannasch and Jones (1959), however, indicated that MPN method gave a count 20 times greater than MF technique when used with sea water.

Bradley and Emurwon (1968) using Modified Endo-Medium and MF with East African surface water, found that too many non-coliforms developed on the Endo-

medium. False positive reactors have also been reported on this medium (Schiff *et al.*, 1970). The technique is therefore best employed for the recovery of coliforms from treated water.

2.7.3. OTHER TECHNIQUES

Other procedures belong to a new generation of techniques which are developed with the objective of reducing the enumeration time which seems to be the major disadvantage of the standard techniques for bacteriological analysis of water.

The use of Presence - Absence (P-A) Test, as an alternative to Membrane Filtration and Multiple Tube Technique, for monitoring the quality of drinking water was first suggested by Clark (1968). Initial studies used double strength MacConkey broth modified by addition of 10g per litre of tryptone. The test was performed by adding 50 ml of water sample to 50 ml of the modified broth in glass-screwed bottles containing inverted Durham tubes. The P-A bottles were incubated at 37°C for five days and checked daily for growth and acid or acid and gas production. Inoculum from positive presumptive bottles were transferred to confirmatory medium and on MacConkey agar plate. The first study revealed that P-A Test produced 478 confirmed positive results for coliforms whereas, Membrane Filtration Technique produced only 317 confirmed positive results. The P-A Test produced a higher number of positive tests, demonstrating a greater sensitivity for detection of coliforms than the Membrane Filtration Technique (Clark *et al.*, 1982).

A defined substrate method (Edberg *et al.*, 1989) has been applied to drinking water to simultaneously enumerate total coliform and total *E. coli* directly from water samples. Following an incubation period at 35°C for 24 hours,

development of a yellow colour from the initially colourless solution was specific for total coliforms. Fluorescence at 266nm in the same tube(s) demonstrated the presence of *E. coli*. The method is known as Autoanalysis Colilert (AC) and has been claimed to give results comparable to the standard methods in presence - absence format.

A Hydrogen Sulphide Screening Test for water quality was compared to the Standard Multiple Tube Technique and found to be highly sensitive and specific and showed a high predictive value (Bukenya, 1990). This test has been recommended as suitable for the developing countries where resources are very limited.

Reasoner and Geldreich (1989) recommended the use of Carbon-14 Labelled Mannitol to detect coliforms in water by testing the production of carbon dioxide. It has been claimed that this technique can give results within 4-5 hours.

Specific enzymes can be used as surrogate measures of coliform levels (Berg and Fiksdal, 1988). Lechevallier *et al.*, (1983) proposed an enzymatic procedure for identification of coliform, based on O-nitrophenyl-b-galactopyranoside (ONPG) hydrolysis and cytochrome oxidase activities. A direct Membrane Filtration method incorporating MU-B-D-galatosidase into agar medium allowed the detection of as few as one faecal coliform per 100 ml within 6 hours.

CHAPTER THREE

MATERIALS AND METHODS

3.1. AREA OF STUDY

3.1.1. DESCRIPTION

The study was carried out in Kibera slums which is located in Kibera Sub-location, approximately 7 kilometres southwest of the Nairobi City centre. Kibera is bordered to the south by the steep valley of Mutoine River, to the east by the Nairobi Dam, to the north by the Golf Course and Woodley estates and to the west by Ngong Forest (Figure 1). The Kibera slums are comprised of nine villages, namely, Mashimoni, Kambi Muru, Kianda, Lindi, Laini Saba, Gatuikira, Soweto, Siranga and Makina (Figure 2). In 1969, Kibera had a population of 13,000 (Kenya population census 1969, Vol.1). By 1979, it was 25,000. These figures indicate that the population has been increasing at a rate of about 6,000 persons every 5 years. Although it is difficult to ascertain the exact population, Kibera sublocation has an estimated population of about 300,000 - 500,000 people (Anon, 1987).

3.1.2. ENVIRONMENTAL FACTORS

The general environment of the area both inside and outside the houses was noted and recorded. Details of the site, type of outside water tanks and their surroundings were also recorded.

3.2. STERILIZATION OF GLASSWARE AND MEDIA

All glassware used in the study (e.g sample bottles, pipettes, petridishes, Durham tubes etc) were thoroughly washed with hot water containing detergent and rinsed with distilled water. They were then dried in a hot air oven at 100°C.

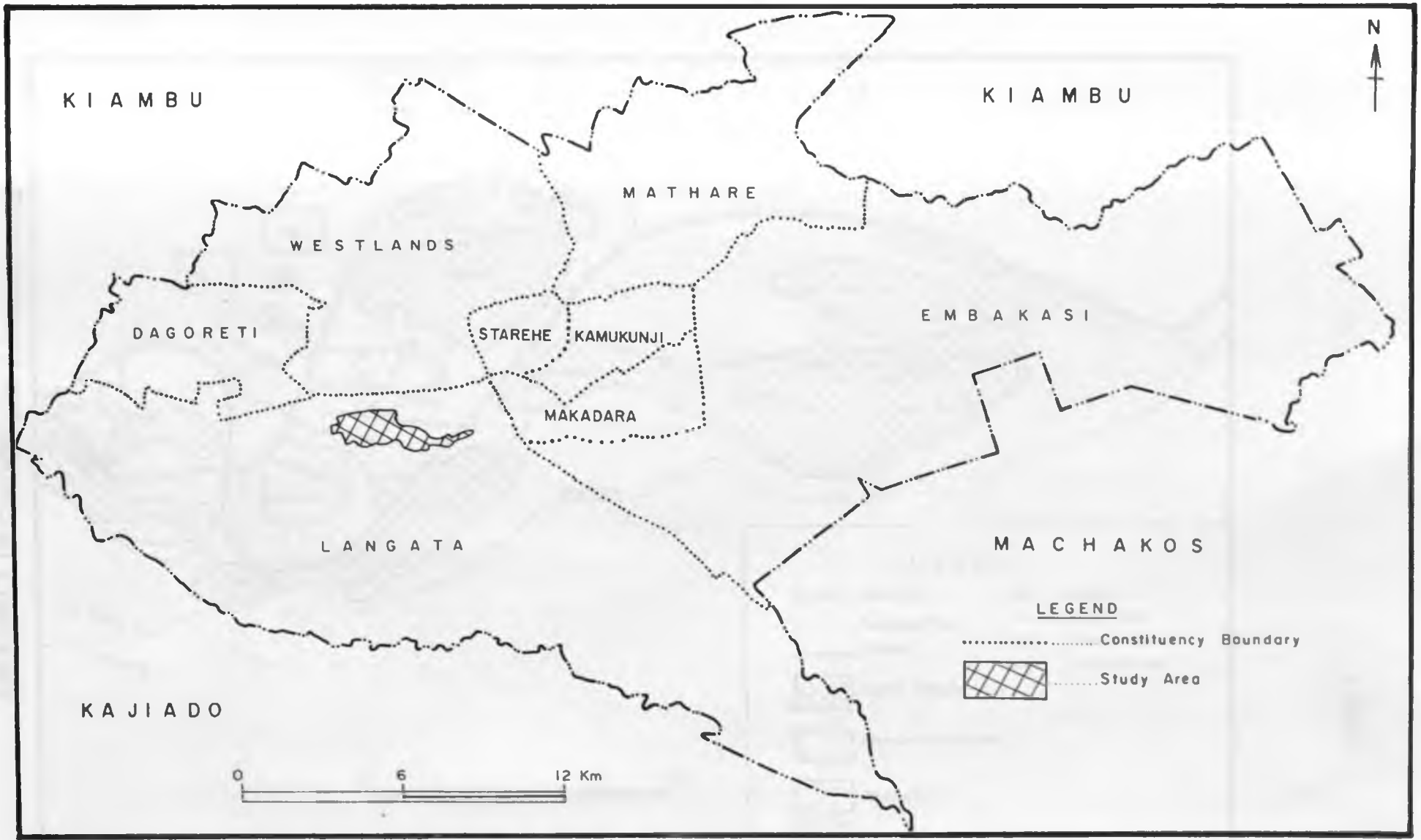

Fig. 1 : Location of the Study Area within Nairobi

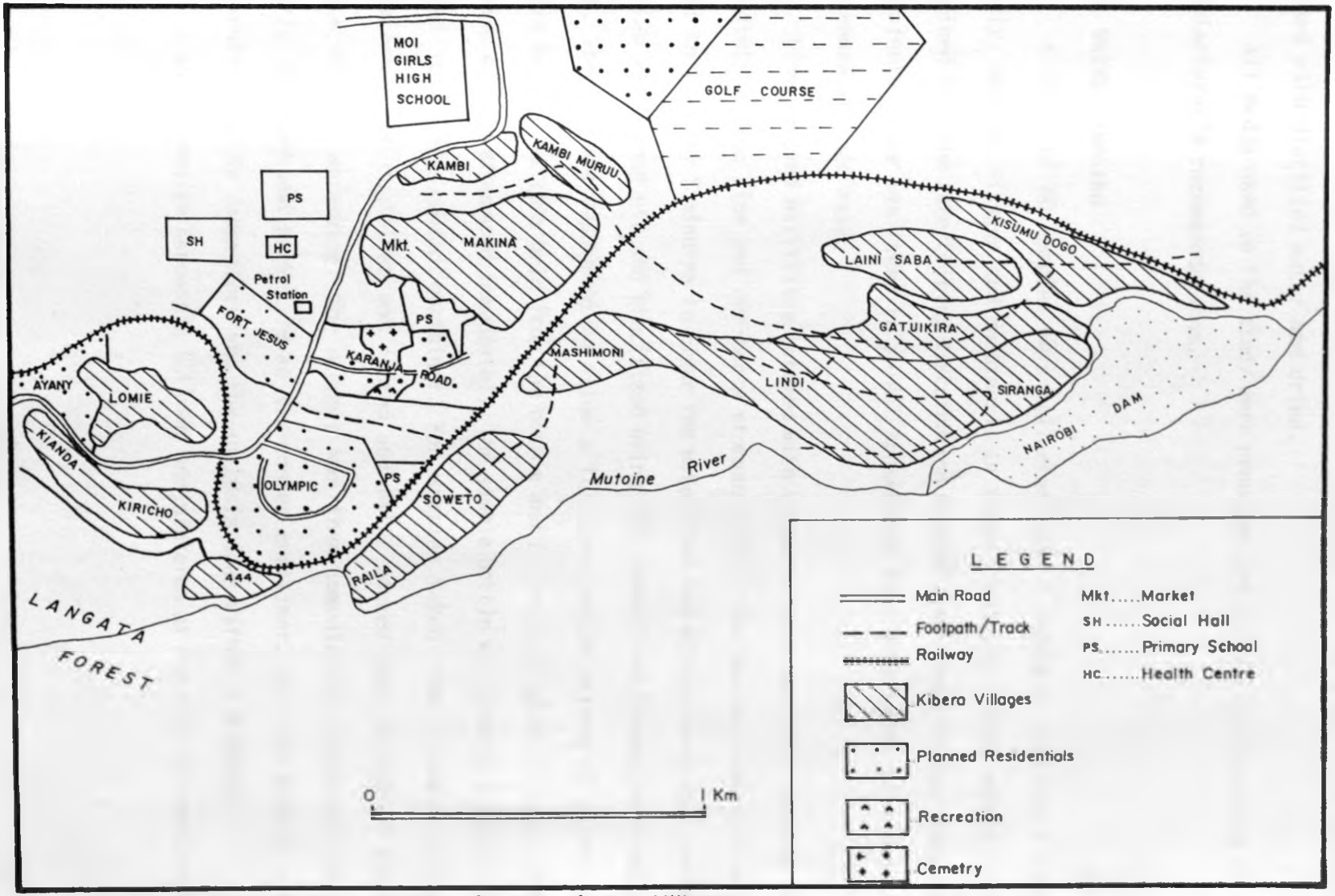

Fig. 2 Kibera : Approximate location of some of the Villages.

