HEALTH RISKS ASSOCIATED WITH WASTEWATER USED FOR IRRIGATION IN URBAN AGRICULTURE, IN NAIROBI KENYA.

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DECLARATION:

I hereby declare that this thesis is my original work and has not been submitted for the award of a degree in any other university.

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LIST OF ABBREVIATIONS

%:	Percentage
AIDS:	Acquired Immuno Deficiency Syndrome
BVM:	Bachelor of Veterinary Medicine
Dr:	Doctor
DRC:	Democratic Republic of Congo
FAO:	Food and Agriculture Organization of the United Nations
FC:	Faecal Coliform
ICMSF:	The International Commission on Microbiological Specifications for Food
IDRC:	International Development Research Centre
IWMI:	International Water Management Institute
Km^2:	Kilometer Squared
LTM:	Lauryl Tryptose Medium
MAC:	*Mycobacterium avium* Complex
MPN:	Most Probable Number
Msc:	Masters of Science
NSSF:	National Social Security Fund
PBS:	Phosphate Buffered Saline
PhD:	Doctor of Philosophy
RUAF:	Resource Center in Urban Agriculture and Food security
RVF:	Rift Valley Fever
S.D:	Standard Deviation
TCBS:	Thiosulfate Citrate Bile salts Sucrose Agar
UA:	Urban Agriculture
UNDP:	United Nations Development Program
UNEP:	Unite Nations Environmental Program
UN- Habitat:	United Nations Habitat
UNPD:	United Nations Population Division
UNPE:	Urban Population and the Environment

UPA: Urban and Peri Urban Agriculture

WHO: World Health Organization

WSP: Water Safety Plan

ABSTRACT

Wastewater can be defined as any water that has been adversely affected in quality by anthropogenic influence. It is used extensively for irrigation in Kenya, and in other countries where water is scarce. Risks involved in re-use of wastewater have necessitated the World Health Organisation (WHO) to formulate guidelines for irrigation water for example: total coliform counts not to exceed $1X10^4$ cfu/100 ml for leaf crops. The study a survey evaluated levels of contamination of the wastewater, the irrigated vegetables, and respective soils and associated health risks. Comparison was also made between vegetables obtained from the irrigated farms and those bought in selected market outlets. The areas covered were two urban slums located in Nairobi, Kenya: Maili Saba and Kibera. The markets studied included: Gikomba, Wakulima, Kibera and Korogocho. Emphasis was on bacteriology: total coliform counts and presence of *Vibrio cholera* and *Salmonella* Typhi; and parasitology: helminth larvae and eggs, and protozoa. This was done using standard bacteriological and parasitological procedures. Benefits and risks of wastewater farming (including respective awareness), as well as mitigation strategies, were identified through focus group discussions and questionnaire survey.

Results from a questionnaire survey indicated food security according to the farmers: ability to grow crops throughout the year and nutrition as important benefits that the farmers could attribute to usage of wastewater. On the contrary, there, seemed to have been general lack of awareness towards risks involved in usage of wastewater. Of the 232 farmers interviewed, only 28% identified health risks as a constraint, while 22.4% were not aware of any respective risks. Most farmers engaged in risky behaviours that could easily result in disease transmission: Eighty two

percent (190) of respondents ate sugarcane among other crops while in the wastewater-irrigated farms, while 37.9% (88) admitted to not wearing protective clothing while working on their farms. Thirty (30) samples taken from selected manholes and canals used for irrigation, others taken from vegetables from farms and markets (182), soil (64) and faecal samples (174).Water and vegetable samples were analysed for bacteriology and parasitology. The faecal and soil samples were analysed for parasitology. Wastewater yielded average coliform counts of 1.89×10^7 per 100milliliters, which was statistically significantly ($p<0.02$) above the WHO guidelines. Parasite larvae (13%), *Balantidium coli* (86%) and *Entamoeba coli* (6.6%) were isolated. One sample yielded *Vibrio cholera*. Kibera farm vegetables (55) also had high contamination with faecal coliforms, averaging 3.78×10^5 per 100 milliliters; and yielded parasites (64) that included: *Entamoeba hystiolytica* (14%), *Entamoeba coli* (14%), *Balantidium coli* (6%). One vegetable sample was found to have an egg of *Schistosoma haematobium*. There were statistically significant differences in average contamination levels between wastewater irrigated farm vegetables (3.78×10^5 per 100ml) and those from Gikomba (5.18×10^6 per 100ml), Wakulima (4.0×10^6 per 100ml) and Korogocho (5.2×10^8 per 100ml) markets ($p=0.000$, $p=0.001$ and $p=0.000$, respectively). Soil contamination was at an average of 46 parasitic larvae per kilogram, and 12.5 *Ascaris lumbricoides* eggs per gram. Comparing faecal analyses, wastewater farmers were shown to contain higher intensity of parasite infestation compared to the non wastewater users. Faecal sample results of the wastewater farming community (149) showed *Trichuris trichura* (18%); *Ancylostoma* (24%); *Strongyloides* (2%); *Ascaris lumbricoides* (16%); *Entamoeba coli (*14%); and *Entamoeba hystiolytica* (1.3%). One faecal sample showed eggs of *Schistosoma mansoni*. On the other hand, from the 24 faecal samples from non-wastewater farming community, *Trichuris trichura* was isolated (8%); *Ancylostoma* (41%); and *Ascaris lumbricoides* (12.5%). The Maili Saba men (n=51) had a higher variety of parasitic infestations *Trichuris trichura* (13.7%), *Strongyloides* (2%), *Entamoeba coli* (17.6%), *Anchylostoma spp* (15.6%), *Entamoeba hystiolytica* (4%) and *Ascaris lumbricoides* (13.7%). One case of *Schistosoma mansoni* was noted in a boy, compared to their counterparts, the Kibera Men (n=10) (*Anchylostoma spp* (10%), *Ascaris lumbricoides* (40%) and *Entamoeba coli* (20%)). There was no significant difference between parasite infestation rates in the women in the two study sites.

This study has shown that, while there are benefits to wastewater farming in Kenya, there are also risks involved. These are indicated by the parasite burden found in wastewater users, as compared to the non-users. The isolation of *Vibrio cholerae* organisms from wastewater highlights the risk of wastewater as a source of these pathogenic organisms for humans. The total coliform count in wastewater was not only higher than the recommended level WHO, but also an indicator that the farmers were using almost raw sewage for irrigation. This study also indicated lack of awareness among the wastewater users, with regard to the respective risks. Thus, awareness campaigns need to be initiated so as to educate the farmers on how to safeguard themselves. The observation that market vegetable coliform counts were higher than farm vegetable ones has introduced another aspect of vegetable contamination; one that originates from the vegetable handlers: the middle-people and traders. Consumers are, therefore, advised to cook there vegetables well before eating. Domestication of the WHO guidelines to the Kenyan scenario and their enforcement is highly recommended.

CHAPTER ONE

1.0. INTRODUCTION

Wastewater commonly refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources (http://en.wikipedia.org/wiki/Wastewater accessed 8/4/2010). It is usually a combination of domestic effluent consisting of black water (excreta, urine and associated sludge), grey water (kitchen and bathroom wastewater), water from commercial establishments and institutions, including hospitals, industrial effluents and storm water, and other urban runoff, (Van der Hoek, 2004). Wastewater is commonly used for irrigation in Urban and Peri urban Agriculture.

Urban Agriculture or Peri Urban Agriculture may be defined as an industry located within the fridges of a town, city or metropolis, which grows or raises, processes and distributes a diversity of food and non food products using and reusing largely human and material resources, products and services largely to the urban area as described by Mougeort (Da Silva, 2011). Livestock keeping in urban and peri urban areas has been documented in many countries including Kenya, (Guendel, 2002) and in Hyderabad, India, where livestock is kept next to the farmers' house in the city (Buechler, *et al,* 2002). Urban Agriculture tends to utilise urban resources such as wastewater.

Due to water scarcity, reuse of wastewater has become the main option for use in agriculture (Blumenthal, *et al*, 2000). This is especially so in the eastern Mediterranean region where water resources have dwindled to less than 180m^3 per capita such as Yemen and Palestine (Saleem *et. al.* 2006). Wastewater can be recycled and reused through planning. Althhough some countries like Israel that have been able to reclaim 67%, India and South Africa have each reclaimed about 25%; of their wastewater through planned reuse, un planned reuse is, however, much greater (Fattal *et. al,* 2005). In Jordan Morocco, Turkey and Cyprus some form of direct or indirect wastewater reuse takes place (Fattal *et al.* 2005). The sources of this waste water are: (1) Domestic used grey water without urine and faeces, (2) Industrial wastewater composed of water from industrial processes with varying concentration of heavy metals and (3) Domestic used black water mixed with faeces and urine (Kilelu, 2004). Sewer lines are also blocked and diverted for use in irrigation in urban agriculture. These sources of wastewater contain various levels of pollutants and often exceed the WHO recommendations of 1 X 10^3 cfu/100ml and < 0.1 nematode egg / liter for unrestricted irrigation (WHO, 1989, 2006).

Studies in Nairobi, Kenya showed that 34% of irrigators in Maili Saba were using raw sewage for irrigation (Cornish and Kielen, 2004). The irrigated land was approximately 2200 hectares. In Senegal, wastewater irrigation was preferred to other sources of water due to higher profits stemming from its greater availability, reduced fertilizer costs and higher yields and production (Faruqui, *et al,* 2004). In Pakistan untreated wastewater is used for irrigation in over 80% of communities in urban and peri-urban areas of approximately 10,000 inhabitants (Ensink, *et al,* 2004).

The challenge of wastewater reuse is usually the threat to public health. The main impact on health for developing countries is from diseases caused by helminthes (roundworms, hook worms, tapeworm and guinea worm), protozoa and bacteria. This occurs when untreated wastewater is used to irrigate vegetables or salad crops that are then eaten raw (Faruqui, 2002). The informal methods of irrigation used by farmers (watering cans, buckets, water hoses) increase the risk of contamination of crops (contact of water with edible parts) and general exposure of farmers (Keraita, *et al,* 2002).

The Hyderabad Declaration (2002) recognizes that: Wastewater use in agriculture (raw, diluted or treated) is increasing in global importance, particularly in urban and peri-urban agriculture. With proper management, wastewater use contributes significantly to sustainable livelihoods, food security and quality of the environment. Without proper management, wastewater use poses serious risks to human health and the environment. In view of this, it is very important to assess the health risks involved, find ways to mitigate them by involving the community in the process of understanding the risks and collectively finding solutions that are workable and long lasting.

1.1 OBJECTIVES

1.1.1 OVERALL OBJECTIVE

To determine the health risks associated with utilization of wastewater for irrigating crops.

1.1.2 SPECIFIC OBJECTIVES

1.) To determine the benefits and risks in wastewater reuse for agriculture in urban and peri-urban areas of Nairobi

2.) To determine the awareness of farmers of the health risks involved.

3.) To assess the level of contamination of wastewater, vegetables and soil from wastewater irrigated farms and vegetables from markets

4.) To identify the risk factors associated with wastewater and suggest mitigation strategies that can reduce the risk posed by use of wastewater for irrigation.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 WASTEWATER

2.1.1. Introduction

Wastewater comprises liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations. In its most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources (Wikipedia, 8/4/2010).

Wastewater is usually a combination of domestic effluent consisting of black water (excreta, urine and associated sludge), grey water (kitchen and bathroom wastewater), water from commercial establishments and institutions, including hospitals, industrial effluents and storm water, and other urban runoff (Van der Hoek, 2004).

Estimates indicate that within the next 50 years, more than 40% of the world's population will live in countries facing lack of water or water scarcity (Hinrichsen, et al, 1998). Most livelihood activities depend on the availability of water and yet in many semi-arid and arid regions of the world, fresh water is a scarce resource. Fresh surface water is usually only available in sufficient quantities during the rainy seasons, which normally last for periods of 4 months. The rainfall also tends to be erratic, thus necessitating irrigation. Water for irrigation is also required during long dry seasons. Ground water is normally expensive to access; there are high costs associated with drilling wells and pumping of the water.

Seeking other sources of water to support livelihoods, therefore, becomes critical. Near urban centers wastewater is often available year round in sufficient quantities (Buechler, 2005). Water quantity and quality are both issues of concern and recycling of wastewater is one of the main options as a new source of water in water-scarce regions (Blumenthal, *et al*, 2000).

As the cities and towns grow in population they have increasing problems with the disposal of urban wastes and wastewater and maintaining air and river water quality (RUAF 2006). A lot of wastewater is generated in cities, for example: the twin city of Hubli-Dharwad India generates approximately 60 million litres of wastewater per day (Bradford *et al*, 2002).