Sodium thiosulphate was added (0.1ml, 3%) to each sample bottle and all the glassware sterilized at 160°C for 2 hours. The glass bottles used to sample water for chlorine analysis were thoroughly washed with water and detergent, rinsed with distilled water and dried.

All media used in the study were prepared and sterilized according to the manufacturer's recommendations.

3.3. WATER SAMPLING

A total of 80 samples were collected from 3 randomly selected villages namely, Makina, Siranga and Mashimoni. In these villages, random samples were obtained from the intertwining distribution systems, out-house storage tanks and containers. Care was taken to select households that drew water from the same out-house storage tank.

Five hundred millilitre bottles with stoppers were used. For samples from the distribution line and out-house storage tanks, the tap was opened to allow water to flow for 2 minutes to clear the water that was within the piping system. The tap was turned off and sterilized using 70% alcohol and flaming with a blow lamp. The tap was regulated to allow a thin and gentle stream of water. The sample bottle was then held from the bottom and filled with water to about three quarter way and stoppered immediately. The sample bottle was clearly labelled and packed in an ice cooled container. For samples taken from in-house storage containers, the container was lifted and water poured into an opened sample bottle without splashing. The stopper was then immediately replaced, bottle clearly labelled and packed in an ice-cooled container. All the samples were transported to the laboratory and the analysis done within 3-6 hours.

A questionnaire (Appendix 1.1) was administered at the time of sampling to

determine the risk factors which could affect the "quality" of household water.

3.5. NON-QUESTIONNAIRE PARAMETERS

Water temperatures were taken using a thermometer (Brannan 760 mm) and recorded for each sample taken. The prevailing environmental conditions of each sampling point were noted and recorded.

The pH values and chlorine levels of the water samples were determined in the laboratory using a pH meter (Kent EIL 7020) and standard Lovibond comparator discs (Disc 3/4 c2) respectively.

3.6. BACTERIOLOGICAL EXAMINATION OF WATER SAMPLES

3.6.1. TOTAL BACTERIAL COUNT USING THE POUR PLATE METHOD.

Oxoid dehydrated plate count agar was prepared according to the manufacturer's recommendations (Appendix 3.1). The agar was maintained at 45-50°C in a water bath until required. The water sample in the bottle was shaken vigorously to evenly distribute the microorganisms in the sample. The stopper was removed and the bottle mouth flamed. Using a sterile pipette, one ml of the water sample was withdrawn and serially diluted in test tubes containing nine ml of sterile physiological saline. Each sample was diluted ten fold upto 10^{7} and one ml of each dilution was withdrawn and dispensed aseptically into sterile petridishes in duplicates.

A 20-ml quantity of the molten agar at 45-50°C was added to each petridish containing the diluted water sample and immediately mixed by rotating it in a figure eight. The agar in each petridish was allowed to cool and solidify. The petridishes were then incubated at 37°C for 48 hours. After the incubation time, the petridishes with countable colonies were selected and the colonies counted

using a colony counter. The mean count number for each sample was recorded as total bacterial count per ml of water on PCA at 37°C for 24-48 hours.

3.6.2. TOTAL COLIFORM COUNT USING MULTIPLE TUBE TECHNIQUE

3.6.2.1. PRESUMPTIVE TEST

Double strength MacConkey broth (Oxoid) was used (Appendix 3.2). Fifty ml of double strength broth were distributed into one universal bottle. In addition, 10 ml of the same broth were distributed into five universal bottles. Five ml-single strength broth was distributed into a set of five fermentation tubes. All the universal bottles and fermentation tubes were each provided with inverted Durham tubes for collection of any gas formed. The broth was sterilized in a pressure cooker at 121°C for 15 minutes and then cooled.

Water samples were shaken several times to distribute the microorganisms, bottle stoppers removed and mouths flamed. Using a sterile pipette, 10 and 50 ml of the sample was transferred into the universal bottles containing 10 and 50 ml of double strength broth respectively, while 1 ml of the sample was transferred into each of the five fermentation tubes containing 5 ml single strength broth. All the bottles and tubes were incubated at 37°C for 24-48 hours and observed for gas and acid production. The Most Probable Number of coliform was computed from McCrady's statistical table (Appendix 6.1).

3.6.2.2. CONFIRMATORY TEST USING SOLID MEDIUM

Eosin methylene blue agar (EMBA) was reconstituted, prepared and sterilized according to manufacturer's recommendations (Appendix 3.3). A 20ml-amount of the molten agar was aseptically dispensed into sterile petridishes and cooled. The broth in the positive presumptive tubes (subsection 3.6.2.1) was mixed by

rotating the tubes several times. Using a sterile wire loop, a small portion of the broth culture was removed from each of the tubes and streaked onto a plate of EMB agar. All the plates were incubated at 37°C for 24 hours. Appearance of deeply coloured nucleated colonies with or without metallic surface lustre on the plates within the incubation period constituted a positive confirmatory test.

3.6.3. FAECAL COLIFORMS.

A small portion of the culture from each positive presumptive tube was recultured in Brilliant green lactose bile broth prepared as summarised in Appendix 3.4 in fermentation tubes and incubated in a water bath at 44.5°C for 24 hours. The tubes were immersed in the water bath to the level of the broth tube. Production of acid and gas after the incubation period indicated presence of faecal coliforms.

3.6.4. TEST FOR ESCHERICHIA COLI

Plates of Eosin methylene blue agar (Oxoid) of the confirmed test (subsection 3.6.2.2) showing a metallic sheen were recultured on another EMBA plate, for further isolation. The streaked plates were incubated at 37°C for 24 hours. Colonies showing metallic sheen were tested for production of Indole, acid (Methyl red reactions), acetylmethylcarbinol (Voges-Proskaurer test) and growth on Citrate media (IMViC) to confirm whether they were *E. coli*.

A portion of the colony having a metallic sheen was inoculated into a fermentation tube containing Tryptone water broth prepared as given in Appendix 3.5. Two portions from the same colony were inoculated into a tube containing Methyl-red Voges Proskaurer medium (MRVP), prepared as given in Appendix 3.6, and another portion into a universal bottle containing Simmons citrate agar which was

prepared as given in Appendix 3.7. All tubes were incubated at 37°C for 48 hours. After the incubation period, Indole reagent (Appendix 3.8) was added to Tryptone water, Methyl red reagent (Appendix 3.9) into one tube of MRVP, and Creatinine (Appendix 3.10) and Potassium hydroxide (Appendix 3.11) to the other MRVP tube. Presence of *E.coli* microorganisms were indicated by the following reactions in of IMViC test: Indole positive, Methyl red positive, VP negative and Citrate negative (IMViC ++--). Confirmed *E. Coli* microorganisms were preserved in Nutrient agar (Appendix 3.12).

3.6.6. SEROTYPING OF ESCHERICHIA COLI ISOLATES

Samples of *Escherichia coli* isolates preserved in Nutrient agar were inoculated onto MacConkey agar prepared as shown in Appendix 3.13 and incubated at 37°C for 24-48 hours. Serotyping of the isolates was done using the commercial Polyvalent and Monovalent test sera (Denka Seiken Co., Japan).

A drop of polyvalent test serum was placed on a clean glass slide. A discrete *E.coli* colony was then taken from the culture on MacConkey agar plate and thoroughly mixed with the polyvalent serum on the glass slide to form an emulsion. The glass slide was rotated ten to twenty times while observing for agglutination. The procedure was repeated for all the eight polyvalent test sera and *E.coli*. *E.coli* isolates showing positive agglutination reaction were subjected to a further agglutination test using monovalent test sera to determine the specific serotype.

3.6.5. FAECAL STREPTOCOCCI

Sodium azide broth (Appendix 3.14) was used. Double-strength broth was

distributed into two sets of five fermentation tubes in 5 and 10 ml quantities. Five ml of single-strength broth were distributed into another set of fermentation tubes. All the tubes were sterilized in a pressure cooker at 121°C for 15 minutes and then cooled. Ten mls of the sample were inoculated in the series of tubes containing 10 ml double strength medium. While 1.0 ml and 0.1 ml of the sample were inoculated into the series of tubes containing 5 ml double strength and 5 ml single strength broth respectively as was done in the presumptive coliform test (subsection 3.6.2.1). All the tubes were incubated at 44°C to 45°C for 48 hours. The tubes were examined at the end of 18 hours, 24 hours and 48 hours. Production of acid in 18 - 48 hours indicated the presence of faecal streptococci. The Most Probable Number of faecal streptococci was calculated from the McCradys' statistical tables (Appendix 6.2).

3.6.5.1. CONFIRMATORY TEST

MacConkey agar was prepared as recommended by the manufacturers (Appendix 3.13). It was sterilized, dispensed in sterile petridishes and cooled. An inoculum from the positive azide (subsection 3.6.5) tube was streaked on MacConkey agar and incubated at 37°C for 48 hours. Growth of minute red colonies on the media confirmed the presence of faecal streptococci in the sample.

3.7. STATISTICAL ANALYSIS.

Statistical analysis of the data was done using Harvard Professional Computer. The data was first entered into Data base (Dbase) and then transferred to Statistix (SX) and SAS system from where it was analyzed. The continuous variables were subjected to the Wilk-Shapiro test to determine whether they conformed with the assumption of normal distribution. The total bacterial count,

Most Probable Number and the faecal streptococci numbers were found not to agree with this assumption hence transformed to natural logarithm. A summary statistics of all continuous variables and a frequency distribution of all non-continuous variables was done.

One way analysis of variance (ANOVA) (Daniel, 1983) was performed to compare variation of water temperature, pH, total bacterial count, coliform count and faecal streptococci between out-house and in-house water. Questionnaire derived variables were also tested against other variables. Correlation analysis was done to determine the existence of any association between the continuous variables.

CHAPTER FOUR

RESULTS

4.1. WATER SOURCES AND WASTE DISPOSAL

Most households obtained water from water out-house tanks (Figure 3a) or standpipes (Figure 3b). The latter were supplied with water by the Nairobi City Council through a vast network of intertwining pipes made of either metal or plastic. Some pipes were old and rusty while others had rubber seals to prevent leakage.

There was no proper drainage to carry waste water from households. Waste water was left to flow along the spaces between houses and also the footpaths (Figure 4). Garbage disposal facilities did not exist. Refuse from houses was dumped in open spaces between the blocks of houses. Several households shared a single pit latrine which was not kept clean.

4.2. PHYSICAL AND CHEMICAL ANALYSES OF WATER SAMPLES

The analytical results of the water temperatures for all study samples are shown in Appendix 4 and Appendix 5.1 The lowest and the highest temperatures were 17°C and 26°C with a mean of 22.96°C and a standard deviation of 1.69°C.