According to Van der Hoek (2004), urban wastewater is seen as a combination of all or some of the following:

- Domestic effluent consisting of black water (excreta, urine and associated sludge) and grey water (kitchen and bathroom wastewater)
- Water from commercial establishments and institutions, including hospitals
- Industrial effluents
- Storm water and other urban runoff (Figure 2.1).

The actual proportion of each constituent within each urban sewage load will vary due to spatial and temporal differences. In India it is estimated that 73% of wastewater is untreated (Scott, *et al*, 2004). In irrigation, the term "marginal quality water" is used to refer to such water (Van der Hoek, 2004). The quality may pose a threat to sustainable agriculture and/or human health.

In Kenya it is estimated that the annual quantity of renewable freshwater resources available is 20.2 billion m^3 (Onjala, 2002), though this figure is dependent on the rainfall amount, the aridity of the area and the ground water available. The resultant average water supply is approximately 690 m^3 per capital per annum, where as the global bench mark is 1,000 m^3 per capital per annum. Kenya is therefore classified as a chronically water scarce country (Onjala, 2002). This means that there is barely enough water available for human consumption let alone for irrigation. As in most urban areas in Africa which are characterised by poor sewage connectivity, Kenya has only 14% of the 215 urban centres in the country is covered with sewerage facilities (Githuku, 2009). That means the wastewater is not available for reclamation and reuse.

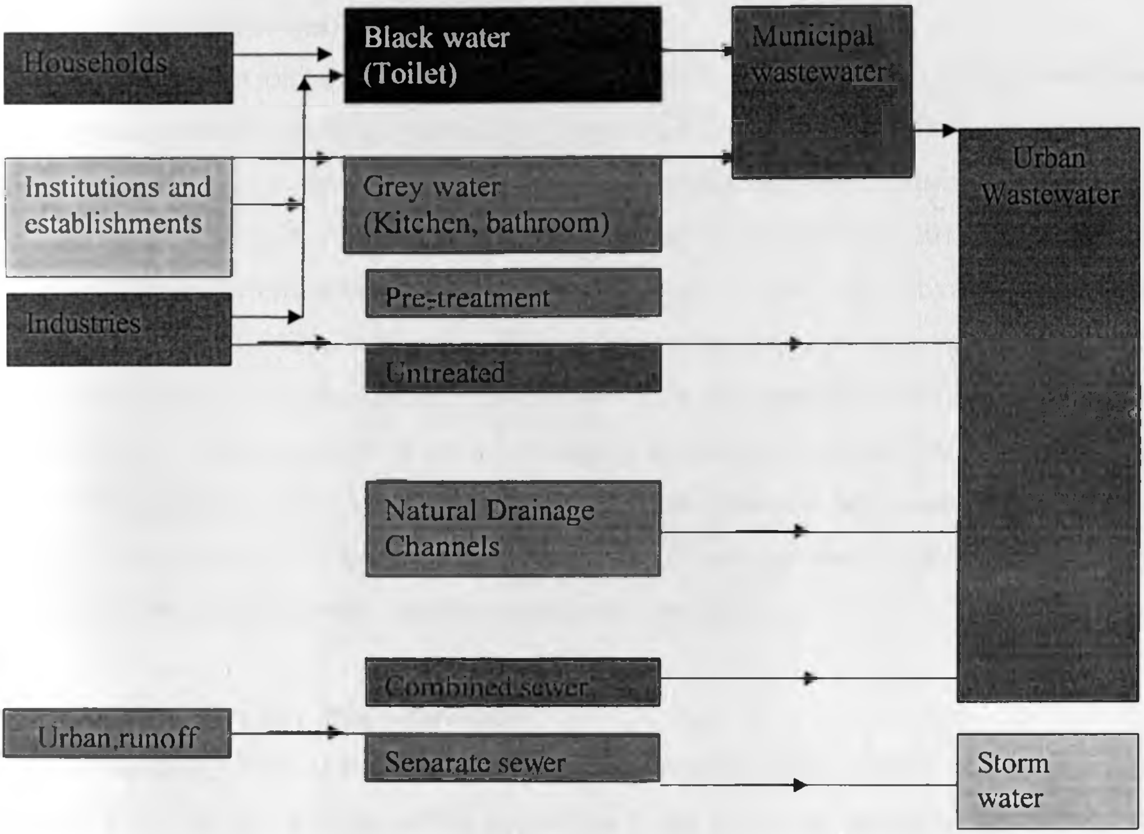

Figure 2. 1: Sources of urban wastewater (source: Van der Hoek (2004).)

2.1.2 Applications of wastewater.

Treated wastewater can be reused for drinking, in industry (cooling towers), in agriculture, and in the rehabilitation of natural ecosystems (e.g Lawns and Golf courses). Wastewater has been used in agriculture either as treated or in its raw form. Approximately 84 % of Israel sewage is treated or reclaimed water that is reused in agriculture irrigation; (Dreizin, Y. 2011). In Vietnam and Pakistan alone, an estimated 10,000 - 30,000 hectares of land are cultivated with undiluted wastewater (IWMI, 2006). In Kumasi, Ghana, farmers use wastewater sources on about 12,000 hectares which is more than twice the area covered by the country's formal irrigation schemes (IWMI 2006). Unfortunately, in most developing countries wastewater treatment systems are hardly functioning or have a very low coverage. These results in large scale water pollution of rivers and the use of very poor quality water (from rivers) for crop irrigation especially in the vicinity of urban centres where wastewater is greatly produced.

2.1.3. The people who utilize wastewater

In 2005 in Kenya, 21% of the population are urban dwellers, with a density of 1,981 persons per square kilometre. Of this the urban population living in slums was between 60-80% (UN-Habitat, 2008). As population increases, this places high demands for fresh water while the amount of wastewater discharged into the environment increases, thus leading to more pollution of clean water sources (WHO 2006).

The growing competition between agriculture and urban areas for high quality fresh water supplies (particularly in arid, semi-arid and densely populated regions) increases the pressure on this resource. More fresh water is abstracted and used in agriculture in arid and semi-arid countries than for any other purpose (i.e. for domestic uses and industrial uses combined) (Blumenthal, *et al*, 2000). In many cases, usage of wastewater, excreta and grey water in agriculture is taken to be a better option than usage of higher-quality fresh water, because crops benefit from the nutrients they contain. Usage of wastewater, and excreta, therefore, helps in meeting agricultural-water demand and allows for preservation of high-quality water resources for drinking (WHO 2006).

2. 2 URBAN AGRICULTURE

Urban agriculture (UA) may be defined as the growing of crops and keeping of livestock within and around cities (RUAF, 2006). Urban Agriculture is also defined as the growing of food crops and non-food crops and the raising of livestock, which are consumed locally within urban and peri-urban boundaries (Kilelu, 2004). Though it is not possible to delineate precise boundaries where the peri- urban zone starts or ends but it is the area adjacent to an urban center, influenced by pressure on land-use conversion from rural to urban usage; ready access to a large market; ready access to services and physical inputs; increasing problems of waste management and pollution from the urban center (Hide and Kimani, 2000). Due to the lack of working definition as to what entails "urban" and "peri-urban" they are used interchangeably in the concept of urban agriculture for the purposes of this thesis.

Urban Agriculture (UA) is differentiated from rural agriculture in that it is integrated in the urban economy and ecological system. For example in UA, the urban population are the labourers, There is use of typical urban resources (like organic waste as compost and urban wastewater for irrigation), direct links with urban consumers, direct impact on urban ecology (positive and negative), being part of the urban food system, competing for land with other urban functions and being influenced by urban policies and plans among others. Urban agriculture is not a relic of the past that will fade away since the practice increases as the city grows. Urban Agriculture is not brought to the city by rural immigrants, but an integral part of the urban system (RUAF, 2006).

Urban agriculture is widely practiced around the world. According to UNDP (1996), there were initially 800 million people globally working in urban agriculture, where it has gained increasing significance, popularity and advocacy in recent years. Urban agriculture is rapidly growing in importance as an economic sector in many cities globally. The rapid urbanization that is taking place goes together with a rapid increase in urban poverty and urban food insecurity. It is estimated that by year 2020 the developing countries of Africa, Asia, and Latin America will be home to some 75% of all urban dwellers, including eight of the anticipated nine mega-cities with populations in excess of 20 million. It is also expected that by year 2020, 85% of the poor in

Latin America, and about 40-45% of the poor in Africa and Asia will be concentrated in towns and cities (RUAF, 2006).

They will also have increasing problems with the disposal of urban wastes and wastewater and maintaining air and river water quality (RUAF, 2006). Land-use will change from predominantly agricultural to non-agricultural in cities, dictated by urbanization in the form of industries, residential and recreational space. This development will have the effect of reducing the available fertile land for agriculture on which the poor persons depend. However, there will be an emergence of a growing market. Adapting to these changes farmers will take advantage of the ready market to produce crops such as vegetables. This trend is already seen in many cities across the world: of African cities are Tamale, Ghana (Amarchey, 2005) Lagos, Nigeria (Anosike *et al* 2005) Harare, Zimbabwe (Mbiba 2000), Kampala, Uganda (Nabulo 2004), and Nairobi, Kenya (Foeken and Mwangi, 2000).

The contribution of UA to food security and healthy nutrition is probably its most important asset. Food production in the city is largely a response of the urban poor to inadequate, unreliable and irregular access to food and the lack of purchasing power (RUAF, 2006). In Harare, Zimbabwe, over 60% of the maize and leafy vegetables produced on-plot is consumed by the household (Mbiba 2000). In a survey done in Nairobi by Ishani and others (2003a), livestock was kept for subsistence purposes. The number of livestock kept was small and only milk, as a product was for sale. The space for keeping livestock was inadequate

Urban agriculture provides a complementary strategy to reduce urban poverty and food insecurity and enhance urban environmental management. Therefore playing an important role in enhancing urban food security since the costs of supplying and distributing food to urban areas based on rural production and imports continue to increase. The supply does not satisfy the demand especially of the poorer sectors of the population. Urban agriculture contributes to local economic development (RUAF, 2006). The urban and peri-urban sheep and goat keeping in Nairobi as part of Urban Agriculture was due to the less work involved in keeping them compared to cattle. The initial investment was low and affordable, demand for the meat was high and returns were good (Ishani *et al.*, 2003a). Poverty alleviation and social inclusion of the urban poor and women in particular was recognized. There was the effect of making cities greener and the productive reuse of urban wastes (RUAF, 2006).

2. 2.1 People involved in urban agriculture

A large part of the people involved in urban agriculture are persons of varying social economic status. They range from retired civil servants, and other middle and high salaried people (Foeken and Mwangi, 2000). In many cities, one will often find lower and mid-level government officials, school teachers involved in agriculture, as well as richer people who are seeking a good investment for their capital. In Nairobi, Kenya although all types of households are represented the poor(er) households are over-represented. There is a general belief that these are recent immigrants. This is, however, not true because the urban farmer needs time to get access to urban land, water and other productive resources (Foeken and Mwangi, 2000).

Women constitute an important part of urban farmers; 29% of respondents to a survey in Kisumu, were female who headed households and carried out the farming activities themselves (Ishani *et al*, 2003b). A third of the respondents in a similar survey in Nairobi, were female household heads and even in the male headed households most of the burden of taking care of the livestock was left to the women (Ishani *et al*, 2003b). In a study in Dar es Salaam, Lupala, (2003) revealed that in the urban settlement of Mabibo, 90% of the people in charge of keeping livestock were women. One reason why more women are involved in UA is that related processing and selling activities can be more easily combined with their other tasks in the household, while it is difficult to combine it with urban jobs that require travelling to the town centre or industrial areas, where most men are occupied (RUAF 2006).

Other persons involved in urban agriculture are the consumers who are mostly the urban populations of the towns. The food is either consumed in their houses or in hotels around the city centre. There is the category which supplies various types of inputs such as seeds, capital and extension services. Produce is also handled by middle men or women who buy from the farm and sell in various estates or markets. The produce is also transported from the farm to various markets and sometimes to far areas, as it happens with Napier grass when there is drought (UNDP, 1996 and RUAF, 2006).

2. 2.2. Locations where urban agriculture is practiced.

Urban agriculture may take place in locations inside the cities, intra-urban, or in the peri-urban areas. The activities may take place on the homestead, on-plot (Where the household lives), or on land away from the residence, off-plot (far from the household), on private land (owned, leased), on public land (parks, conservation areas, along roads, streams and railways), or on semi-public land (schoolyards, grounds of schools and hospitals). These are described by various authors (RUAF, 2006; Foeken and Mwangi, 2000 (Nairobi); Mbiba, 2000 (Zimbabwe). Nabulo and co workers (2004) described other sites that included former waste dumping sites, wetlands and scrap yards in Kampala, Uganda.

2. 2.3. Types of produce.

Urban agriculture includes food products, from different types of crops (grains, root crops, vegetables, mushrooms, fruits), animals (poultry, rabbits, goats, sheep, cattle, pigs, guinea pigs, fish among others), non-food products (like aromatic and medicinal herbs, ornamental plants, tree products among others.) or combinations of these. Often the more perishable and relatively high-valued vegetables and animal products and by-products are favoured (Tegegne, 2004; Mbiba, 2000; RUAF, 2006). Production units in urban agriculture in general tend to be more specialized than rural enterprises. Hide and Kimani (2000) reported in Nairobi, Kenya growth of exotic vegetables such as Chinese cabbage.

2. 2.4. Types of economic activities

Urban agriculture includes agricultural production activities such as growing of food crops, keeping of livestock, ornamental plant and medicinal herbs. It also involves related processing and marketing activities and this may include processing milk into yoghurt for sale as well as inputs (e.g. compost). In urban agriculture, production and marketing tend to be more closely interrelated in terms of time and space than for rural agriculture, thanks to greater geographic proximity and quicker resource flow (Tegegne, 2004; RUAF, 2006).

2. 2.5. Wastewater irrigated produce destination / degree of market orientation.

In most cities in developing countries, an important part of urban agricultural production is for self-consumption, with surpluses being traded (Mbiba 2000). However, the importance of the market-oriented urban agriculture, both in volume and economic value, should not be underestimated. For about 40% of produce that is off plot in Harare (Mbiba 2000) and 52% in Democratic Republic of Congo (DRC), (Thys and Mfoukou-Ntsakala, 2003), the main motivation was income generation. Products are sold at the farm gate, by cart in the same or other neighbourhoods, in local shops, on local (farmers) markets or to intermediaries and supermarkets. Mainly fresh products are sold but part of it is processed for own use, cooked and sold on the streets, or processed and packaged for sale to one of the outlets mentioned above (RUAF, 2006).

In addition to production for home consumption, large amounts of food are produced for other categories of the population. An estimated (UNDP, 1996) 200 million urban residents provide food for the market and 800 million urban dwellers are actively engaged in urban agriculture in one way or another. In Dakar Senegal 60% of the vegetables consumed within the city are from urban agriculture (Niang, et al, 2002).

2. 2.6. Scales of production and technology used in Urban Agriculture

In the city, we may encounter individual or family farms, group or cooperative farms and commercial enterprises at various scales ranging from micro- and small farms (the majority) to medium-sized and some large-scale enterprises (Mbiba, 2000; Oruwari and Jev, 2004). Urban agriculture to a large extent complements rural agriculture and increases the efficiency of the national food system in that it provides products that rural agriculture cannot supply easily (e.g. perishable products, products that require rapid delivery upon harvest), that can substitute for food imports and can release rural lands for export production of commodities (Oruwari and Jev, 2004). When irrigation is used as a technology, only the basics of watering cans are adopted. Male farmers in Lagos are more likely to use machinery because of the large pieces of land cultivated (Anosike, *et. al.*, 2005).

2.3 WASTEWATER REUSE IN URBAN AGRICULTURE

Wastewater reuse in urban agriculture is either direct or indirect. Direct reuse occurs where sewer lines are tapped (Huibers *et al.*, 2004). Indirect reuse of wastewater occurs when; the wastewater is disposed off into rivers and the resulting contaminated river water is used for irrigation (Blumenthal, et al., 2000). Or where surface water such as ponds and lakes becomes polluted with wastewater and is consequently used for irrigation in UA such as seen in South America, Bolivia (Huibers, *et al.*, 2004).

In Asia examples of wastewater use for UA are in the drought prone semi-arid areas of Andhra Pradesh state, India .Wastewater generated from the twin cities of Hyderabad and Secunderabad is used for irrigation and contributes to their food security (Buechler and Devi, 2000). In other areas untreated wastewater is used for irrigation in over 80% of all Pakistan communities with a population of over 10,000 inhabitants. A survey in four provinces of Pakistan showed that wastewater was used in 50 out of 60 visited cities (Ensink, *et al.*, 2004).

In Africa, indirect use of wastewater is evident in Kumasi Ghana where the city's urban drainage system flows into the Sisa river which joins the Oda river which is what the farmers use for irrigation. The water quality was measured and found to have 31,000 CFU/ 100 ml, 31 times above what is recommended by WHO for unrestricted irrigation (Cornish and Lawrence 2001). Other areas of Ghana include Tamale and Accra where wastewater is used for irrigation in UA with 10^4-10^6 CFU/ 100 ml being recorded (Keraita and Drechel, 2004).

In Nairobi Kenya, wastewater use is both direct and indirect as Hide and Kimani (2000) found out. The sources of water for irrigation were varied, 56% use rivers and streams, 36% raw sewage water and 6% piped water from treated city council systems.

2.4. CONTAMINATION OF RIVERS AND WATER SOURCES

Contamination of rivers and water sources followed the random disposal of waste and refuse into water sources (Ishani, *et al.*, 2003a). In poor neighbourhoods sanitation was poor and lacked toilets. In Asia only 45% of large cities were covered by sewers of which 35% was treated to a secondary level. In Africa the situation was worse with only 18% of the population in large cities covered by sewer system and none was treated to a secondary level (Scott, *et al.*, 2004). In a survey of Kibera (a slum in Nairobi), residents reported they resorted to throwing solid waste in open drains. When a pit latrine filled up, a passage was opened up during the rains and the contents flowed into one of the drainage channels, thereby emptying the pit. Flying toilets (which are plastic bags containing human waste) were commonly thrown from homes to the street. The run off ended up in Nairobi River, which was then used for irrigation (Richards and Godfrey, 2003).

Most of the pollution of rivers and water sources tended to be down stream of cities. Due to the high growth of population in cities either from high fertility rates or due to rural urban migration, there was generation of large amounts of wastewater. In Cochobamba, Bolivia the volume of wastewater was expected to double by 2025 (Huibers *et al* 2004). There was also a scarcity of fresh water. The wastewater generated was then used in urban agriculture within the cities or downstream in the peri-urban areas of the cities.

Although wastewater irrigation was thought to occur only in major cities it has also been seen downstream of small towns and cities (Scott, *et al.*, 2004). The types of crops, livestock and fish that farmers can raise were affected by the quality of the wastewater and the characteristics of the natural environment (Buechler, 2005).

2.5 BENEFITS OF WASTEWATER USE IN URBAN AGRICULTURE

The use of wastewater for irrigation was seen as a way of disposing urban sewage water with several advantages: for example, most crops produced higher yields when watered with untreated wastewater without addition of inorganic fertilizers. (Faruqui *et al.*, 2004) This is because it contains a lot of nutrients. Wastewater irrigation has been reported to reduce the growth period for crops increasing the number of times per year of harvests (Faruqui, *et al.*, 2004).

The main benefit of urban agriculture and the reason for cultivation by most farmers was food (41%), easy access to markets (21%) and economic empowerment (9%). This showed that food security was the most important reason for UA in Kampala, Uganda (Nabulo, *et al.*, 2004). This was also the case in Kumasi, Ghana where vegetables are produced for home consumption (Keraita and Dreschel, 2004). Women are seen to benefit most from UA as it contributes to their livelihood, food security and household income. This was shown when women respondents to a questionnaire said that if they were to stop urban agriculture only 1% would not be affected. (Nabulo, *et al.*, 2004).

Wastewater is an alternative water source in arid and semiarid areas where water is scarce (Feenstra, *et al.*, 2000). Wastewater is also reliable all year round unlike rain that is seasonal and scanty (Keraita and Dreschel, 2004). Wastewater is also available on demand and sufficient for more crops in a year. This has the effects of generating employment increasing the land value and income from crops and livestock (Buechler and Devi, 2004). Wastewater irrigated produce has served as a source of income especially for the urban poor. For example, at least 80% of the farmers involved in wastewater irrigated urban agriculture in Nairobi reported this activity as their main source of income. Dry season peri-urban vegetable farming is seen as a significant source of income generation in wastewater irrigation farming in Ghana (Keraita and Dreschel, 2004).

2.6. CONSTRAINTS OF WASTEWATER USE IN URBAN AGRICULTURE.

The main constraint of wastewater use is the threat to public health related to insufficiently treated wastewater. Microbial and chemical contaminants can cause diseases if wastewater is not well treated, and used to produce food crops (Kilelu, 2004). However the major constraint identified by farmers tends to be the lack of enough wastewater for all involved. Availability of water and poor water quality were ranked as the primary constraint to irrigation in a survey in

Nairobi, Kenya (Hide and Kimani, 2000). Most do not associate health risks with the use of wastewater. Market gardeners in Ouagadougou city in Burkina Faso reject any possibility of being victims of waterborne diseases and thus may contaminate members of their families. They do not "have reason to think" water should be considered a medium through which diseases known to them are transmitted (Ouedraogo, 2002).

Another constraint reported was environmental degradation. This occurred at several levels: there was salinization of the farms and build up of heavy metals in the soil profile. In Cochobamba, Bolivia there are extremely high concentrations of cadmium (Cd), chromium (Cr^{6+}), and lead (Pb) in the soil (Huibers, *et al.*, 2004).

2.7. GUIDELINES IN THE USE OF WASTEWATER.

The World Health Organization (WHO) has had several guidelines on wastewater reuse. This has been updated over time as research and new advances emerge. The latest is the 2006: "*Guidelines for the safe use of wastewater, excreta and greywater*" replacing the 1989 WHO guide lines: "*Health guidelines for the use of wastewater in agriculture and aquaculture*". This has long been in use and some of the aspects have been super ceded while some have been reinforced. The relevant sections can be found in Appendix (1.0).

Kenya does not have any National guidelines on the use of wastewater or excreta in Agriculture or Aquaculture.

2.8 HEALTH RISKS ASSOCIATED WITH URBAN AGRICULTURE IN RELATION TO USE OF WASTEWATER IRRIGATION.

Irrigation with untreated wastewater can represent a major threat to public health (of both humans and livestock), food safety, and environmental quality. Wastewater has been implicated as an important source of health risk for chronic, low-grade intestinal disease like amoebiais as well as outbreaks of more acute diseases including cholera in Jerusalem and Dakar and typhoid in Santiago (Scott, *et al.*, 2004). The health of the urban poor is particularly linked to inadequate management of wastewater. Chronic diarrhoeal and gastrointestinal diseases, which

disproportionately affect urban slum dwellers that have inadequate sewerage and sanitation facilities, are clearly major negative outcomes of exposure to wastewater (Fattal, *et al.*, 2004).
There are many ways through which untreated wastewater can lead to human diseases in urban and per urban agriculture. Coliform bacteria are mainly transmitted to humans from wastewater via the contamination of crops irrigated with wastewater especially for crops eaten raw (Zeeuw and Lock, 2000; Fattal *et al*, 2004). Another route is by consumption of contaminated meat from domestic animals that have ingested tapeworm eggs (*Taenia saginata*) from faeces in untreated sewage. Poorly treated sewage may contain viable stages of the hookworms that contaminate soils and affect agricultural workers who expose their bare skin to the soil (i.e. direct contact) as they work on the farms. Transmission of pathogens may also take place by fertilization of fish ponds with human and animal wastes (e.g. overhanging latrines, overhanging poultry cages, ducks, and addition of urban night soil and use of wastewater) (Zeeuw and lock, 2000; Fattal, *et. al*., 2004).

Wastewater irrigation of vegetables and fodder may serve as transmission route for heavy metals in the human food chain. Wastewater is increasingly being used to irrigate fodder that supplies an urban and peri-urban livestock-based production chain (Scott *et al*., 2004). With deteriorating wastewater quality, the health of the livestock may be seriously impaired and the quality of their milk and meat may be affected due to heavy metal accumulation, which may transfer the danger to humans (Buechler, 2005).
The main health risks associated with urban and peri urban agriculture can be grouped into the following categories according to Zeeuw and lock (2000):

a) Contamination of crops with pathogenic organisms (e.g. bacteria, protozoa, viruses or helminths), by use of polluted water from streams, or inadequately treated wastewater or organic solid wastes.
b) Human diseases transferred from disease vectors attracted by agricultural activity. e.g. breeding of vectors such as the *Anopheles* and *Culex* mosquitoes which transmits malaria and filariasis respectively (Ensink, *et. al*., 2004). Others are snails that are vectors of schistosomosis.

c) Human diseases associated with unsanitary post harvest processing, marketing and preparation of locally produced food e.g. *Salmonella* Food Poisoning
d) Contamination of crops and/or drinking water by residues of agrochemicals e.g. pesticides
e) Contamination of crops by uptake of heavy metals from contaminated soils, air or water e.g. in Japan a chronic disease 'itai itai" (it pains) that affects especially old women is caused by the accumulation of cardium.
f) Transmission of diseases from domestic animals to people (zoonosis) during animal husbandry, processing or meat consumption e.g. taeniasis and cysticercosis
g) Occupational health risks for workers in the food-production and food-processing industries e.g. one may get cuts and scratches from their work and be exposed to diseases present in the food being prepared (vegetables irrigated with wastewater).