The temperature range for out-house water was 19.5°C to 26.0°C with a mean of 23.03°C and a standard deviation of 1.56°C (Appendix 5.2). In-house water had a temperature range of 17.0°C to 24.5°C with a mean of 22.94°C and a standard deviation of 1.74°C (Appendix 5.3). There were no significant differences between in-house and out-house water temperatures ($P = 0.8500$, Appendix 5.4). Village-specific water temperatures are shown in Appendices 5.5 to 5.7. There were no significant differences between water temperature among the villages ($p = 0.8121$, Appendix 5.8)

Figure 3a: Photograph showing an out-house storage tank.

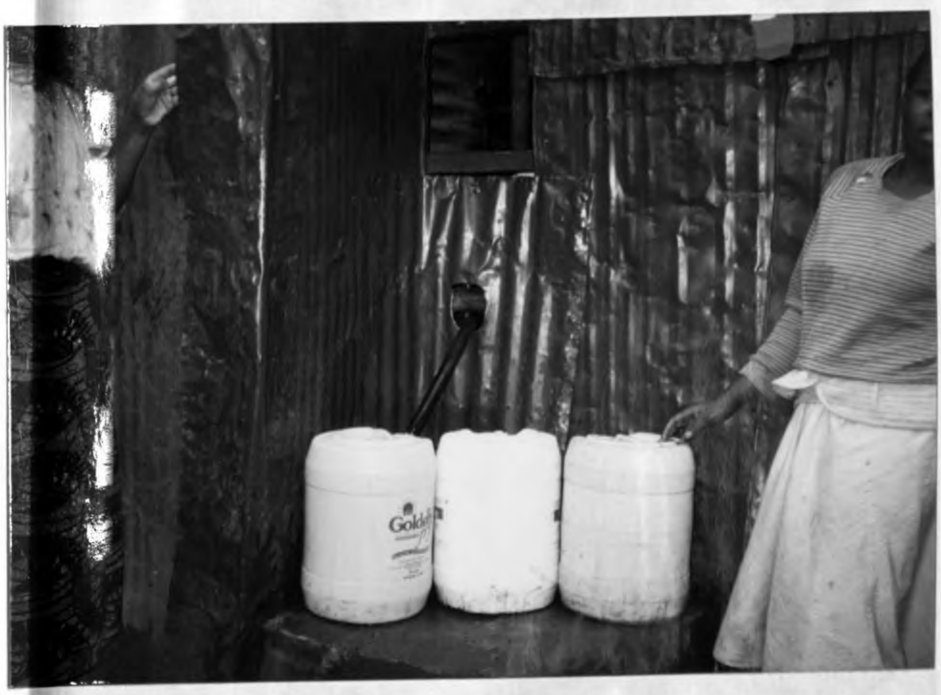

Figure 3b: Photograph showing a standpipe

Figure 4a: Photograph showing the environment within Kibera at the time of sampling.

Figure 4b: Photograph showing a type of in-house water storage container

The pH values for all water samples and their summary statistics are shown in Appendix 4 and Appendix 5.1. The lowest pH was 6.0 and the highest 7.3 with a mean of 6.68 and a standard deviation of 0.28. The pH range of the out-house water was 6.00 to 7.00 with a mean of 6.58 and a standard deviation of 0.30 (Appendix 5.2). The pH range of in-house water was 6.3 to 7.2 with a mean of 6.72 and a standard deviation of 0.27 (Appendix 5.3). There were significant differences between in-house and out-house water pH, this being higher in the latter ($p = 0.0475$, Appendix 5.9). Village-specific water pH are shown in Appendices 5.5 to 5.7. These were significantly different from each other ($p = 0.0001$, Appendix 5.10)

The level of chlorine in all samples was 0.5mg/litre

4.3. RESULTS FROM BACTERIOLOGICAL ANALYSES OF WATER SAMPLES

4.3.1. TOTAL BACTERIAL COUNT (TBC)

The TBC per 100mls of each of the eighty water samples are summarised in Appendix 4 and Appendix 5.1. The counts obtained showed great variations. The lowest count was 1.00 and the highest 4200 with a mean and a standard deviation of 625.76 and 92.96 respectively. TBC for out-house water had a range of 1.00 to 305.00 with a mean of 48.55 and a standard deviation of 71.22 (Appendix 5.2). In-house water had TBC ranging from 8.00 to 4200 with a mean of 818.17 and a standard deviation of 981.74. Out-house and in-house water had significant Total Bacterial Count differences ($p = 0.0001$, Appendix 5.11). In-house water had higher TBC.

The summary statistics for the TBC in water from the three villages are shown in Appendices 5.5 to 5.7. There were no significant differences in TBC between the three villages ($p = 0.5918$, Appendix 5.12).

In this study, both the temperature (p = 0.1963) and the pH (p = 0.7654) did not significantly affect the TBC (Appendix 5.13).

4.3.2. COLIFORM COUNT

The Most Probable Number of coliforms was computed from a 5-Tube Statistical Table and recorded as number of coliforms per 100mls of water sample. The results and summary statistics are shown in Appendix 4 and Appendix 5.1. Sixty four samples, (80%) were positive for coliforms. The lowest and highest coliform counts were 0 and 161 respectively with a mean of 79.86 and a standard deviation of 76.11. Coliform counts for out-house water ranged from 0 to 92 with a mean of 9.3 and a standard deviation of 21.38 (Appendix 5.2). The range of the out-house water coliform counts was from 0 to 161 with a mean of 103.38 and a standard deviation of 73.20 (Appendix 5.3).

The coliform counts were barely significantly different between in-house and out-house water (p = 0.0486, Appendix 5.14). In-house water had a higher coliform count. Village-specific summary statistics for coliform counts are shown in Appendices 5.5 to 5.7. There were no significant differences in coliform counts between the villages (p = 0.0682, Appendix 5.15). The temperature (p = 0.0981) and pH (p = 0.2449) did not significantly affect the coliform counts (Appendix 5.13). The relationship between TBC and coliform count was significant (p = 0.0001, Appendix 5.13).

4.3.3. FAECAL COLIFORMS

The presence of faecal coliforms was enumerated on the basis of positive-negative technique (production of acid and gas at 44.5°C). The results obtained are shown in Appendix 4. Thirty two samples (40%) were positive for faecal

coliforms (Appendix 5.16). Of these, 6.25% were from out-house water and 93.75% from in-house water.

Village-specific faecal coliform frequencies (Appendix 5.17) indicate that Makina had a total of 43.75%, Siranga 31.25% and Mashimoni 25% of faecal coliforms found in, in-house water.

4.3.4. FAECAL STREPTOCOCCI

The results of the analyses of all the water samples for Faecal streptococci are shown in Appendix 4 and Appendix 5.1. Thirty nine samples (48.75%) were positive for faecal streptococci. The range was 0 to 542 with a low and high count of 2 and 542 respectively. The mean was 49.9 and standard deviation 119.63 (Appendix 5.1). Counts of faecal streptococci for out-house water ranged from 0 to 70 with a mean of 3.60 and a standard deviation of 15.64 (Appendix 5.2). The range for in-house water was 0 to 542 with a mean and standard deviation of 65.33 and 134.60 respectively (Appendix 5.3).

The counts were not significantly different between in-house and out-house water ($p = 0.5586$, Appendix 5.18). Ranges of the village-specific faecal streptococci, their means and standard deviations are shown in Appendices 5.5 to 5.7. There were no significant differences among the villages ($p = 0.2496$, Appendix 5.19).

4.3.5. SEROTYPING OF ESCHERICHIA COLI ISOLATES

Serotyping of thirty two (40%) of *E.coli* isolated in the study water samples showed that twenty eight (87.5%) were non-enteropathogenic and 4 (12.5%) were enteropathogenic (Appendix 4, Appendix 5.19). Out of these, 3 were from in-house containers and one form out-house tank.

Village-specific analyses indicate the enteropathogens came from one out-house tank in Makina, two in-house containers in two different houses in Makina and one in-house container in Siranga village.

4.4. QUESTIONNAIRE DERIVED VARIABLES

Members of 60 households were interviewed in this study. The results and summary statistics of their responses are presented in Appendix 2 and Appendices 5.20 to 5.37.

The number of individuals living in each household ranged from one to eleven persons with a mean of 4 and a standard deviation of 2.3709 (Appendix 5.20). There were no significant differences between the number of persons living in the households and TBC ($p = 0.8561$), Coliform counts ($p = 0.6460$) and the Faecal streptococci numbers ($p = 0.2815$, Appendix 5.13).

All households stored their water in containers of which 54 (90%) had containers made of plastic, 4 (6.67%) had earthenware containers and 2 (3.33%) had metal containers (Appendix 5.21). Fifty eight (96.7%) households covered their containers while, the remaining 2 (3.3%) did not (Appendix 5.22). Presence or absence of covers on storage containers did not significantly affect the quality of stored water ($p = 0.5421$, Appendix 5.23 for TBC, $p = 0.3738$, Appendix 5.24 for Coliform count and $p = 0.3203$, Appendix 5.25 for Faecal streptococci count $p = 0.3203$).

All households owners who were interviewed said they used their stored water for drinking, cooking and cleaning/washing. Stored water took an average of 2.28 days to replenish with the containers taking an average of 4.43 days before they were cleaned. The duration between cleaning the containers and the water replenishing duration did not affect the bacteriological quality of water

(Appendices 5.26 to 5.28). Water was processed by boiling in 42 (70%) of the households while in 18 (30%) it was not. The TBC ($p = 0.0687$, Appendix 5.29), Coliform count ($p = 0.6927$, Appendix 5.30) and Faecal streptococci count ($p = 0.5627$, Appendix 5.3) were not significantly different between processed and unprocessed water in this study.

A cup or mug was used to scoop drinking water from the containers in 26 (43.3%) of the households while in 34 (56.7%), drinking water was poured out of the containers. Total bacterial counts and faecal streptococci counts were higher in households that scooped water than in those that poured out their drinking water ($p = 0.0202$, Appendix 5.32 and $p = 0.0082$, Appendix 5.33 respectively). However, there were no significant differences in coliform counts between households that used scoops and those that poured out their drinking water from the storage containers ($p = 0.0986$, Appendix 5.34).

Members in 42 (70%) of the households interviewed were aware that water could act as a vehicle for disease transmission. However, the total bacterial counts and coliform counts were not significantly related to this. Members from 32 (81%) households that knew water as a vehicle for disease transmission said they were aware of measures they could institute to ensure water was safe. However, this did not influence the quality of their stored water ($p = 0.1040$, Appendix 5.35 for Total Bacterial count and $p = 0.9256$, Appendix 5.37 for Coliform count).

CHAPTER FIVE

DISCUSSION

Water plays important roles in supporting human life. For example, drinking, cooking, washing, vegetable gardening, animal husbandry, brewing, or plastering walls and floors. These activities have consequences for the level of nutrition, income and hygiene of the whole family. However, the way the water is handled may cause the water to be a risk to the health of people and animals. Generally, there are three ways by which water can cause various diseases: namely drinking contaminated water, contact with contaminated water and lack of water for proper hygiene. Thus water has a great potential for transmitting a wide variety of diseases. These include, cholera, typhoid, paratyphoid, infectious hepatitis, amoebic and bacillary dysenteries. Provision of "safe" drinking water is therefore one of the major measures in the management of these diseases (Henry *et al.*, 1990).

The steady upward trend in urbanization in Nairobi in the last two decades has lead to a 6 - 8% annual growth rate in the population (Obudho, 1986). This has consequently led to crowding of people in unplanned squatter settlements, where provision of basic amenities such as adequate and quality water do not exist. The current study was therefore designed with the objectives of assessing the physical and bacteriological quality of drinking water and to determine risk factors that could affect the "quality" of household water in Kibera which is a slum area.