Other major potential health hazards associated with urban agriculture are physical, chemical, biological and psychosocial (Cole, *et al.,* 2006). The physical hazards may include injury from sharp objects such as broken bottles and needles in waste dumps. Chemical hazards involve exposure through contact of chemicals with the skin, inhalation of dust from contaminated soil or gaseous emissions and through ingestion of food contaminated with toxic wastes from soil and wastewater. Psychosocial issues may arise due to insecurity due to unclear land tenure, loss of farmland, fear of threat and violence or overload due to long hours of work. Biological risks may be due to parasitic worms, bacterial and vector borne diseases (Cole, *et al.,* 2006).

These health risks are totally ignored and the incidence of disease is not linked to wastewater reuse. Wastewater is equated by most to portable water. Observations in Ouagadougou, Burkina Faso, was that women and men soaked their hands in this water and then went on to eat, breast feed babies *etcetera*, without washing their hands (Ouedraogo, 2002).

2.9. EFFECTS OF WASTEWATER ON FARM WORKERS

Use of untreated wastewater for crop irrigation causes a significant increase in infection with intestinal nematodes in farm workers in area where such infections are endemic. The intensity of

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2.9. EFFECTS OF WASTEWATER ON FARM WORKERS

Use of untreated wastewater for crop irrigation causes a significant increase in infection with intestinal nematodes in farm workers in area where such infections are endemic. The intensity of infection (number of worms per person) and the effects of infection were higher in waste-water users. Anaemia due to hookworm infections is also common. Impact of amoebiasis on farm workers has not been fully understood. Cholera can also be transmitted to farm workers irrigating with raw wastewater from a town where cholera outbreak is occurring as happened in the Jerusalem 1970 outbreak (Blumenthal, *et al.*, 2000).

Blumenthal and others (1996) reported that farm workers and their children in contact with wastewater through irrigation had a significantly higher prevalence of *Ascaris* infection than those in the control group, using rain-fed agriculture. The excess infection was greater in children than in adults. Young children aged 0-4 years had increased rate of diarrhoeal disease (Cifuentes, *et al.,* 1993). Actual increased health risk was observed in farmers and their families in the Haroonabad area of Punjab province in Pakistan. Farmers *who* were irrigating their land using wastewater had higher prevalence of diarrhoeal diseases than farmers irrigating their land with canal or well water. The prevalence of diarrhoeal diseases was also high in children of farmers working with wastewater. The most common problem was associated with iron deficiency anaemia, which was explained by a high prevalence of 80 percent hookworm infections observed in farm workers exposed to wastewater. Hookworms infect individuals via penetration of the skin. The lack of protective clothing (use of bare feet) observed in farmers in this area explains the high prevalence of infection (Feenstra, *et al.*, 2000).

In Senegal many farmers suffer from ill health because of direct contact with the wastewater- the lack of footwear or gloves makes them vulnerable to infection by parasites, transmitted either orally (placing unwashed hands in the mouth) or through the skin (parasites burrowing directly into the body). At Ouakam, where only wastewater is available 60% of the farmers were infected with intestinal parasites. At Pikine, where water sources are mixed, the level of infection was lower; about 40%. The commonest parasites were *Ascaris lumbricoides* (round worm), *Trichuris trichiura* (whip worm) and *Strongyloides stercoraltis* (thread worm) (Faruiqui, *et. al.*, 2004).

The lack of protective clothing is seen to be important in perpetuation of some of the health risks. In Kampala Uganda, 55% of women farmers are seen to practice UA using wastewater and are, therefore, more exposed to its hazardous effects (Nabulo, *et. al.*, 2004). Only 37% of the women use protective clothing while 42% of respective men put on protective clothing.

2.10. EFFECTS ON CONSUMERS OF VEGETABLE CROPS

Table 2.1 shows that pathogens survive for quite some time after they have adhered to the crops. (USEPA, 1992). This poses a serious health risk when wastewater is used for irrigation especially for crops eaten raw and the necessary precautions of stopping irrigation for 2 weeks before the crops are harvested are not taken into account.

Table: 2.1 Typical pathogen survival times at 20-30^{0}C (in days).

Pathogen	Freshwater and sewage	Crops	Soil
Viruses	<120 but usually <50	<60 but usually <15	<100 but usually <20
Bacteria	<60 but usually < 30	<30 but usually <15	< 70 but usually <20
Protozoa	< 30 but usually <15	<10 but usually < 2	< 70 but usually <20
Helminths	Many months	< 60 but usually < 30	Many Months

Source: (USEPA, 1992)

When unrestricted irrigation was carried out there was evidence to suggest that the use of untreated wastewater to irrigate vegetables led to increased helminth infection (mainly *Ascaris lumbricoides* infection), bacterial infections (typhoid, cholera and *Helicobacter pyroli*) and symptomatic diarrhoeal disease in consumers (Blumenthal and Peasey, 2002). Faruqui and others (2004) reported that harvested wastewater-irrigated plants for sale were found to be contaminated with amongst other pathogens, *Amoeba*, *Ancylostoma*, and *Ascaris* which cause amoebic dysentery, hookworm, and roundworm infestations, respectively.

Vegetables are also prone to recontamination. It has been speculated that the major sources of bacterial contamination of fresh vegetables may be drawn from the distribution, handling and marketing system rather than from production (Zeeuw and Lock, 2000). For consumers the general concern is for crops eaten raw such as lettuce, tomatoes and onions which are the specialty of some farmers as they fetch a higher market price (Faruqui, *et al.*, 2004).

2.11 ZOONOSES SPREAD BY WASTEWATER IRRIGATION

2.11.1. Taeniasis and cysticercosis

Cattle feeding on pastures irrigated with raw wastewater can become heavily infected with the larva stage of *Taenia saginata (Cysticercus bovis)* as had occurred in Australia. Taeniasis and cysticercosis are transmitted by consumption of meat infected with tapeworm eggs ingested by animals that scavenge on human faeces, or of crops irrigated with improperly treated sewage. Pig tapeworms (*Taenia solium*) create more severe effects in humans than beef tapeworms (Zeeuw and lock, 2000). Studies indicate that the incidence of cysticercosis is quite alarming, especially that of *Cysticercus cellulose* (*T. solium cyst*) derived from pigs. About 30% of the pigs in South America were detected as having cysticercosis nodules by palpation method in their tongue and about 2-24% of the people in rural areas of Bolivia have *Taenia solium* in their intestines (Katrient, 2000).

WHO considers cysticercosis a serious problem when the incidence rate exceeds 1% (Katrient, 2000). Transmission of the parasites occurs when human excreta containing eggs of *Taenia solium* contaminates wastewater. The wastewater is then used for irrigation of crops for human consumption. If a person consumes raw vegetables such as lettuce or fruits that do not need peeling such as strawberries he or she can ingest the *Taenia solium* eggs. In this case the cycle that normally takes place in the pig takes place in the human body. The cysts then form in various parts of the body, some in the brain resulting to neurocysticercosis (NCC) which causes symptoms similar to epilepsy or brain tumour (Katrient, 2000).

2.11.2. Bacterial zoonosis

Salmonella and *Campylobacter* can be transmitted through contamination of animals that are a source of food to humans. Animals (especially poultry) shed pathogens in their faeces in slaughterhouses, which may contaminate the meat during processing. The processing plants release a lot of wastewater with these pathogens (Zeeuw and Lock, 2000). A survey in Kisumu, Kenya showed that the common diseases were Typhoidal and Non Typhoidal Salmonella (a water borne disease acquired through drinking of water contaminated with livestock faeces), anthrax (from consumption of un-inspected meat), and brucellosis (from drinking raw untreated milk). Ishani *et al* (2003b),

2.12. *VIBRIO CHOLERAE* AND *SALMONELLA* TYPHI

Wastewater has been implicated as an important source of health risk for chronic, low-grade intestinal disease like amoebiasis as well as outbreaks of more acute diseases including cholera in Jerusalem and Dakar and typhoid in Santiago (Scott, *et al.*, 2004). When wastewater is used to irrigate vegetables to be consumed raw, it has been linked to cholera and typhoid as well as to faecal bacterial diseases, diarrhoea and dysentery, among consumers of wastewater-irrigated produce (Buechler *et al*, 2002).

Typhoidal and Non typhoidal Salmonellosis in humans is generally contracted through consumption of contaminated food of animal origin (mainly meat, poultry, eggs and milk), although many other foods, including green vegetables contaminated with manure, have been implicated in its transmission. The causative organisms pass through the food chain from primary production to households or food-service establishments and institutions (WHO, 2005).

2.13. PREVENTION AND CONTROL MEASURES SUGGESTED IN THE LITERATURE.

A number of mitigation measures regarding the use of wastewater in urban agriculture have been posited by Zeeuw and Lock (2000), and include: improved inter sectoral linkages between health, agriculture, livestock, waste and environmental management; well-defined priorities and joint strategies; adoption of clear waste re-use policies for urban agriculture which are based on health criteria and impact assessments of waste re-use schemes in agriculture would be useful. Others would include; identification of quality standards for municipal waste streams and composts produced; monitoring of quality of soils, irrigation water from rivers and wastewater outlets, and of composts; certification of safe production areas; restriction of crop choice in areas where wastewater is used but water quality cannot be guaranteed, establishment of adequate wastewater treatment facilities with appropriate water treatment technologies (e.g. waste stabilization pond systems rather than sludge treatment plants - the former are cheaper to establish and maintain and retain more nutrients).

The farmer education on management of health risks (for workers and consumers) associated with re-use of wastewater in agriculture, should include:

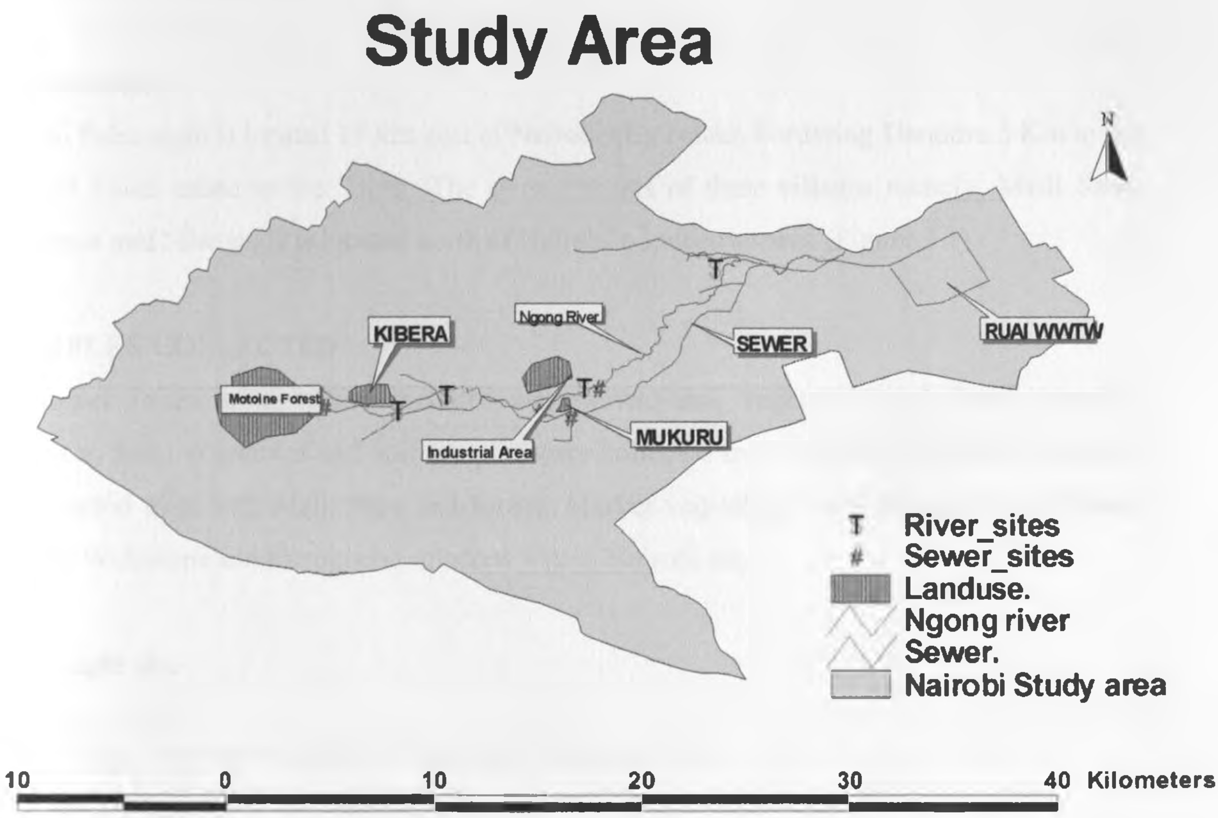
a) Avoidance of direct exposure to wastewater and soils treated with wastewater, e.g. by using boots and protective clothing, and regular washing of hands and feet
b) Adaptation of crop choice in wastewater-treated land: e.g. it is not appropriate to grow fresh salad crops like tomato, lettuce, parsley and cucumber with poorly-treated wastewater; these could be replaced by fodder, fiber, wood and seed crops
c) Application of drip irrigation or other localized irrigation methods (rather than sprinkler, gravity or spraying). Irrigation with wastewater must be stopped three weeks prior to harvesting
d) Consumer education (scraping and washing of fresh salads; eating only well-cooked crops, meat and fish from wastewater-fed crops, animals and ponds).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1. STUDY AREA

The study was undertaken in two slum areas in Nairobi, Kenya. These two slum areas were Kibera and Maili Saba, located in urban and peri-urban areas, respectively.