Variables, such as temperature, chlorine levels and pH have been suggested to affect the microbial counts in water (Sayler *et al.*, 1975). The water temperature in this study showed a mean of 22.96°C and a standard deviation of 1.69°C. There were no significant differences between in-house and out-house

water temperatures. The pH values showed a mean of 6.68 and a standard deviation of 0.28. These pH values lie within the acceptable limits of 6.5 - 8.5 according to the WHO 1984 guidelines. Controlling the pH level minimizes corrosion and encrustation in the distribution system, which results from complex relationships between pH and other constituents such as carbon-dioxide, hardness, alkalinity and temperature.

Addition of chlorine to polluted water supplies kills pathogenic microorganisms thus rendering such water fit for human consumption. According to WHO (1996), treated water should have more than 0.5mg/l residual chlorine concentration after at least 30 minutes contact time for it to be effective in eliminating pathogens. The level of chlorine determined in all the study water samples in Kibera was 0.5 mg/l.

It has been demonstrated that there is a significant association between inadequate environmental sanitation and high morbidities of waterborne diarrhoea and enteric pathogens (Henry *et al.*, 1981). During this study, it was observed that the general environmental conditions prevailing at that time within Kibera were such that they greatly increased the chances of water contamination. For example, there was no provision of proper and effective sewage, waste water and garbage disposal facilities. Furthermore, pipes which supplied out-house tanks from which residents drew water for daily use were old and rusty, others had rubber tubbing tied around them to seal leakages from breakages and loose joints. All these posed tremendous risks of contaminating water supplies with pathogenic microorganisms. Feachem *et al.*, (1978) in their study of the relation between water supplies and disease in Lesotho, found out that piped water supplies were polluted (197 faecal coliforms and 284 faecal streptococci per 100 ml of water) via loose joints of pipes which went through wet and muddy areas. Frequent

analyses of the total counts of these bacteria have been used as a measure of the quality (WHO, 1971). In this study, total bacterial counts ranged from 1 to 4200 with a mean of 626 per ml and a standard error of 912 per ml. Specifically, the means of total bacterial counts were higher for in-house than out-house water sources.

The use of certain intestinal bacteria as indicators of water contamination from human/animal faeces is a universally accepted procedure for monitoring and assessing the microbial quality of water supplies (WHO, 1971). The indicator bacteria include coliforms, faecal coliforms, faecal streptococci and clostridia. The coliforms are assessed by the Most Probable Number (MPN) which is a statistical technique which gives a rough estimate of the number of coliform bacteria in a given volume of water (APHA, 1989). In the Kibera study, The MPN showed that 35% of out-house tanks and 95% of in-house water in containers were contaminated with coliforms. The coliform count was significantly different between out-house and in-house water. The count was higher in the in-house water.

The results of this study showed that both out-house and in-house water was contaminated to various degrees by coliforms. According to the Kenya Bureau of standards (1985), treated water should contain no coliforms whether of faecal origin or not. Based on these standards, 35% of out-house tanks which are the sources of water for Kibera require disinfection. Although out-house water tanks were contaminated, there seems to be further increase in bacteriological counts in water in the in-house containers. The total bacterial count, coliform count and the faecal streptococci count were all significantly higher for in-house than out-house water. These findings are quite similar to those of Enge (1983) who reported that although 85% of the tested standpipe water in a village in Botswana was fit for drinking, only 65% of the same water in household containers was fit

for drinking.

Of the faecal coliforms, *E.coli* is always present in the faeces of human, animals, and birds in large numbers. *E.coli* bacteria are rarely found in water that has not been contaminated with faecal matter. Therefore, *E.coli* is an essential indicator of water pollution by faecal material of human and animal origins. In this study, it was found out that thirty two (40%) of all water samples were positive for *E.coli*. Among these, 6.25% were from out-house tanks and 93.75% from in-house containers. Serotyping of *the E.coli* isolates showed that 87.5% were non-enteropathogenic while the rest (12.5%) were enteropathogenic.

Apart from *E.coli*, occurrence of faecal streptococci in water also indicates faecal pollution. However, faecal streptococci are short-lived compared to coliforms and therefore their absence could give wrong impression that water is safe when other microorganisms are still surviving. Nevertheless, faecal streptococci are useful in assessing doubtful coliform results. The results of this study showed that 48.75% of all the samples were contaminated by faecal streptococci. It has been recommended that a ratio of faecal coliforms to faecal streptococci of greater than 3:1 indicates that faecal contamination is of human origin whereas a ratio of less than 0.7:1 is of animal origin (Mara and Oragui, 1981; APHA, 1989). These ratios were not determined in the current study.

Various methods of handling water, such as storage of water in open containers or in vessels that are not regularly cleaned, use of communal cups to draw water and hands touching the water during collection have been associated with increase in the risk of water contamination with bacteria (Burgers *et al.*, 1988). Results of this study indicate that households that used a cup/mug to scoop drinking water from storage containers had higher total bacterial counts

and faecal streptococci numbers than households that poured out their drinking water from storage containers. These findings compare to those of Yeager *et al.*, (1991) who reported a higher incidence of diarrhoea of children in households where a cup had been used to retrieve water than in those using water reservoirs with a tap.

The type of container used can influence the bacteriological quality of the stored water. An experiment carried out in a village where 30 plastic containers with small openings were distributed free of charge showed that piped water stored in those containers was not easily contaminated. In this study, 90% of householders stored their water in plastic containers, 6.67% in earthen containers and 3.33% in metal containers. Drinking water was stored in separate containers in 10% of households while in 90% of households drinking water was kept in containers for general domestic use. Although Feachem *et al.*, (1978) found that households which stored their water in containers from which water was frequently added and removed were more prone to pollution, no relationship could be established in this study between the bacteriological quality and the type of container used to store water.

Storage of water for several weeks at temperatures of between 10-15°C destroys most pathogenic bacteria. It has also been shown that if storage containers are not open to further contamination, stored water will purify itself of most harmful bacteria by natural process (Watt, 1986). In this study, stored water was replenished at an average rate of 2.3 days and the containers were cleaned at an average interval of 4.4 days. No general trend could be discerned between the bacteriological quality of water and these durations. This is probably because it was a cross-sectional study.

Processing water makes it free of most pathogenic bacteria thus rendering

it fit for human consumption. Addition of chlorine or boiling are some of the methods available for improving the water quality. In Nairobi, addition of chlorine to water remains the general procedure. But, at the domestic level, boiling of drinking water is the preferred method. Boiling kills microorganisms including the pathogenic ones. If such water is not subjected to contamination it is safe for drinking. Although 70% of surveyed households said they processed their water by boiling before drinking, there was no bacteriological difference between the "processed" and "unprocessed" water. This is possibly due to the contamination of the already processed water or that some of the households indicated that they processed the water while they actually had not.

Water contamination after collection is very different, from an epidemiological point of view, from contamination at the source. The former may be attributed to drawing of water in the house using dirty scoops, containers not securely covered or regularly cleaned. Water contamination at in-house level partly negates the value of providing clean water at the source. However, its health significance is limited because pathogens transmitted by this route will be intrafamily. However, a house may have frequent visitors who may drink from the stored water and in this way transmission of pathogenic organisms may be widespread.

Water, personal and domestic hygiene, effective disposal of human excreta and waste water are quite significant in combating waterborne diseases (IRC, 1993). In this study, 70% of households indicated that they knew that water acts as a vehicle for disease transmission. Of these, 58.3% said they knew the preventive measures that could be applied to ensure water is safe for use. However, no relationship could be established between awareness and bacteriological quality of water.

CONCLUSIONS

1. Thirty five percent of out-house tanks sampled were contaminated with coliforms, 10% with faecal coliforms and 10% with faecal streptococci.

2. Ninety five percent of in-house containers were contaminated with coliforms, 50% with faecal coliforms and 61.7% with faecal streptococci.

3. Forty percent of all samples were positive for *E.coli* with 87.5% being non-enteropathogenic and 12.5% enteropathogenic.

4. Bacterial pollution of stored water was mainly attributed to drawing of water using contaminated scoops as well as touching the water with contaminated hands.

RECOMMENDATIONS

1. Educational programmes on environmental and personal hygiene should be instituted to prevent contamination of water at the distribution and domestic levels.

2. Boiling of drinking water should be encouraged since there is contamination at the source.

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LIST OF APPENDICES

APPENDIX 1. QUESTIONNAIRE USED IN A SURVEY TO DETERMINE THE MICROBIOLOGICAL QUALITY OF DRINKING WATER IN KIBERA SUBLOCATION OF NAIROBI.

Date: / /1996 Village

1. Name of the household owner
2. Head of the household

   0. Father 1. Mother 2.Others
3. Occupation (father)
4. Occupation (mother)
5. Others
6. Relationship of interviewee with head of family:

   0. head of family
   1. Spouse
   2. Offspring
   3. Brother/sister
   4. Niece/nephew
   5. Others. Specify
7. Number of people living in the household
8. Where do you get your household water from?

   0. Tap in the house
   1. Tap outside house (within 10 m radius of the house)
   2. Tap away from the house (over 10 m)
   3. Borehole
   4. Buy from "water kiosks"

5. Others. Specify

9. If tap is not in the house, estimate the distance in meters M

10. How do you store water in the house?

a. No storage. 0. No 1. Yes

b. Containers (with covers). 0. No 1. Yes

c. Buckets/basins (no covers). 0. No 1. Yes

11. If water is stored, what are its uses?

a. Drinking 0. No 1. Yes

b. Cooking 0. No 1. Yes

c. Cleaning/washing 0. No 1. Yes

d. Others. Specify

12. How do you draw water from the storage container?

0. Scooping using jug, cup, tin etc

1. Tap

2. Pouring out from the container

3. Others. Specify

13. If stored water is used for drinking, is it processed before use?

a. No b. Yes

14. If yes, how?

1. Boiled

2. Chlorinated

3. Others. Specify

15. How often do you replenish the stored water?

0. Daily

1. Weekly

2. More than a week. Specify

16. How often do you clean the storage container(s),

0. Daily

1. Weekly

2. More than a week.

Specify

17. Describe the procedure of cleaning the container(s)

18. What kind of changes do you observe in the dirty container(s)?

0. No changes

1. Slimy material in container

2. Discolouration. Describe

3. Others. Specify

19. Do you know any health problems associated with water?

a. No b. Yes

if yes, which ones

0. Diarrhoea

1. Vomiting

2. Others. Specify

20. How, in your opinion, do such problems arise?

0. Lack of treatment

1. improper storage

2. Others. Specify

21. Has any member of the household suffered such problems in the last 1 year?

0. No 1. Yes

22. Specify age of affected person

0. child

1. young adult

2. Adult

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23. Do you know any preventive measures against such problems?

0. none

1. Boiling

2. Others. Specify

APPENDIX 2: QUESTIONNAIRE DERIVED VARIABLES OBTAINED WHEN SIXTY HOUSEHOLDS IN KIBERA SUBLOCATION WERE INTERVIEWED TO DETERMINE RISK FACTORS THAT COULD INFLUENCE THE QUALITY OF IN-HOUSE WATER.