Key: RUAI WWTW= Ruai Wastewater treatment works

Figure 3.1: The study area

3.1.1. Kibera

Kibera is the largest slum in Nairobi (229 hectares) and the second largest in sub- Sahara Africa. There are eight villages that make up Kibera: Makina, Mashimoni, Laini Saba, Kisumu ndogo, Silanga, Lindi, Gatwikira and Soweto. Although the official estimates put the population at 500,000 most people agree this is a conservative figure and the actual population is nearer one million. This means that nearly a quarter to a third of Nairobi's population lives in Kibera (Richards and Godfrey, 2003).

3.1.2. Maili Saba

The Maili Saba slum is located 15 km east of Nairobi city center, bordering Dandora 5 Km to the North and Saika estate to the South. The slum consists of three villages namely; Maili Saba, Mwengenya and Silanga. It is located north of Nairobi's Industrial area (Figure 3.1)

3.2 SAMPLES COLLECTED

The samples taken in the study included wastewater, soil, vegetables and faecal samples. Wastewater, farm vegetables and soil samples were collected from Kibera while faecal samples were collected from both Maili Saba and Kibera. Market vegetables were obtained from Kibera, Gikomba, Wakulima and Korogocho, markets within Nairobi city.

3.2.1. Sample size

Dohoo *et al.*, (2003)
The following formula was used to determine the sample sizes

a) $n = z^2pq/L^2$

n =sample size, z=1.96, p= Assumed prevalence of 0.5; q=1-p, L= Precision of 0.05

= 384

b) Adjustment for finite population (N=Estimated population of the farmers at 200)

$= n' = 1/(1/n+1/N)$

$= n' = 1/(1/384+1/200) = 131$

The focus group discussions had eighty one (81) participants. Each site had a gender disaggregated group. Kibera had a total of fourteen (14), seven (7) women and seven (7) men. Maili Saba had a total of sixty seven (67) a sub group of Nine (9) men Ten (10) women. There were two hundred and thirty two (232) household questionnaires; Two hundred and six (206) were from Maili Saba while twenty six (26) were from Kibera. All the farmers in Kibera at that time had questionnaires administered to them. This was the total population of farmers using wastewater in Kibera for farming.

Samples collected were wastewater (30), vegetables collected (182), soils (64) and faecal samples (174). Wastewater samples collected were 30, one sample (200 ml) was divided into three subsets and the following tests were carried out; bacteriology analysis for *Salmonella* Typhi, *Vibrio cholera*, faecal coliforms and a different set of sample (one liter) was collected and analyzed for parasitology. A total of 64 farm vegetables were collected from Kibera. The 64 samples were divided into two one set of the vegetables and analyzed for parasitology and bacteriology. Results were recorded for 64 samples in parasitology and 55 samples in bacteriology. A total of 64 Kibera farm soil were sampled and analyzed for parasitology.

Constraints were experienced in the sampling of the Maili Saba wastewater, farm vegetables and soils. This was as a result of insecurity in the country at the time and the unwillingness of the farmers to continue with the project.

3.3 FOCUS GROUP DISCUSSIONS

The focus group discussions were conducted in the two places that were involved in wastewater farming, which is Kibera and Maili Saba in Nairobi Kenya; the groups were disaggregated based on gender. The study was conducted between November and December 2006. The Focus Group Discussions had a total of eighty one (81) participants, Sixty seven from Maili Saba, Fifty eight (58) women and nine (9) Men. Fourteen (14) participants were from Kibera, seven (7) women and seven (7) men. Tools and methods used were as shown in Appendix 2.0: An introductory table was used to capture the general information of the participants. A daily activity profile was used to record distribution of labour among the farmers. A seasonal activity calendar was used to determine the irrigation patterns. From the data, crop and livestock priority ranking was carried out and a trend line was drawn. This was to determine the trend of wastewater farmers over the years. Access and control of resources was also evaluated and a problem risk analysis done in form of a problem tree (Kitzinger, 1995)

The focus group discussion utilized the ranking method. This is where farmers were able to list the issue being discussed e.g. benefits and using fifty (50) stones piled according to the order of importance of the issue to each individual. The results were recorded and a group average was arrived at.

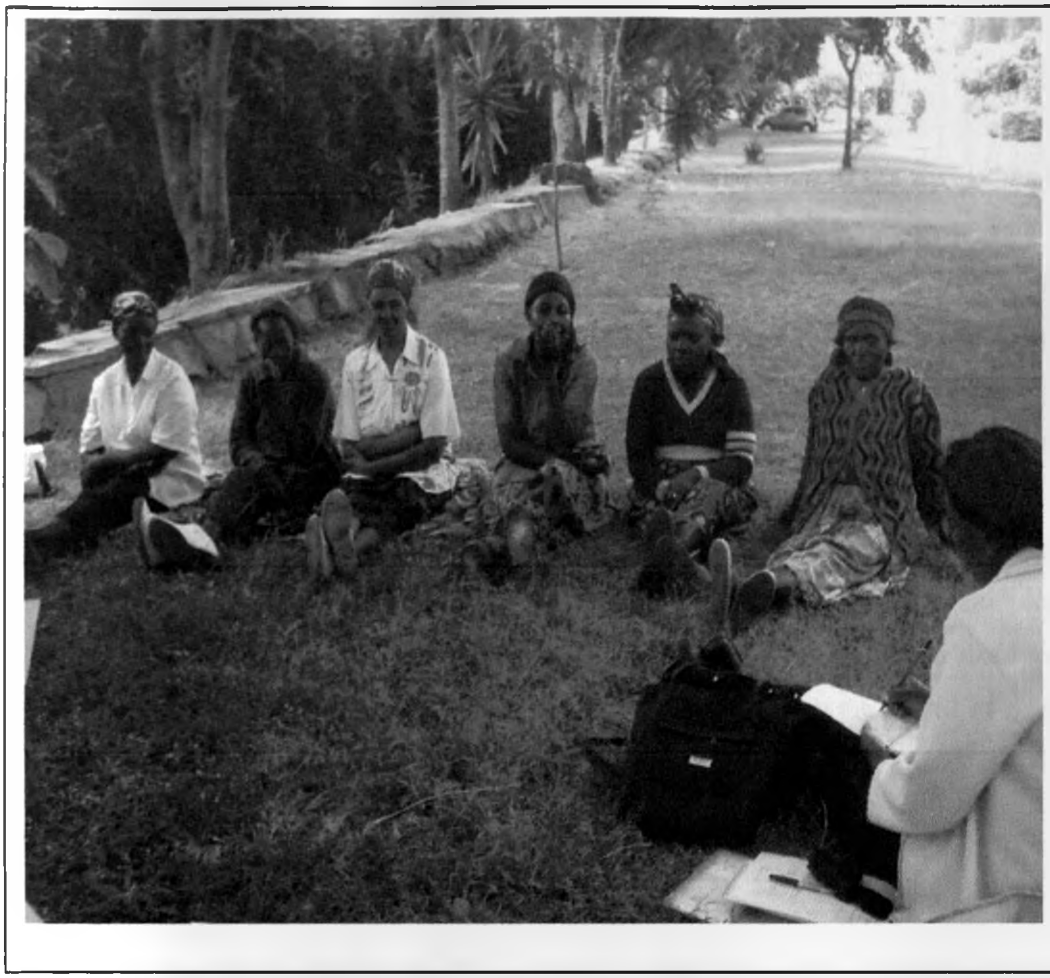


Figure 3.2: Illustrates one of the women focus group discussions in Kibera.

3.4 QUESTIONNAIRE SURVEY AND FAECAL SAMPLING:

A household questionnaire (Appendix 3.0) survey was carried out in the two urban slum areas. Information sort for included the personal details of education, benefits and constraints experienced, perceived health risks due to wastewater irrigation, risky behaviour and suggested mitigation strategies. The survey was carried out in the month of March 2007. There was a total of two hundred and thirty two questionnaire administered. Two hundred and six were from Maili Saba while twenty six were from Kibera. The households that carried out wastewater farming were targeted. In Maili Saba every other household was interviewed, while in Kibera all wastewater farmers at the time were interviewed as this was the total number of persons involved in wastewater farming. Interviewed households were also requested for stool samples: one adult stool sample and one child stool sample were collected within 24 hours. The stool samples were transported to the laboratory in a cool box. In the Laboratory they were stored in a refrigerator at + 4^0C before analysis.

3.5. SAMPLE COLLECTION AND HANDLING

3.5.1. Wastewater.

Sampling procedure: Bottles (Schott Duram bottles -500ml- made in Germany) for bacteriology sampling were sterilized and dechlorinated using sodium thiosulfate to neutralize residual chlorine. For parasitology bottles used were plastic - 2 litre- (made in Kenya). The mouth of the bottle was directed towards current - if water was not flowing it was pushed along so water flowed into the bottle. Figure 3.3 Shows a manhole with over flowing wastewater (one of the sampling sites). Figure 3.4 Shows a wastewater garden, where a parasitology sample is being picked in Kibera.

Figure 3.3: One of the sampling sites, overflowing manhole in Kibera, Nairobi.

Figure 3.4: A wastewater garden and one of the canals being sampled for parasitology, Kibera.

The bottles were then placed in a cool box with icepacks and transported to the laboratory at + 4 ^{0}C. Processing was carried out within 6 hours.

3.5.2. Soil

The Kibera farmers owned several plots each. All the farmer's plots were sampled once (thirty two samples) then repeated after a season therefore a total number of sixty four soil samples were picked from different plots of land. Each sample contained about 500 grams of soil. This was picked from the irrigated plots in Kibera, using a soil auger hanger; it included soil from the surface to a depth of 6 inches. A sampling frame (Figure 3.3) was placed on the plot in a zigzag position and subsoil picked at 1 meter equidistance using the same hanger and placed in a plastic container. The soil was mixed and a sample of 500grams picked and packed in a sterile plastic bag, as described by Roepstorff and Nansen (1998). The sample labelled with a number that corresponded to the owner of the plot. The sample was then transported to the laboratory in a cool box at +4 ^{0}C.

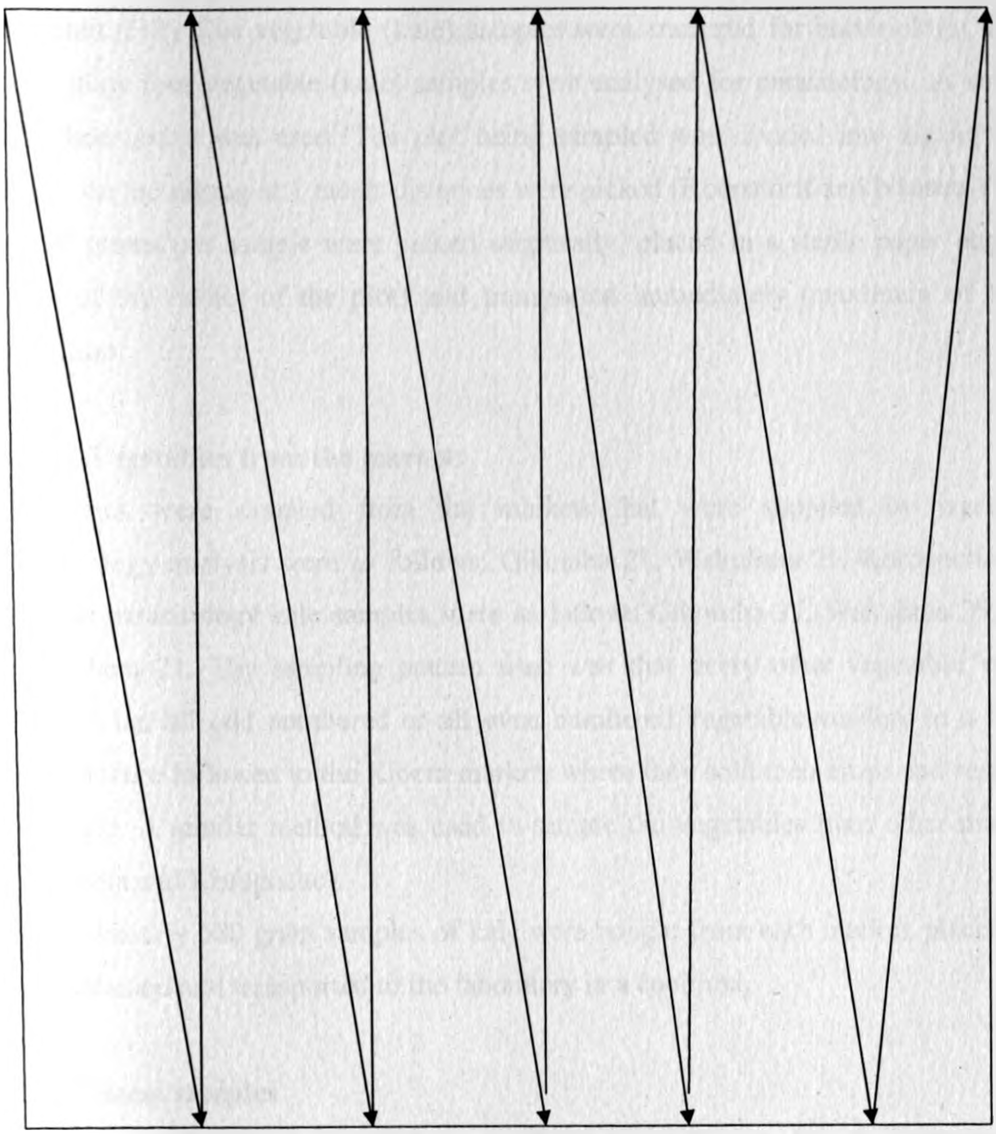


Figure 3.5: Sampling frame utilized for soil sampling and vegetable sampling (Roepstorff and Nansen 1998).

3.5.3. Vegetables.

3.5.3.1 Vegetables from Kibera farms:

The Kibera farmers owned several plots each. All the farmer's plots were sampled once (thirty two samples) then repeated after a season therefore a total number of sixty four samples were collected. Fifty five vegetable (kale) samples were analyzed for bacteriology, faecal coliforms, while sixty four vegetable (kale) samples were analysed for parasitology. A sampling frame as described above was used. The plot being sampled was divided into zigzag lines and plants falling on the zigzag at 1 meter distances were picked (Roepstorff and Nansen 1998). The leaves at 500 grams per sample were picked aseptically, placed in a sterile paper bag, labelled (date, name of the owner of the plot) and transported immediately (maximum of two hours) after collection.

3.5.3.2 Vegetables from the market:

The kales were sampled from the markets that were supplied by wastewater farmers. Bacteriology analysis were as follows; Gikomba 21, Wakulima 21, Korogocho 21, and Kibera 21. The parasitology kale samples were as follows Gikomba 37, Wakulima 39, Korogocho 21, and Kibera 21. The sampling pattern used was that every other vegetable vendor would be sampled i.e. all odd numbered or all even numbered vegetable vendors in a row. The Kibera farmers were followed to the Kibera markets where they sold their crops and respective sampling was done. A similar method was used to sample the vegetables from other markets (Gikomba, Wakulima and Korogocho).

Approximately 500 gram samples of kale were bought from each market, placed in sterile paper bags, labelled and transported to the laboratory in a cool box.

3.5.4. Faecal samples

Feacal samples were collected from Maili Saba and Kibera with the sampling pattern where every other wastewater -using household interviewed in the questionnaire survey was requested for a faecal sample. The sampling procedure involved the households being provided with two faecal poly pots labelled a and b and an index card that was to be filled stating the name, age and sex of the person who gave the faecal sample. The labelling a and /or b corresponded to the index card information on which sample was which. The following day the faecal poly pots were collected with at least 5 grams of faecal sample and the information on the index card. The samples were then placed in cool boxes and transported at +4^{0}C and transferred to a refrigerator in the laboratory until further processing. The non wastewater users from Maili Saba were neighbours to the wastewater users who were willing to give their faecal samples. The samples from the wastewater farmers in the various sites were as follows; Maili Saba 131, Kibera 18 and Non waste water farmers were 24.

3.6 LABORATORY ANALYSIS

Samples collected for laboratory analysis were as follows: Wastewater samples from Kibera, processed for bacteriology and parasitology (30 samples). Farm gate vegetables i.e. Kales (*Brassica oleracea*), processed for bacteriology (55 samples) and for parasitology (64 samples); Vegetable i.e. Kales (*Brassica oleracea*) purchased from Gikomba, Kibera, Korogocho and Wakulima, processed for bacteriology (84 samples) and for parasitology (118 samples). Faecal samples for farming community: Kibera (18 samples) Maili Saba (139 samples); and the non farming community (24 samples).

Laboratory analysis was done on (1), wastewater used for irrigation, (2), vegetables irrigated using the wastewater plus vegetable crops subsequently marketed and others in the markets (3), soil samples from the wastewater irrigated areas and (4), faecal samples from wastewater farming and non- farming communities. Wastewater samples were analysed bacteriologically for total coliforms, (Marvin (1984) Holt (1994) and Bridson (1998)). Presence of *Salmonella* species and *Vibrio cholerae*, (Marvin (1984) Holt (1994) and Bridson (1998)) and parasitologically for presence of helminth larvae and eggs ((Roepstorff and Nansen, 1998), (Arcari *et al*, 2000) (Cheesbrough, 1987)). Vegetable crops were analysed for total coliform counts (Marvin (1984) Holt (1994) and Bridson (1998)) and presence of helminth larvae and eggs (Roepstorff and Nansen, 1998). Soils were analysed only for presence of helminth eggs and larvae, ((Roepstorff and Nansen, 1998), (Arcari *et al*, 2000)). While faecal samples were analysed for general presence of parasites (hook worms, round worms, tapeworms and protozoa) (Cheesbrough, 1987).

3.7. PROCESSING OF VEGETABLES FOR COLIFORM COUNTING

When the vegetables samples arrived in the laboratory they were labelled again for ease of reference. Twenty five grams was weighed in sterile plastic bags (stomacher bags, manufactured by seward medical®). The sample was then topped up with 225 ml of Phosphate Buffered Saline (PBS), the mixture placed in a stomacher laboratory blender machine, manufactured by seward medical® and mixed for one minute. The PBS was then used as the original sample. Dilutions were made using sterile water when the original sample was too concentrated. A concentrated sample was one that was not able to attain an end point in the test. Therefore dilutions were undertaken. The most probable number technique was used for determination of the total and faecal coliforms, a standard Most Probable Number (MPN) Index used to show an estimate of the number of total and faecal coliforms. An Eijkman test confirmatory tests was done (Marvin (1984) Holt (1994) and Bridson (1998)).

3.8. FAECAL COLIFORM, MOST PROBABLE NUMBER TECHNIQUE

The most probable number technique comprises of the presumptive test and the confirmatory (Eijkman) test.

3.8.1 Presumptive test

This was carried out following standard methods as described by Marvin (1984), Holt (1994) and Bridson (1998).

This was carried out for the waste water used in irrigation and for the vegetable samples. The test consisted 3 sets of 5 tubes each. Each of the first set of tubes which already had 10 ml of double strength Lauryl Tryptose Medium (LTM) broth manufactured by Oxoid, UK with an inverted durham tube was inoculated with 10 ml of thoroughly mixed wastewater and vegetable extract sample. Each of the second set of tubes which already had 5 ml of single strength LTM broth with an inverted durham tube was inoculated with 1 ml of the wastewater sample and vegetable extract and thoroughly mixed. Each of the third set of tubes which already had 5 ml of single strength LTM broth with an inverted durham tube was inoculated with 0.1 ml of the wastewater vegetable extract sample, and thoroughly mixed. All the test tubes were incubated at $37^0C \pm$

0.5^{0}C for 24 -48 hours. A positive test was indicated by turbidity and gas produced (collected in the durham tubes), indicative of at least one faecal coliform present.

The names of the manufacturers of the media and equipments are annexed in Appendix 5.0

3.8.2 Confirmatory (Eijkman)

Holt (1994) and Bridson (1998).

The positive tubes from the presumptive test were used. The contents of one such tube were sub cultured into a brilliant green lactose bile broth (Oxoid, UK) that had an inverted durham tube and incubated at 44.5^{0}C for 18-24 hours. A positive reaction was shown by turbidity and gas production. A loopful of the positive brilliant green broth was placed on MacConkey medium (Oxoid, UK) which would indicate the lactose-fermenting typical colonies of *E. coli.* A gram stain on the suspect colonies was carried out and results recorded. Positive samples were cultured for other confirmatory tests such as Indole, Methyl red, Voges proskauer and Simmons citrate i.e. the IMViC biochemical tests were carried out as described by Marvin (1984) Holt (1994) and Bridson (1998).

3.8.3 Calculation of the MPN

A standard Most Probable Number Index was used to show an estimate of the number of total and faecal coliforms. The MPN Index is a standard determined statistically for a fifteen tube test (Method of Poission Zeroes, http://www.hc-sc.gc.ca/fn-an/res-rech/analy-meth/microbio/appendix-annexe_d01-eng.php). The table of statistics was used to interpret the laboratory results to give the number of coliform in a sample.

3.9. ISOLATION AND CHARACTERIZATION OF *SALMONELLA TYPHI* AND *VIBRIO CHOLERAE* SPECIES FROM WATER SAMPLES.

3.9.1 *Salmonella* Typhi

Isolation of the organism was done using MacConkey agar (Oxoid, UK), after enrichment through Tetrathionate broth. Non-lactose fermenting colonies (pale) that grew after 18-24 hours' incubation on MacConkey Agar were gram stained. If Gram negative rods were observed, the organisms were further tested biochemically using Indole, Methyl red, Voges Proskaver, Citrate, Urease tests and reaction on Triple Sugar Iron Agar (Oxoid, UK). The Gram staining and biochemical reactions for *S.* Typhi are given in Appendix (4.0). All media used were manufactured by Oxoid UK.

3.9.2 *Vibrio cholerae*

Isolation of the organism was done using Thiosulfate Citrate Bile Salt (TCBS) agar (Oxoid, UK) after enrichment through Alkaline Peptone Water. Sucrose fermenting colonies (yellow) on TCBS that grew after 18-24 hour incubation were gram stained. If gram negative rods curved or straight were observed, the organisms were further tested with oxidase reaction and string test. Serological typing was then done on suspect colonies using respective O and H antisera (Cat. No. BS3233 distributed by CDC for LRN Labs). The gram staining, biochemical and serological reactions for *Vibrio cholerae* are given in Appendix 4.0 All media were manufactured by Oxoid UK.

3.9.3 Storage of Isolates

Once an isolate was identified pending the serology or other confirmatory tests, it was stored in 3% Tryptose soy broth (Oxoid, UK) in 15% glycerol. The storage medium was prepared (Bridson, 1998) and mixed aseptically. The medium was then dispensed into 5 ml sterile cryovials (manufactured by Laxbro®). These were then autoclaved at 121^0C for 15 minutes. The organisms to be stored/ frozen were then emulsified using a voltex mixer appropriately with the storage medium in the cryovials. Labels of the date, lab number and the type of isolate was done and placed in a freezer at – 80^0C.

3.10. PARASITOLOGICAL PROCEDURES

3.10.1. Faecal sample analysis

The formal ether technique was used (Cheesbrough, 1987). Two grams of faecal samples were weighed and placed into a sterile centrifuge tube with seven ml of formal saline. The sample was thoroughly mixed using a voltex mixer, sieved and the sediment discarded. The remaining mixture was topped up with three ml of diethyl ether and thoroughly mixed on a voltex. The mixture was centrifuged at 2500 rpm for five minutes. After separation the supernatant was discarded. Using a pasteur pipette a drop of the sediment was then placed onto a glass slide and a drop of iodine was added. The mixture was covered with a cover slip and viewed under a microscope using low power magnification (X4) and high power magnification (X10) when necessary. These were examined for various types of parasitic helminth eggs (Hook worm eggs, *Trichuris trichura* eggs, Trematode eggs, Tape worm eggs, *Ascaris* eggs and protozoa). Results were recorded.