	No.	H.No	Source	Type	Use	Drawing	Process	R	C	Aware	Dse	PM
MAKINA VILLAGE												
GROUP - 1												
1	7	H1	0	0	0	1	1	14	30	1	1	1
2	9	H2	0	1	0	1	1	1	1	1	1	1
3	7	H3	0	2	0	0	1	1	14	1	0	0
4	1	H4	0	2	0	1	0	3	3	1	0	1
5	1	H5	0	2	0	1	0	3	3	0	0	0
6	6	H6	1	1	0	1	1	5	5	1	0	1
GROUP - 2												
7	5	H1	1	2	0	0	0	2	14	0	0	0
8	6	H2	0	0	0	0	1	1	1	0	0	0
9	4	H3	0	2	0	0	0	1	1	1	0	1
10	5	H4	0	2	0	1	1	2	1	0	0	0
11	2	H5	1	2	0	0	1	3	3	1	0	1
12	5	H6	0	2	0	1	0	1	3	0	0	0
13	4	H7	1	2	0	1	1	2	2	1	0	1
GROUP - 3												
14	3	H1	1	2	0	0	0	2	2	1	0	1
15	2	H2	1	1	0	0	1	3	3	0	0	0
16	8	H3	1	2	0	1	0	3	3	1	0	1

	No.	H.No	Source	Type	Use	Drawing	Process	R	C	Aware	Dse	PM
GROUP - 4												
17	5	H1	1	2	0	0	1	4	4	1	0	1
18	3	H2	1	2	0	1	0	7	3	1	0	1
19	7	H3	1	2	0	0	0	3	1	1	0	1
GROUP - 5												
20	2	H1	1	2	0	0	0	1	30	1	0	1
21	9	H2	0	2	0	0	0	2	2	1	0	1
22	4	H3	0	2	0	1	0	3	3	1	0	0
GROUP - 6												
23	5	H1	0	2	0	0	0	3	3	1	0	1
24	2	H2	0	2	0	0	0	1	2	1	0	0
25	7	H3	1	1	0	1	1	2	2	1	0	1
STRANGA VILLAGE GROUP - 1												
26	3	H1	1	2	0	1	0	1	4	0	0	0
27	3	H2	1	2	0	1	0	3	7	1	0	1
28	4	H3	0	2	0	1	0	1	3	1	0	1
29	6	H4	0	2	0	1	0	2	2	0	0	0
30	3	H5	0	2	0	1	0	2	2	0	0	0
31	9	H6	0	2	0	1	0	1	1	0	0	0
GROUP - 7												
32	3	H1	0	2	0	0	0	1	4	0	0	0

	No.	H.No	Source	Type	Use	Drawing	Process	R	C	Aware	Dse	PM
33	2	H2	1	2	0	0	0	3	30	0	0	0
34	3	H3	0	2	0	0	0	1	7	1	0	0
GROUP - 3												
35	11	H1	1	2	0	0	1	1	3	1	0	1
36	7	H2	0	2	0	1	0	1	2	1	1	1
37	2	H3	0	2	0	1	0	1	1	0	0	0
GROUP - 4												
38	2	H1	0	2	0	0	0	1	3	1	0	1
39	3	H2	1	2	0	0	0	1	1	1	0	1
40	5	H3	1	2	0	0	0	1	2	1	0	1
GROUP - 5												
41	1	H1	1	2	0	0	0	2	1	0	0	0
42	1	H2	0	2	0	0	0	2	2	1	0	1
43	3	H3	1	2	0	0	0	1	2	1	0	1
GROUP - 6												
44	5	H1	1	2	0	0	1	2	2	1	0	1
45	2	H2	1	2	0	0	0	2	2	1	1	0
46	5	H3	0	2	0	0	1	3	3	1	0	0
GROUP - 7												
47	4	H1	1	2	0	0	1	1	3	1	0	1
48	2	H2	0	2	0	0	0	2	2	1	0	0
49	6	H3	0	2	0	0	0	1	7	1	0	1

	No.	H.No	Source	Type	Use	Drawing	Process	R	C	Aware	Dse	PM
MASHTMONT VILLAGE GROUP - 1												
50	4	H1	1	2	0	1	0	4	4	0	0	0
51	10	H2	1	2	0	0	0	1	3	1	0	1
GROUP - 2												
52	5	H1	1	2	0	1	0	3	3	0	0	0
53	2	H2	1	2	0	1	1	2	2	1	0	1
54	2	H3	0	2	0	1	1	7	7	0	0	0
GROUP - 3												
55	4	H1	1	2	0	0	0	3	3	1	0	1
56	3	H2	1	2	0	0	0	2	2	1	0	1
57	3	H3	0	2	0	0	1	1	1	1	0	1
GROUP - 4												
58	4	H1	1	2	0	0	1	1	1	1	0	1
59	5	H2	0	2	0	1	0	3	3	0	0	0
60	5	H3	0	2	0	1	0	1	2	1	1	0

KEY:
NO = Number of persons living in each household

H.No = Village and group specific house number

SOURCE = Estimated distance between water source and the houses in metres
0 = more than 10 metres : 1 = less than 10 metres

TYPE = Type of container used to store water
0 = metal : 1 = earthenware : 2 = plastic

USE = Use for stored water. 0 = cleaning, drinking, cooking, washing etc

DRAWING = Method used to draw drinking water from storage container.
0 = by means of a scoop : 1 = Pouring out

PROCESS = Presence/absence of water processing
0 = present : 1 = Absent

R = Duration in days taken to replenish water in containers

C = Duration in days taken to clean the storage containers

AWARE = Awareness of water as a vehicle of disease transmission
0 = Unaware : 1 = aware

DSF = Presence/absence of water borne disease in the household
0 = no disease : 1 = disease

PM = Awareness of preventive measures
0 = unaware : 1 = aware

APPENDIX 3: MEDIA COMPOSITION AND PREPARATION

3.1. PREPARATION OF PLATE COUNT AGAR (Oxoid, Basingstoke, England)

	gram per litre
Yeast extract	2.5 gram
Trypione	5.0 gram
Glucose	1.0 gram
Agar No. 1	15.0 gram

Seven and a half gram of the media were suspended in 1.0 l of distilled water and dissolved by boiling the mixture with constant stirring. It was then sterilized in a pressure cooker at 121°C for 15 minutes and cooled to 55°C. The pH of the agar was 7.0. A 20 ml of the medium was distributed into sterile petri dishes and left to solidify.

3.2. PREPARATION OF MACCONKEY BROTH (Biotec, England)

	gram per litre
Peptone	20.0 gram
Lactose	10.0 gram
Bile salts	5.0 gram
Sodium chloride	5.0 gram
Bromocresol Purple	0.01 gram

The double strength MacConkey broth was prepared by dissolving 80 gram of the mixture of the above reagents in 1.0 l of distilled water. The single strength MacConkey broth was prepared by dissolving 40 gram of the same reagents in 1.0 l of distilled water. Each solution was dispensed into universal bottles and fermentation tubes containing Durham tubes. All bottles and tubes containing the broths were sterilized in a pressure cooker at 121°C for 15 minutes. The pH of the broth was 7.4.

3.3. PREPARATION OF EOSIN METHYLENE BLUE AGAR (Oxoid, Basingstoke, England)

	gram per litre
Peptone (Oxoid L37)	10.0 gram
Lactose	10.0 gram
Dipotassium hydrogen phosphate	2.0 gram
Eosin Y	0.4 gram
Methylene Blue	0.06 gram
Agar NO.3 (Oxoid L 13)	15.0 gram

Thirty seven and a half gram of the medium were suspended in 1.0 l of distilled water and completely dissolved by boiling. The mixture was sterilized in a pressure cooker at 121°C for 15 minutes and cooled to 60°C. The medium was shaken in order to oxidize the Methylene Blue (so as to restore the blue colour). The pH of the agar was 6.8. The agar was dispensed into sterile petri dishes and left to solidify.

3.4. PREPARATION OF (2%) BRILLIANT GREEN LACTOSE BILE BROTH (Oxoid, Basingstoke, England)

	grams per litre
Peptone (Oxoid)	10.0 gram
Lactose	10.0 gram
Ox-Bile (Purified	20.0 gram
Brilliant Green	0.0133 gram

Forty gram of the above reagents were suspended in 1.0 l of distilled water. The broth was distributed into fermentation tubes fitted with Durham tubes. The broth was sterilized in a pressure cooker at 121°C for 15 minutes. The pH of the broth was 7.4.

3.5. PREPARATION OF TRYPTONE WATER (Oxoid)

	gram per litre
Tryptone	10.0 gram
Sodium chloride	5.0 gram

Fifteen gram of the medium were suspended in 1.0 l of distilled water and dissolved by boiling. The mixture was sterilized in a pressure cooker at 121°C for 15 minutes and cooled to 60°C. The pH of the agar was 7.5. The medium was distributed into sterile fermentation tubes.

3.6. PREPARATION OF METHYL-RED VOGES-PROSKAUER MEDIUM (MRVP)(Oxoid, Basingstoke, England)

	gram per litre
Peptone (Oxoid L49)	5.0 gram
Phosphate buffer	5.0 gram
Dextrose	5.0 gram

Fifteen gram of the medium were suspended in 1.0 l of distilled water and dissolved by boiling. The mixture was sterilized in a pressure cooker at 121°C for 15 minutes and cooled to 60°C. The pH of medium was 7.5. The medium was dispensed into sterile fermentation tubes.

3.7. PREPARATION OF SIMMONS CITRATE AGAR (Oxoid, Basingstoke, England)

	gram per litre
Magnesium sulphate	0.2 gram
Ammonium dihydrogen phosphate	1.0 gram
Dipostssium phosphate	1.0 gram
Sodium Citrate	2.0 gram
Sodium chloride	5.0 gram
Lab M Agar No.2	15.0 gram
Bromothymol blue	0.08 gram

Medium weighing 24.2 gram were suspended in 1.0 l of distilled water and dissolved by boiling with constant stirring. The agar was sterilized in a pressure cooker at 121°C for 15 minutes. The pH of the agar was 6.8. The medium was dispersed into sterile universal bottles and left to solidify.

3.8. PREPARATION OF INDOLE REAGENT (EHRLICHS REAGENT) (Cowan and Steel 1974)

p-dimethylaminobenzaldehyde	1 gram
Absolute Ethanol	95 ml
Conc. HCL	20 ml

One gram of p-dimethylaminobenzaldehyde was dissolved in 95 ml of absolute ethanol. Twenty ml of concentrated hydrochloric acid were added to the solution. The final solution was put in a brown bottle to protect it from light.

3.9. PREPARATION OF METHYL RED SOLUTION (Cowans and Steel 1974)

Methyl-red	0.4 gram
Ethanol	40.0 ml
Distilled water	100.0 ml

Methyl-red weighing 0.04 gram was dissolved in 40 ml of ethanol and diluted using 100 ml of distilled water.

3.10. PREPARATION OF 1% CREATINE SOLUTION (Cowan and Steel 1974)

Creatine	1.0 gram
0.1 N-HCL	100.0 ml

One gram of creatine was dissolved in 100 ml of 0.1 N-Hcl acid.

3.11. PREPARATION OF 40% POTASSIUM HYDROXIDE (Cowan and Steel 1974)

Potassium Hydroxide (KOH)	40.0 gram
Distilled water	100.0 ml

Forty gram of potassium hydroxide was added to 100 ml of distilled water.

3.12. PREPARATION OF NUTRIENT AGAR

	grams per litre
LAB M Peptone	5.0 gram
LAB M Beef Extract	3.0 gram
Sodium chloride	8.0 gram
LAB M Agar No.2	12.0 gram

Twenty eight gram of the medium were suspended in 1.0 l of distilled water. This was dissolved by bringing to boil with constant stirring. It was sterilized in a pressure cooker at 121°C for 15 minutes and dispensed into universal bottles and fermentation tubes, and left to solidify. The pH of the agar was 7.3.

3.13. PREPARATION OF MACCONKEY AGAR (Oxoid, Basingstoke, England)

	grams per litre
Peptone (Oxoid L37)	20.0 gram
Lactose	10.0 gram
Bile salts (Oxoid L55)	5.0 gram
Neutral red	0.075 gram
Agar No. 3 (Oxoid L13)	12.0 gram

Forty seven gram of the medium were suspended in 1.0 litre of distilled water and by boiling to completely dissolve. The mixture was sterilized in a pressure cooker at 121°C for 15 minutes and cooled to 60°C. The agar was mixed well and dispensed into sterile petri dishes and left to solidify.

3.14. PREPARATION OF SODIUM AZIDE MEDIUM

	gram per litre
Peptone	10.0 gram
Sodium chloride	5.0 gram
Dipotassium phosphate	5.0 gram
Monopotassium phosphate	2.0 gram
Glucose	5.0 gram
Yeast	3.0 gram
Sodium azide	0.25 gram
1.6% bromocresol purple	3.0 ml

Double strength sodium azide broth was prepared by dissolving 66.5 gram of the mixture of the above reagents in 1.0 l of distilled water. A single strength sodium azide broth was prepared by dissolving 33.25 grams of the mixture of the same reagents in 1.0 l of distilled water. Each solution was dispensed into fermentation tubes and universal bottles. All tubes and bottles were sterilized in a pressure cooker at 121°C for 15 minutes.

APPENDIX 4: RESULTS OBTAINED WHEN EIGHTY WATER SAMPLES FROM KIBERA SUBLOCATION WERE EXAMINED FOR TOTAL BACTERIAL COUNT (TBC), TOTAL COLIFORM COUNT (MPN), PRESENCE OR ABSENCE OF FAECAL COLIFORMS (FC), FAECAL STREPTOCOCCI (FS), WATER TEMPERATURES, CHLORINE AND PH VALUES.

Sample No.	Water source type	Water temperature	Cl mg/l	pH values	TBC	MPN	FC	Type of *E.coli*	FS
HAKINA VILLAGE GROUP - 1									
1	S0	26°C	0.5	6.8	2	0	0	*E.coli* negative	0
2	S	22°C	0.5	6.7	6	0	0	*E.coli* negative	0
3	H1	24.5°C	0.5	6.8	880	161	1	Non Enteropathogenic	240
4	H2	18°C	0.5	7.0	472	43	1	Non Enteropathogenic	49
5	H3	24.5°C	0.5	7.0	275	161	1	Non Enteropathogenic	79
6	H4	24°C	0.5	7.2	600	161	1	Non Enteropathogenic	542
7	H5	24.5°C	0.5	7.0	1164	161	1	Non Enteropathogenic	240
8	H6	18°C	0.5	7.1	50	11	0	*E.coli* negative	5
GROUP - 2									
9	S	24.5°C	0.5	6.3	28	5	1	Enteropathogenic	0
10	H1	24.5°C	0.5	6.4	172	43	1	Enteropathogenic	0
11	H2	20°C	0.5	6.5	270	5	1	Non Enteropathogenic	0
12	H3	23.5°C	0.5	6.3	245	161	0	*E.coli* negative	0
13	H4	23.5°C	0.5	6.5	370	161	0	*E.coli* negative	0
14	H5	24°C	0.5	6.4	447	161	1	Non Enteropathogenic	0
15	H6	24°C	0.5	6.4	1020	161	1	Non Enteropathogenic	0

Sample No.	Water source type	Water temperature	Cl mg/l	pH values	TRC	HPN	FC	Type of *E.coli*	FS
16	H7	24°C	0.5	6.8	67	4	0	*E.coli* negative	0
GROUP - 3									
17	S	23°C	0.5	6.7	28	0	0	*E.coli* negative	0
18	H1	22.5°C	0.5	6.8	130	54	0	*E.coli* negative	0
19	H2	24.5°C	0.5	6.7	121	8	0	*E.coli* negative	0
20	H3	17°C	0.5	6.9	3900	161	1	Non Enteropathogenic	4
GROUP - 4									
21	S	21°C	0.5	7.0	2	0	0	*E.coli* negative	0
22	H1	23.5°C	0.5	6.9	34	5	0	*E.coli* negative	0
23	H2	23°C	0.5	7.0	240	161	1	Non Enteropathogenic	8
24	H3	23.5°C	0.5	7.0	600	161	1	Non Enteropathogenic	542
GROUP - 5									
25	S	22°C	0.5	6.9	14	0	0	*E.coli* negative	0
26	H1	23°C	0.5	6.9	480	2	0	*E.coli* negative	0
27	H2	24°C	0.5	7.1	1020	6	0	*E.coli* negative	22
28	H3	24°C	0.5	7.0	400	4	0	*E.coli* negative	0
GROUP - 6									
29	S	24.5°C	0.5	7.0	305	0	0	*E.coli* negative	0
30	H1	22.5°C	0.5	7.1	420	0	0	*E.coli* negative	0
31	H2	24°C	0.5	7.0	1290	161	1	Enteropathogenic	141

Sample No.	Water source type	Water temperature	Cl mg/l.	pH values	TBC	MPN	FC	Type of *E.coli*	FS
32	H3	18.5°C	0.5	7.0	43	17	0	*E.coli* negative	2
STRANGA VILLAGE GROUP - 1									
33	S0	25°C	0.5	6.0	30	35	0	*E.coli* negative	0
34	S	23.5°C	0.5	6.5	81	17	0	*E.coli* negative	2
35	H1	22.5°C	0.5	6.5	1500	161	1	Non Enteropathogenic	240
36	H2	23°C	0.5	6.5	521	161	0	*E.coli* negative	6
37	H3	23°C	0.5	6.3	52	1	0	*E.coli* negative	0
38	H4	22.5°C	0.5	6.5	2200	161	0	*E.coli* negative	0
39	H5	23°C	0.5	6.4	310	161	1	Enteropathogenic	0
40	H6	23.5°C	0.5	6.4	1040	161	1	Non Enteropathogenic	348
GROUP - 2									
41	S	24°C	0.5	6.4	2	5	0	*E.coli* negative	0
42	H1	21°C	0.5	6.9	71	2	0	*E.coli* negative	0
43	H2	24°C	0.5	6.8	40	2	0	*E.coli* negative	0
44	H3	21°C	0.5	6.8	180	5	0	*E.coli* negative	2
GROUP - 3									
45	S	22.5°C	0.5	6.9	22	0	0	*E.coli* negative	0
46	H1	24°C	0.5	6.9	137	161	1	Non Enteropathogenic	7
47	H2	24°C	0.5	6.9	600	161	1	Non Enteropathogenic	79

Sample No.	Water source type	Water temperature	Cl mg/L	pH values	TBC	MPN	FC	Type of *E.coli*	FS
48	H3	24.5°C	0.5	6.9	3500	161	1	Non Enteropathogenic	141
GROUP - 4									
49	S	24°C	0.5	6.4	125	0	0	*E.coli* negative	0
50	H1	20°C	0.5	6.5	200	0	0	*E.coli* negative	0
51	H2	23.5°C	0.5	6.5	210	92	0	*E.coli* negative	2
52	H3	24.5°C	0.5	6.6	3000	92	0	*E.coli* Negative	2
GROUP - 5									
53	S	22°C	0.5	6.7	27	0	0	*E.coli* Negative	0
54	H1	23°C	0.5	6.8	1800	161	1	Non Enteropathogenic	0
55	H2	23°C	0.5	6.9	1390	161	1	Non Enteropathogenic	11
56	H3	23.5°C	0.5	6.7	560	161	1	Non Enteropathogenic	17
GROUP - 6									
57	S	21°C	0.5	6.8	1	0	0	*E.coli* negative	0
58	H1	23°C	0.5	7.0	73	161	0	*E.coli* negative	5
59	H2	23°C	0.5	6.9	20	1	0	*E.coli* negative	0
60	H3	24.5°C	0.5	6.9	1132	161	0	*E.coli* negative	13
GROUP - 7									
61	S	23°C	0.5	6.9	31	5	0	*E.coli* negative	0
62	H1	23°C	0.5	7.1	8	3	0	*E.coli* negative	0
63	H2	23.5°C	0.5	7.0	700	161	1	Non Enteropathogenic	40
64	H3	22°C	0.5	6.8	33	7	0	*E.coli* negative	9

Sample No.	Water source type	Water temperature	Cl mg/L	pH values	TBC	HPN	FC	Type of *E.coli*	FS
MASHTHONT VILLAGE									
GROUP - 1									
65	S0	24°C	0.5	6.2	6	0	0	*E.coli* negative	0
66	S1	19.5°C	0.5	6.4	100	13	0	*E.coli* negative	70
67	H1	24.5°C	0.5	6.5	650	161	0	*E.coli* negative	33
68	H2	24°C	0.5	6.5	200	161	1	Non Enteropathogenic	2
GROUP - 2									
69	S	24°C	0.5	6.5	100	92	1	Non Enteropathogenic	0
70	H1	23.5°C	0.5	6.5	1000	161	1	Non Enteropathogenic	14
71	H2	23°C	0.5	6.6	853	161	1	Non Enteropathogenic	542
72	H3	23.5°C	0.5	6.6	1002	161	1	Non Enteropathogenic	172
GROUP - 3									
73	S	22°C	0.5	6.1	3	0	0	*E.coli* negative	0
74	H1	20°C	0.5	6.3	28	0	0	*E.coli* negative	0
75	H2	23.5°C	0.5	6.4	1170	161	0	*E.coli* negative	22
76	H3	23.5°C	0.5	6.4	1000	161	1	Non Enteropathogenic	7
GROUP - 4									
77	S	23°C	0.5	6.4	58	0	0	*E.coli* negative	0
78	H1	24°C	0.5	6.5	2000	161	0	*E.coli* negative	2
79	H2	24°C	0.5	6.4	4200	161	1	Non Enteropathogenic	109
80	H3	23.5°C	0.5	6.3	3000	161	1	Non Enteropathogenic	221

KEY:
S = Sample from out-house tank
H = Sample from in-house container
TBC = Total bacterial count Per 100ml water
FC = Presence or absence of *E.coli*
FS = Faecal streptococci per 100ml water
S0 = Sample from the mainline supplying out-house tanks.