3.10.2. Isolation of helminth eggs and larvae from vegetables

The modified Baermann technique (Roepstorff and Nansen, 1998) was used. Freshly collected vegetable samples of approximately 500 grams were placed on a large piece of double layer cotton gauze fashioned into a bag. This was then immersed into a bucket containing tap water. This was left at room temperature for the first 24 hours with the bag being manually agitated periodically. After which the bag was removed and fresh tap water run over it and into the bucket. The contents of the bucket were left to sediment for at least an hour. The sediment was then decanted into a 1-liter urine jar over twenty four hours. The larvae and eggs accumulated at the bottom and were harvested using a pasteur pipette from the measuring cylinder. A drop or two of the harvested solution were placed on a microscope slide and stained using a 10 % iodine solution (Lugols iodine). The slide was placed under a microscope lens (X4, X10, X40) and parasitic helminth larvae counted. Parasitic and free living helminth larvae were distinguished. The parasitic larvae had an elongated, straight-sided (filariform) oesophagus, occupying approximately one third of the body length, while the free-living larvae had a rhabditiform oesophagus (Viney, 2011). The parasitic larvae exhibited a retained sheath or cuticle of the second stage larvae, elongating beyond the tail of its body (Zajac and Conboy, 2006) The sample was recorded as positive or negative for the helminth larvae and or eggs if the slide showed more than two counts of the larvae or eggs.

3.10.3. Isolation of eggs and larvae from soil

The modified Baermann technique (Roepstoff and Nansen, 1998) was used for helminth larvae. The soil sample was mixed thoroughly and a sub sample of 50 grams was weighed by means of a weighing balance, Mettler PM 4600. The sub sample was uniformly collected and placed on a sieve layered with double gauze. This was placed on top of a plastic container filled with tap water until the water just touched the sieve. The sample was left in the sieve for eighteen to twenty four hours. The helminth larvae migrated through the sieve while retaining soil particles.
The contents of the plastic container were poured into a conical flask and left at room temperature overnight. The larvae accumulated at the bottom and were harvested using a pasteur pipette. A drop or two of the harvested solution was placed on a microscope slide and stained using 1 % iodine solution (Lugols). The slide was placed under a microscope (X40, X100, X400) and parasitic larvae observed and counted over the whole field of the microscope slide. Parasitic and free living nematodes larvae were distinguished. Counting was done for two slides and the counts averaged. The numbers of helminth larvae were recorded as counts per kilogram of soil.
Floatation method (Arcari *et al*, 2000): was used for isolation of helminth eggs. A small amount of soil sample (2 gram) was mixed with about 28 ml of floatation medium (concentrated salt solution) and poured into a tube so that the liquid just came over the top of the tube. The mixture was allowed to sit for about 15 minutes while the eggs floated to the top and the rest of the soil matter sunk to the bottom. A cover slip was placed on the top of the tube before the incubation period started or at the end. The cover slip was then transferred to a microscope slide. The slide was observed under low power magnification (X400) and the high power magnification(X1000) if needed. The eggs were counted from the top right side of the microscope slide to the bottom, then to the top until the slide was completed. A second slide of the same sample was counted and both were recorded in a rough data sheet. An average was arrived at and the results transferred to the official data sheet.

3.11 DATA MANAGEMENT

Data for focus group discussions data were recorded in Micro soft Excel spreadsheets and word documents; while household data was input into a cspro database 3.3 (Published by the U.S. cenusu bureau www.census.gov) and the laboratory analysis data was entered into Ms Excel spread sheets (Microsoft Vista Windows). The various data generated were each processed, where applicable for averages, standard deviations and comparison of proportions between the two study sites using Stata version 10 (www.quantec.co.za) . The results are as indicated in the results section.

CHAPTER FOUR

4.0 RESULTS

4.1. HISTORICAL PROFILE OF WASTEWATER IRRIGATION

4.1.1 Maili Saba and Kibera

The focus group discussions (FGDs) revealed the historical background of the Maili Saba study slums from as far back as the colonial times (before 1963). The men recalled that it was a sisal farm owned by a white settler. The workers of the farm who were mainly men and a few who had their wives were allowed to plant food crops in the valley. In 1958 the sisal farm collapsed and was sold to a local politician rendering the farm workers squatters. From 1958 to 1980's rain fed agriculture and livestock keeping thrived. With the construction of the sewer line in 1990 wastewater farming started.

This marked the beginning of intensive farming. Plot sizes also decreased due to increase in population. In the late 1990's and early 2000's estates were built, further reducing the available land for farming. Subsequently some farmers opted to become hawkers. Farming is currently more intense and market oriented.

Kibera

The FGDs in Kibera revealed that in the 1980's the farm land was expansive and extended from Langata women's prison to Langata men's prison, to the Ngeno estate and the Jehovah witness's church. Since there were few farmers, large pieces of land were available for cultivation and yields were very good. The farmers depended on rain-fed agriculture. In 1988 the farmers were paid by the Jehovah witness church to relocate. At the time the Nairobi Dam water was clean and was used for domestic purposes and yachting. In 1991 the yachting stopped due to continued pollution of the water. At the time of El Nino season of 1998 vegetation (water hyacinth) invaded the dam growing on the water. The land was grabbed by a private developer and a housing estate started to be built; however it was later demolished.

Wastewater farming started in 1993 after a farmer visited Nakuru and witnessed the technique of blocking manholes. The technology was initially not widely accepted due to its nature. However, as life stresses increased the people lacked alternatives and the type of farming became widely used. The city council of Nairobi, from time to time evicts the farmers for blocking manholes. The road bypass construction crew also continuously destroys the farmer's crops.

The land currently being cultivated is owned by the National Social Security Fund (NSSF). In 1995 the NSSF fenced the land and evicted the farmers. A meeting with officials resulted in the farmers being allowed to use the land as long as they looked after it. The farmers employ guards to look after the fence and contribute towards the costs of maintaining the fence.

As more farmers joined the group a schedule of irrigation was arrived at so that everybody had adequate water.

4.1.2. Results of farming household survey

There were a total of 232 respondents. Twenty six (26) were from Kibera and 206 were from Maili Saba.

4.1.2.1 General household characteristics

The majority 153 (65.9%) of the households practiced mixed farming. This means they planted crops in the study fields and kept some type of livestock at home. There were significantly ($p = 0.02$) more households practicing mixed farming in Maili Saba 141 (68.4%) than in Kibera 12 (46.2%). The average household size in the study sites was approximately 5.96 people (range 1-12) standard deviation of 2.18. There were 70 (30%) female respondents.

4.1.2.2 Education level

Sixty two percent (142) of the respondents had attained some level of primary education. (Table 4.1.and figure 4.1).

Table 4.1: Education level of the respondents by study site.

Characteristic	Kibera n= 26		Maili Saba n=203		Overall n=229	
	No.	%	No.	%	No.	%
Non formal	7	26.9	20	9.9	27	11.8
Primary	14	53.8	128	63.1	142	62
Secondary	5	19.2	49	24.1	54	23.6
College/ Polytechnic	0	0	4	2.0	4	1.7
Others	0	0	2	0.98	2	0.87

Note= 3 respondents did not answer this question.

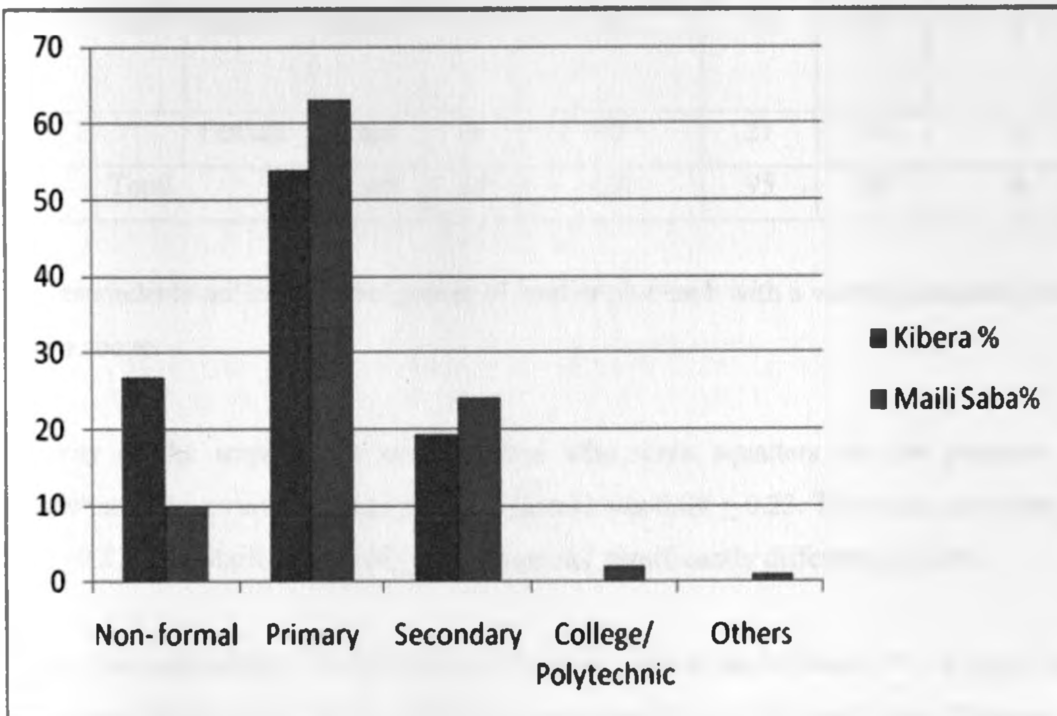


Figure 4.1: Various levels of education reported in the two sites studied in year 2007
*other levels included those who didn't know.

The respondents stated that they had varying types of land tenure as follows (Table 4.2).

Table 4.2: Illustrating the various types of land tenure of the respondents.

Study Site				Land Tenure					Total
				Own	Temporarily offered	Rented	Public	Don't know whose land	Own
Kibera	Sex	Male	Count	2	33	0	0	0	35
		Female	Count	0	21	1	6	1	29
	Total		Count	2	54	1	6	1	64
Maili Saba	Sex	Male	Count	10	80	74	75	4	243
		Female	Count	5	40	21	14	2	82
	Total		Count	15	120	95	89	6	325

The respondents utilized various pieces of land or plot each with a varying ownership status as shown above.

Majority of the respondents were farmers who were squatters for the purposes of Urban Agriculture. The overall average plot size (acres) was 0.09 ± 0.23. The mean plot sizes for Kibera (0.11 ± 0.27) and Maili Saba(0.08 ± 0.20) were not significantly different ($p>0.05$).

Most of the respondents 99 (43.2%) had lived in Nairobi for between 10 -19 years, 56 (24.5%) for between 20-29 years, 26 (11.4%) 30-39 years and 10 (4.4 %) 40-49 years. Between 0-9 Years were 30 (13.1%). This question was not answered by three respondents therefore the n=229.

4.1.2.3. Source of water for home use.

Varying sources of water for home use were reported. All (26) of the Kibera respondents used tap water. Two hundred and five (205) of the respondents from Maili Saba also used tap water. Of the 205 ten used additional sources of water these were two borehole, seven shallow wells and one river water.

4.1.3. Wastewater irrigation practices

Maili Saba

Furrow irrigation was practiced on all crops as it was convenient and utilized gravity. Bucket (overhead) irrigation was sometimes used on nursery crops as they needed frequent irrigation.

Kibera

Furrow and flood irrigation were used interchangeably. Furrow was used more when there was plenty of land. Flood irrigation was used for small pieces of land. Along the furrows maize and napier grass were usually planted.

4.1.4 Length of involvement in wastewater farming.

Various lengths of time of involvement with wastewater farming were reported. Most people were reported (134) to have been involved in wastewater farming for 10-19 years. Others (111) were in the 0-9 year category, (49) in the 20-29 year category. Figure 4.2 gives the graphical presentation of the various lengths of time that the farmers have been engaged in wastewater farming.