APPENDIX 5: SUMMARY RESULTS OF STATISTICAL ANALYSES

5.1. SUMMARY DESCRIPTIVE STATISTICS OF OVERALL CONTINUOUS VARIABLES

	TEMP	PH	TBC	MPN	FS
N	80	80	80	80	80
LO 95% CI	22.586	6.6214	422.59	62.926	23.277
MEAN	22.962	6.6837	625.76	79.862	49.900
UP 95% CI	23.339	6.7461	828.93	96.799	76.523
SD	1.6910	0.2803	912.96	76.105	119.63
SE MEAN	0.1891	0.0313	102.07	8.5088	13.375
MINIMUM	17.000	6.0000	1.0000	0.0000	0.0000
MEDIAN	23.500	6.7000	242.50	48.500	0.0000
MAXIMUM	26.000	7.2000	4200.0	161.00	542.00

5.2. SUMMARY DESCRIPTIVE STATISTICS FOR OUT-HOUSE WATER

	TEMP	PH	TBC	MPN	FS
N	20	20	20	20	20
LO 95% CI	22.295	6.4387	15.219	-0.7080	-3.7176
MEAN	23.025	6.5800	48.550	9.3000	3.6000
UP 95% CI	23.755	6.7213	81.881	19.308	10.918
SD	1.5600	0.3019	71.217	21.384	15.635
SE MEAN	0.3488	0.0675	15.925	4.7816	3.4962
MINIMUM	19.500	6.0000	1.0000	0.0000	0.0000
MEDIAN	23.000	6.6000	27.500	0.0000	0.0000
MAXIMUM	26.000	7.0000	305.00	92.000	70.000

5.3. SUMMARY DESCRIPTIVE STATISTICS FOR IN-HOUSE WATER

	TEMP	PH	TBC	MPN	FS
N	60	60	60	60	60
LO 95% CI	22.491	6.6495	564.56	84.475	30.564
MEAN	22.942	6.7183	818.17	103.38	65.333
UP 95% CI	23.392	6.7872	1071.8	122.29	100.10
SD	1.7445	0.2665	981.74	73.196	134.60
SE MEAN	0.2252	0.0344	126.74	9.4495	17.376
MINIMUM	17.000	6.3000	8.0000	0.0000	0.0000
MEDIAN	23.500	6.8000	476.00	161.00	4.5000
MAXIMUM	24.500	7.2000	4200.0	161.00	542.00

KEY:
TEMP = Water temperature
TBC = Total Bacterial Count on PCA at 37°C in 48 Hours
MPN = Most Probable Number (coliform count)
FS = Faecal streptococci per 100 ml of water samples

5.4. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN TEMPERATURES BETWEEN OUT-HOUSE AND IN-HOUSE WATER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.10416667	0.10416667	0.04	0.8500
Error	78	225.78333333	2.89465812		
Corrected Total	79	225.88750000			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.8500)

5.5. SUMMARY DESCRIPTIVE STATISTICS FOR MAKINA VILLAGE

	TEMP	PH	TBC	MPN	FS
N	32	32	32	32	32
LO 95% CI	22.011	6.7161	210.75	40.299	7.4885
MEAN	22.813	6.8125	471.72	67.281	58.563
UP 95% CI	23.614	6.9089	732.69	94.264	109.64
SD	2.2243	0.2673	723.83	74.839	141.66
SE MEAN	0.3932	0.0473	127.96	13.230	25.042
MINIMUM	17.000	6.3000	2.0000	0.0000	0.0000
MEDIAN	23.500	6.9000	272.50	15.500	0.0000
MAXIMUM	26.000	7.2000	3900.0	161.00	542.00

5.6. SUMMARY DESCRIPTIVE STATISTICS FOR SIRANGA VILLAGE

	TEMP	PH	TBC	MPN	FS
N	32	32	32	32	32
LO 95% CI	22.634	6.5989	284.85	51.090	1.3614
MEAN	23.047	6.6906	612.38	78.781	28.875
UP 95% CI	23.460	6.7824	939.90	106.47	56.389
SD	1.1455	0.2545	908.44	76.805	76.312
SE MEAN	0.2025	0.0450	160.59	13.577	13.490
MINIMUM	20.000	6.0000	1.0000	0.0000	0.0000
MEDIAN	23.000	6.8000	158.50	63.500	1.0000
MAXIMUM	25.000	7.1000	3500.0	161.00	348.00

KEY:
TEMP = Water temperature
TBC = Total Bacterial Count on PCA at 37°C in 48 Hours
MPN = Most Probable Number (coliform count)
FS = Faecal streptococci per 100 ml of water samples

5.7. SUMMARY DESCRIPTIVE STATISTICS FOR MASHIMONI VILLAGE

	TEMP	PH	TBC	MPN	FS
N	16	16	16	16	16
LO 95% CI	22.333	6.3400	323.23	67.308	-0.9456
MEAN	23.094	6.4125	960.63	107.19	74.625
UP 95% CI	23.855	6.4850	1598.0	147.07	150.20
SD	1.4285	0.1360	1196.2	74.840	141.82
SE MEAN	0.3571	0.0340	299.04	18.710	35.455
MINIMUM	19.500	6.1000	3.0000	0.0000	0.0000
MEDIAN	23.500	6.4000	751.50	161.00	10.500
MAXIMUM	24.500	6.6000	4200.0	161.00	542.00

KEY:
TEMP = Water temperature
TBC = Total Bacterial Count on PCA at 37°C in 48 Hours
MPN = Most Probable Number (coliform count)
FS = Faecal streptococci per 100 ml of water samples

5.8. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN TEMPERATURES IN THE THREE VILLAGES

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1.22344	0.61172	0.21	0.8121
Error	77	224.664	2.91772		
Corrected Total	79	225.887			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.8121)

5.9. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN PH BETWEEN OUT-HOUSE AND IN-HOUSE WATER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.30104167	0.30104167	4.05	0.0475
Error	78	5.79383333	0.07427991		
Corrected Total	79	6.09487500			

*** THE DIFFERENCES WERE SIGNIFICANT (P = 0.0475)

5.10. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN PH IN THE THREE VILLAGES

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1.70919	0.85459	14.62	0.0001
Error	77	4.49969	0.05844		
Corrected Total	79	6.20888			

*** THE DIFFERENCES WERE SIGNIFICANT (P = 0.0001)

5.11. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN TBC OUT-HOUSE AND IN-HOUSE WATER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	138.750328	138.750328	61.30	0.0001
Error	78	176.560062	2.263591		
Corrected Total	79	315.310390			

*** THE DIFFERENCES WERE SIGNIFICANT (P = 0.0001)

5.12. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN TBC IN THE THREE VILLAGES

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	4.26763071	2.13381535	0.53	0.5918
Error	77	311.04275927	4.03951635		
Corrected Total	79	315.31038998			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.5918)

5.13. CORRELATION ANALYSIS

Pearson Correlation coefficients / Prob > |R| under Ho: Rho=0 / Number of observations

	LOGTBC	LOGMPN	LOGFS
LOGMPN	0.69885 0.0001 64	-	0.35425 0.0269 39
LOGFS	0.40277 0.0110 39	-	-
TEMP	0.014599 0.1963 80	0.20857 0.0981 64	0.26528 0.1026 39
PH	0.03389 0.7654 80	-0.14746 0.2449 64	0.06704 0.6851 39
CLEAN	-0.13057 0.3200 60	-0.26559 0.0459 57	0.15936 0.3461 37
NO	-0.02391 0.8561 60	0.06215 0.6460 57	-0.18182 0.2815 37
REPLEN	0.02809 0.8313 60	0.11199 0.4069 57	0.20300 0.2282 37

5.14. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN COLIFORM COUNT BETWEEN OUT-HOUSE AND IN-HOUSE WATER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	11.1619270	11.1619270	4.05	0.0486
Error	62	170.9788024	2.7577226		
Corrected Total	63	182.1407294			

*** THE DIFFERENCES WERE SIGNIFICANT (P = 0.0486)

5.15. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN COLIFORM COUNT IN THREE VILLAGES

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	15.3501370	7.6750685	2.81	0.0682
Error	61	166.7905924	2.7342720		
Corrected Total	63	182.1407294			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.0682)

5.16 FREQUENCY DISTRIBUTION OF OVERALL DISCRETE VARIABLES

1. PRESENCE OF E.COLI

	FREQ	PERCENT
NEGATIVE	48	60.0
POSITIVE	32	40.0
TOTAL	80	100.0

2. SEROTYPING

	FREQ	PERCENT
POSITIVE	4	5.0
NEGATIVE	76	95.0
TOTAL	80	100.0

5.17. VILLAGE SPECIFIC BREAKDOWN FOR E.COLI

VILLAGE	SUM	PERCENT
MAKINA	14.0	43.75
SIRANGA	10.0	31.25
MASHIMONI	8.0	25.00
TOTAL	32.0	100.00

5.18. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN FAECAL STREPTOCOCCI IN OUT-HOUSE AND IN-HOUSE WATER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.25170097	1.25170097	0.35	0.5586
Error	37	132.91576245	3.59231790		
Corrected Total	38	134.16746342			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.5586)

5.19. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN FAECAL STREPTOCOCCI IN THREE VILLAGES

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	9.95677347	4.97838673	1.44	0.2496
Error	36	124.21068995	3.45029694		
Corrected Total	38	134.16746342			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.2496)

5.20. SUMMARY DESCRIPTIVE STATISTICS OF QUESTIONNAIRE DERIVED CONTINUOUS VARIABLES

	CLEAN	NO	REPLEN
N	60	60	60
LO 95% CI	2.7725	3.7375	1.7556
MEAN	4.4333	4.3500	2.2833
UP 95% CI	6.0942	4.9625	2.8110
SD	6.4292	2.3709	2.0427
SE MEAN	0.8300	0.3061	0.2637
MINIMUM	1.0000	1.0000	1.0000
MEDIAN	3.0000	4.0000	2.0000
MAXIMUM	30.000	11.000	14.000

KEY:
NO = Number of persons living in the household
CLEAN = Duration in days taken to clean the containers
REPLEN = Duration in days taken to replenish water in container

5.21 FREQUENCY DISTRIBUTION FOR TYPE OF CONTAINER USED TO STORE WATER

TYPE OF CONTAINER

	FREQ	PERCENT
PLASTIC	56	90.00
EARTHENWARE	4	6.67
METAL	2	3.33
TOTAL	60	100.00

5.22 FREQUENCY DISTRIBUTION OF QUESTIONNAIRE DERIVED DISCRETE VARIABLES

1. TYPE OF CONTAINER

	FREQ	PERCENT
CLOSED	58	96.7
OPEN	2	3.3
TOTAL	60	100.0

2. DISEASE AWARENESS

	FREQ	PERCENT
UNAWARE	18	30.0
AWARE	42	70.0
TOTAL	60	100.0

3. CHANGE INSIDE CONTAINER

	FREQ	PERCENT
NO CHANGE	44	73.3
CHANGE	16	26.7
TOTAL	60	100.0

4. DRAWING METHOD

	FREQ	PERCENT
SCOOPING	26	43.3
POURING	34	56.7
TOTAL	60	100.0

5. PRESENCE OF DISEASE

	FREQ	PERCENT
NONE	55	91.7
DISEASE	5	8.3
TOTAL	60	100.0

6. PROCESSING OF WATER

	FREQ	PERCENT
PROCESSED	41	70.0
UNPROCESSED	19	30.0
TOTAL	60	100.0

7. AWARENESS OF PREVENTIVE MEASURES

	FREQ	PERCENT
UNAWARE	25	41.7
AWARE	35	58.3
TOTAL	60	100.0

5.23. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN TRC BETWEEN COVERED AND UNCOVERED CONTAINERS.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.80906086	0.80906086	0.38	0.5421
Error	58	124.80247569	2.15176682		
Corrected Total	59	125.61153655			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.5421).

5.24. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN COLIFORM COUNT BETWEEN COVERED AND UNCOVERED CONTAINERS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	2.35349389	2.35349389	0.80	0.3738
Error	55	161.02162416	2.92766589		
Corrected Total	56	163.37511805			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.3738)

5.25. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN FAECAL STREPTOCOCCI BETWEEN COVERED AND UNCOVERED CONTAINERS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	3.57279645	3.57279645	1.02	0.3203
Error	35	123.02271608	3.51493475		
Corrected Total	36	126.59551254			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.3203)

5.26. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN TBC BETWEEN PROCESSED AND UNPROCESSED WATER.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	7.03224844	7.03224844	3.44	0.0687
Error	58	118.57928811	2.04447048		
Corrected Total	59	125.61153655			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.0687)

5.27. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN COLIFORM COUNT BETWEEN PROCESSED AND UNPROCESSED WATER.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.46742442	0.46742442	0.16	0.6927
Error	55	162.90769363	2.96195807		
Corrected Total	56	163.37511805			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.6927)

5.28. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN FAECAL STREPTOCOCCI BETWEEN PROCESSED AND UNPROCESSED WATER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.22356627	1.22356627	0.34	0.5627
Error	35	125.37194626	3.58205561		
Corrected Total	36	126.59551254			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.5627)

5.29. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN TBC BETWEEN SCOOPING AND POURING

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	11.2525900	11.2525900	5.71	0.0202
Error	58	114.3589465	1.9717060		
Corrected Total	59	125.6115365			

*** THE DIFFERENCES WERE SIGNIFICANT (P = 0.0202)

5.30. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN FAECAL STREPTOCOCCI BETWEEN SCOOPING AND POURING

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	23.2187382	23.2187382	7.86	0.0082
Error	35	103.3767743	2.9536221		
Corrected Total	36	126.5955125			

*** THE DIFFERENCES WERE SIGNIFICANT (P = 0.0082)

5.31. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN TOTAL COLIFORM COUNT BETWEEN SCOOPING AND POURING

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	7.97422529	7.97422529	2.82	0.0986
Error	55	155.40089276	2.82547078		
Corrected Total	56	163.37511805			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.0986)

5.32. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN TBC BETWEEN AWARENESS AND UNAWARENESS OF WATER AS A VEHICLE OF DISEASE TRANSMISSION.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	6.26465072	6.26465072	3.04	0.0863
Error	58	119.34688583	2.05770493		
Corrected Total	59	125.61153655			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.0863)

5.33. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN FAECAL STREPTOCOCCI NUMBERS BETWEEN AWARENESS AND UNAWARENESS OF WATER AS A VEHICLE OF DISEASE TRANSMISSION.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	20.9905558	20.9905558	6.96	0.0124
Error	35	105.6049567	3.0172845		
Corrected Total	36	126.5955125			

*** THE DIFFERENCES WERE SIGNIFICANT (P = 0.0124)

5.34. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN COLIFORM COUNT BETWEEN AWARENESS AND UNAWARENESS OF WATER AS A VEHICLE OF DISEASE TRANSMISSION.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.13772213	1.13772213	0.39	0.5371
Error	55	162.23739592	2.94977083		
Corrected Total	56	163.37511805			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.5371)

5.35. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN THC BETWEEN AWARENESS AND UNAWARENESS OF PREVENTIVE MEASURES.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	5.64229003	5.64229003	2.73	0.1040
Error	58	119.96924652	2.06843528		
Corrected Total	59	125.61153655			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.1040)

5.36. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARE OF DIFFERENCES IN MEAN FAECAL STREPTOCOCCI NUMBERS BETWEEN AWARENESS AND UNAWARENESS OF PREVENTIVE MEASURES.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	14.0081348	14.0081348	4.35	0.0443
Error	35	112.5873778	3.2167822		
Corrected Total	36	126.5955125			

*** THE DIFFERENCES WERE SIGNIFICANT (P = 0.0443)

5.37. SUMMARY ONE WAY ANALYSIS OF VARIANCE FOR COMPARISON OF DIFFERENCES IN MEAN COLIFORM COUNT BETWEEN AWARENESS AND UNAWARENESS OF PREVENTIVE MEASURES.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.02611178	0.02611178	0.01	0.9256
Error	55	163.34900627	2.96998193		
Corrected Total	56	163.37511805			

*** THE DIFFERENCES WERE NOT SIGNIFICANT (P = 0.9256)

APPENDIX 6: McCRADY'S STATISTICAL TABLES

APPENDIX 6.1: MOST PROBABLE NUMBER OF COLIFORMS PER 100 ml SAMPLE AND CONFIDENCE LIMITS USING 1 TUBE OF 50 ml, 5 TUBES OF 10 ml AND 5 TUBES OF 1 ml (FROM KENYA BUREAU OF STANDARDS, 1985).

NUMBER OF POSITIVE TUBES			MOST PROBABLE NUMBER (MPN) PER 100 ml	LIMITS WITHIN WHICH MPN PER 100 ml CAN LIE	
50 ml tube	10 ml tubes	1 ml tubes		Lower limit	Upper limit
0	0	1	1	< 0.5	4
0	0	2	2	< 0.5	6
0	1	0	1	< 0.5	4
0	1	1	2	< 0.5	6
0	1	2	3	< 0.5	8
0	2	0	2	< 0.5	6
0	2	1	3	< 0.5	8
0	2	2	3	< 0.5	11
0	3	0	3	< 0.5	8
0	3	1	5	< 0.5	13
0	4	0	5	< 0.5	13
1	0	0	1	< 0.5	4
1	0	1	3	< 0.5	8
1	0	2	4	< 0.5	11
1	0	3	6	< 0.5	15
1	1	0	3	< 0.5	8
1	1	1	5	< 0.5	13
1	1	2	7	1	17
1	1	3	9	2	21
1	2	0	5	< 0.5	13
1	2	1	7	1	17
1	2	2	10	3	23
1	2	3	12	3	28
1	3	0	8	2	19

NUMBER OF POSITIVE TUBES			MOST PROBABLE NUMBER (MPN) PER 100 ml	LIMITS WITHIN WHICH MPN PER 100 ml CAN LIE	
50 ml tube	10 ml tubes	1 ml tubes		Lower limit	Upper limit
1	3	1	11	3	26
1	3	2	14	4	34
1	3	3	18	5	53
1	3	4	21	6	66
1	4	0	13	4	31
1	4	1	17	5	47
1	4	2	22	7	69
1	4	3	28	8	85
1	4	4	35	12	101
1	4	5	43	15	117
1	5	0	24	8	75
1	5	1	35	12	101
1	5	2	54	18	138
1	5	3	92	27	217
1	5	4	161	39	450

APPENDIX 6.2: MOST PROBABLE NUMBER OF FAECAL STREPTOCOCCI PER 100 ml SAMPLE AND CONFIDENCE LIMITS USING 5 TUBES OF 10 ml, 5 TUBES OF 1 ml AND 5 TUBES OF 1.0 ml (FROM KENYA BUREAU OF STANDARDS, 1985).

NUMBER OF POSITIVE TUBES			MOST PROBABLE NUMBER (MPN) PER 100 ml	LIMITS WITHIN WHICH MPN PER 100 ml CAN LIE	
10 ml TUBES	1 ml TUBES	0.1 ml TUBES		LOWER LIMIT	UPPER LIMIT
0	0	1	2	< 0.5	7
0	0	2	4	< 0.5	11
0	1	0	2	< 0.5	7
0	1	1	4	< 0.5	11
0	1	2	6	< 0.5	15
0	2	0	4	< 0.5	11
0	2	1	6	< 0.5	15
0	3	0	6	< 0.5	15
1	0	0	2	< 0.5	7
1	0	1	4	< 0.5	11
1	0	2	6	< 0.5	15
1	0	3	8	1	19
1	1	0	4	< 0.5	11
1	1	1	6	< 0.5	15
1	1	2	8	1	19
1	2	0	6	0.5	15
1	2	1	8	1	19
1	2	2	10	2	23
1	3	0	8	1	19
1	3	14	10	2	23
1	4	0	11	2	25
2	0	0	5	0.5	13
2	0	1	7	1	17
2	0	2	9	2	21

NUMBER OF POSITIVE TUBES			MOST PROBABLE NUMBER (MPN) PER 100 ml	LIMITS WITHIN WHICH MPN PER 100 ml CAN LIE	
10 ml TUBES	1 ml TUBES	0.1 ml TUBES		LOWER LIMIT	UPPER LIMIT
2	0	3	12	3	28
2	1	0	7	1	17
2	1	1	9	2	21
2	1	2	12	3	28
2	2	0	9	2	21
2	2	1	12	3	28
2	2	2	14	4	34
2	3	0	12	3	28
2	3	1	14	4	34
2	4	0	15	4	37
3	0	0	8	1	19
3	0	1	11	2	25
3	0	2	13	3	31
3	1	0	11	2	25
3	1	1	14	4	34
3	1	2	17	5	46
3	1	3	20	6	60
3	2	0	14	4	34
3	2	1	17	5	46
3	2	2	20	6	60
3	3	0	17	5	46
3	3	1	21	7	63
3	4	0	21	7	63
3	4	1	24	8	72
3	5	0	25	8	75
4	0	0	13	3	31
4	0	1	17	5	46

NUMBER OF POSITIVE TUBES			MOST PROBABLE NUMBER (MPN) PER 100 ml	LIMITS WITHIN WHICH MPN PER 100 ml CAN LIE	
10 ml TUBES	1 ml TUBES	0.1 ml TUBES		LOWER LIMIT	UPPER LIMIT
4	0	2	21	7	63
4	0	3	25	8	75
4	1	0	17	5	46
4	1	1	21	7	63
4	1	2	26	9	78
4	2	0	22	7	67
4	2	1	26	9	78
4	2	2	32	11	91
4	3	0	27	9	80
4	3	1	33	11	93
4	3	2	39	13	106
4	4	0	34	12	96
4	4	1	40	14	108
4	5	0	41	14	110
4	5	1	48	16	124
5	0	0	23	7	70
5	0	1	31	11	89
5	0	2	43	15	114
5	0	3	58	19	144
5	0	4	76	24	180
5	1	0	33	11	93
5	1	1	46	16	120
5	1	2	63	21	154
5	1	3	84	26	197
5	2	0	49	17	126
5	2	1	70	23	168
5	2	2	94	28	219

NUMBER OF POSITIVE TUBES			MOST PROBABLE NUMBER (MPN) PER 100 ml	LIMITS WITHIN WHICH MPN PER 100 ml CAN LIE	
10 ml TUBES	1 ml TUBES	0.1 ml TUBES		LOWER LIMIT	UPPER LIMIT
5	2	3	120	33	281
5	2	4	148	38	366
5	2	5	177	44	515
5	3	0	79	25	187
5	3	1	109	31	253
5	3	2	141	37	343
5	3	3	175	44	503
5	3	4	212	53	669
5	3	5	253	77	788
5	4	0	130	35	302
5	4	1	172	43	486
5	4	2	221	57	698
5	4	3	278	90	849
5	4	4	345	117	999
5	4	5	426	145	1161
5	5	0	240	68	754
5	5	1	348	118	1005
5	5	2	542	180	1405

APPENDIX 7: E.COLI SEROTYPES REPRESENTED IN THE POLYVALENT AND MONOVALENT SERA (DENKA SEIKEN COMPANY, JAPAN).

POLYVALENT SERA	MONOVALENT SERA						
01	01	026	086a	011	0119	0127a	0128
02	044	055	0125	0126	0146	0166	
03	018	0114	0142	0151	0157	0158	
04	06	027	078	0148	0159	0168	
05	020	025	063	0153	0167		
06	08	015	0115	0169			
07	028ac	0112ac	0124	0136	0144		
08	029	0143	0152	0164			