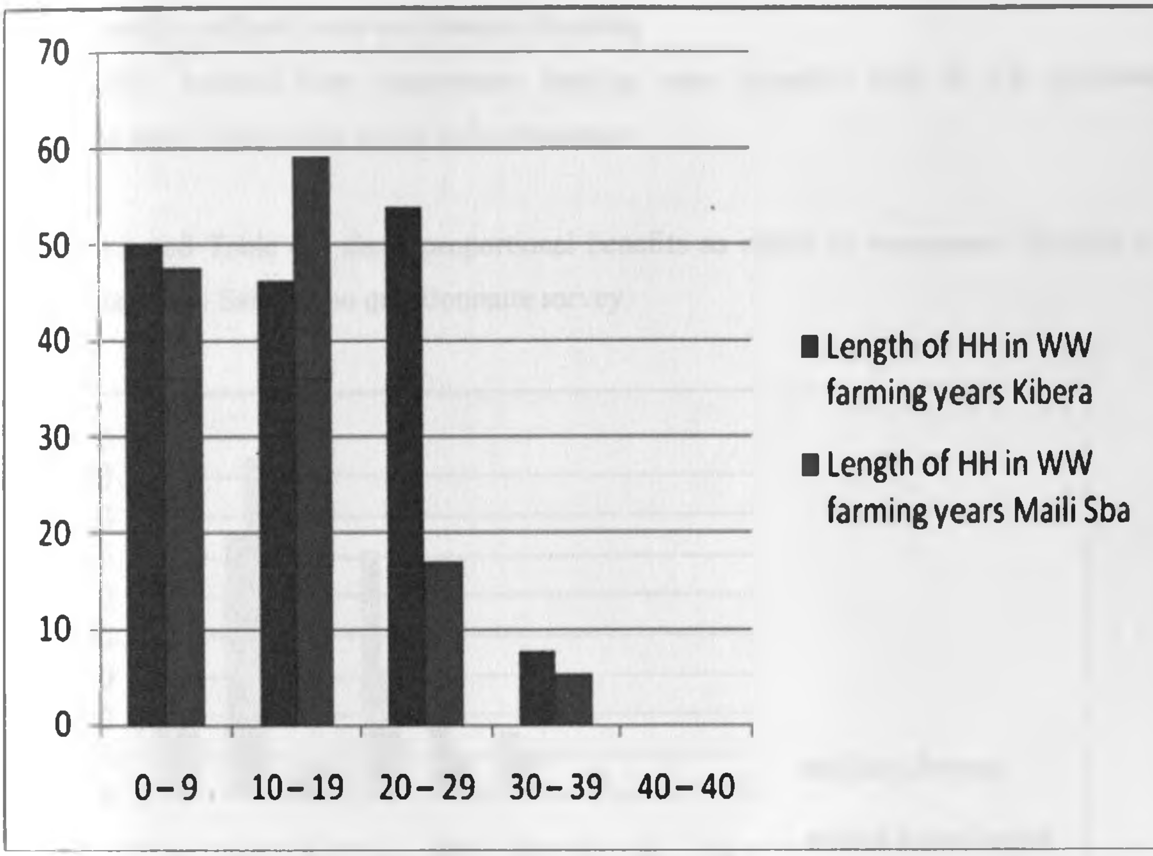


Figure 4.2: Length of involvement in years in waste water farming.

Key: HH= Household, WW= Waste water

Various reasons were given for using wastewater. There were multiple responses. The reason with the highest score out of all the responses was that wastewater being the only source of irrigation water available 132 (56.9%). Fourteen point seven point four percent (34) of the respondents stated that it was a free source of water, which was easily accessible and available all year round. Other responses 91 (39.2%) were that it was a source of nutrients. Most of the farmers who responded this way were from Kibera 20 (76.9%).

4.1.5. Benefits realized from wastewater farming

The benefits realized from wastewater farming were recorded both in the questionnaire/ household survey and in the group focus discussion.

Figure 4.3 and Table 4.3 show proportional benefits as stated by wastewater farmers in both Kibera and Maili Saba in the questionnaire survey.

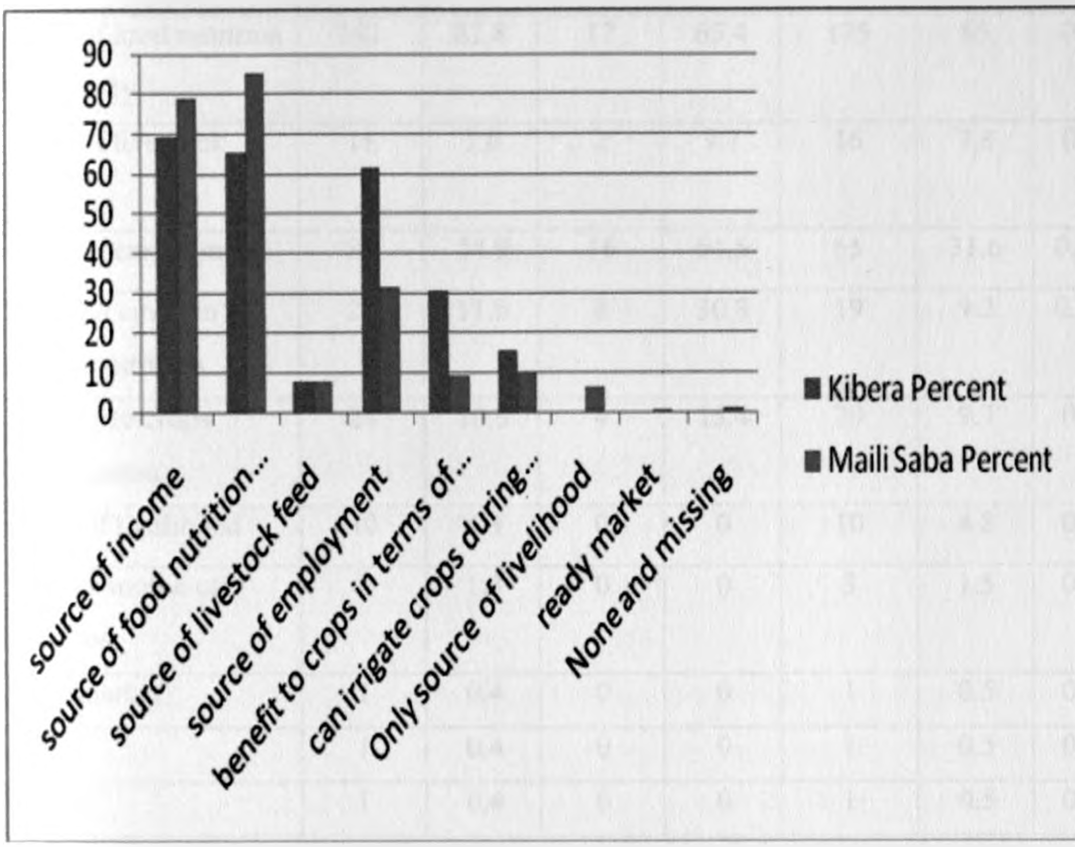


Figure 4.3: Benefits of wastewater farming in Maili Saba and Kibera

Table 4.3: Benefits of wastewater farming in Kibera and Maili Saba

Benefits	Total n=232	Percent	Kibera n=26	Percent	Maili Saba n=206	Percent	p Value
Source of income	181	78	18	69.2	163	79.1	0.25
Source of food nutrition and security	192	82.8	17	65.4	175	85	0.01
Source of livestock feed	18	7.8	2	7.7	16	7.8	0.98
Source of employment	81	34.9	16	61.5	65	31.6	0.003
Benefit to crops in terms of nutrition	27	11.6	8	30.8	19	9.2	0.001
Can irrigate crops during season	24	10.3	4	15.4	20	9.7	0.36
Source of livelihood	10	4.3	0	0	10	4.8	0.25
No other source of livelihood	3	1.3	0	0	3	1.5	0.52
Ready market	1	0.4	0	0	1	0.5	0.72
None	1	0.4	0	0	1	0.5	0.72
Missing	1	0.4	0	0	1	0.5	0.72

Food nutrition and security was the most important overall benefit reported at 192 (82.8%), with a significant difference between the two study sites (p=0.01). The second overall important benefit was source of income at 181 (78%). The third overall import benefit was a source of employment at 81 (34.9%). There was a statistically significant difference between the two sites. The fourth overall benefit was in terms of Livestock feeds at 18 (7.8%).

The farmer's perception of the benefits from the focus group discussions was as follows.

Kibera, the ranking of benefits of wastewater reuse as per the group focus discussions were as per (Table 4.4)

Table 4.4: Kibera Benefits of wastewater use ranking from the Group focus discussions.

Kibera Men	Rank n=100		Kibera Women	Rank n=50	
Water available throughout the year	56	1	Household food security	11	11
Creates employment	12	2	Ability to provide food for others in the dry season	10	10
Food security	10	3	Household income	9	9
Fights poverty	10	3	Self employment	9	9
Generation of Income	6	5	Sense of community	7	7
Contains useful crop nutrients	6	5	Ability to employ others	4	4

The main concern of the participants was food security, employment and income opportunities and the sense of belonging in the community. The Maili Saba scenario is represented in (Table 4.5.)

Table 4.5: Maili Saba benefits of wastewater use; ranking from the Group focus discussions.

Maili Saba Men	Rank n=300	Rank	Maili Saba Women	Rank n= 300	Rank
Self sufficiency in food supply	68	1	Income	75	1
Being Kept Busy	51	2	Food	65	2
Income generation	49	3	Occupation/Employment	48	3
Pays school fees	47	4	Nutrition	41	4
Self Employment	44	5	Family stability	36	5
Availability of WW	41	6	Fertile water	35	6

The group focus discussion benefits ranking was as above. The benefits were similar with the results from the questionnaire survey. The questionnaire results on benefits were however more representative of the population.

4.1.6. Types of crops grown

Common crops grown by both men and women in Maili Saba were Kales (*Brassica oleracea*), Spinach (*Spinacea oleracea*), Black Night Shade (*Solanum nigrum)*, Amaranthus (*Amaranthus caudatus*) and Cow pea (*Vigna unguiculata*). The men ranked the crops in terms of household use from number one downwards as follows; Kales (*Brassica oleracea*), Spinach (*Spinacea oleracea*), Maize (*Zea mays*), Cow pea (*Vigna unguiculata*), Black Night Shade (*Solanum nigrum)*, and Amaranthus (*Amaranthus caudatus*). The women ranked them as Kales (*Brassica oleracea*), Cow pea (*Vigna unguiculata*), Spinach (*Spinacea oleracea*), Black Night Shade (*Solanum nigrum)*, Amaranthus (*Amaranthus caudatus*) and Pumpkin (*Cucurbita maxima*). The criterion that mattered most for the men was the ease of selling the produce. The rest of the crops had similar weighting (Table 4.6).

Table 4.6: Results of proportional ranking of food crops grown in Maili Saba.

Crop	Gender	Household use		Income		Easy Growth	
Maili Saba		Stones piled n= 283(M) 300 (W)	Rank	Stones piled n=300 (All)	Rank	Stones piled n= 300 (All)	Rank
Kales (*Brassica oleracea*),	M	88	1	82	1	69	1
	W	77	1	82	1	47	3
Spinach (*Spinacea oleracea*)	M	56	2	61	2	48	4
	W	52	3	47	3	27	5
Black Night Shade (*Solanum nigrum)*	M	31	5	48	3	41	5
	W	41	4	58	2	29	4
Amaranthus (*Amaranthus caudatus*)	M	24	6	40	5	69	1
	W	39	5	45	4	107	1
Maize (*Zea mays)*	M	48	3	25	6	21	6
	W	-	-	-	-	-	-
Cow pea (*Vigna unguiculata*)	M	36	4	44	4	52	3
	W	58	2	35	5	16	6
Pumpkin (*Cucurbita maxima)*	M	-	-	-	-	-	-
	W	33	6	33	6	74	2

Key: M=Men, W= Women

Kibera

The common crops grown by men and women in Kibera were Kales (*Brassica oleracea*), Amaranthus (*Amaranthus caudatus*), Beans (*Phaseolus vulgaris*) and Spinach (*Spinacea oleracea*). Men ranked them in terms of household use as Beans (*Phaseolus vulgaris*), Kales (*Brassica oleracea*), Cowpea (*Vigna unguiculata*), Amaranthus (*Amaranthus caudatus*), Onions

(*Allium cepa*) and Spinach (*Spinacea oleracea*), while women ranked them as Kales (*Brassica oleracea*), Black Night Shade (*Solanum nigrum)*, Spinach (*Spinacea oleracea*), Amaranthus (*Amaranthus caudatus*), Beans (*Phaseolus vulgaris*) and Maize (*Zea mays)*. In addition men preferred to grow Cowpea (*Vigna unguiculata*) and Onions (*Allium cepa)*, ranking them third and fifth, respectively, while women preferred to grow Black Night Shade (*Solanum nigrum)* and Maize (*Zea mays)*, ranking them second and sixth, respectively (Table 4.7.)

Table 4.7: Results of proportional ranking of food crops grown in Kibera.

Crop	Gender	Household use		Income		Ease of Growth	
		Stones piled	Rank	Stones piled	Rank	Stones piled	Rank
Kales (*Brassica oleracea*)	M	57	2	61	2	77	2
	W	66	1	84	1	55	2
Amaranthus (*Amaranthus caudatus)*	M	47	4	66	1	53	3
	W	45	4	56	3	65	1
Beans (*Phaseolus vulgaris*)	M	84	1	44	4	29	4
	W	41	5	8	6	43	5
Onions (*Allium cepa*)	M	31	5	31	6	19	6
	W	-	-	-	-	-	-
Spinach (*Spinacea oleracea*)	M	27	6	38	5	27	5
	W	52	3	53	4	45	4
Cow pea (*Vigna unguiculata*)	M	54	3	60	3	95	1
	W	-	-	-	-	-	-
Black Night Shade (*Solanum nigrum)*	M	-	-	-	-	-	-
	W	57	2	81	2	52	3
Maize (*Zea mays*)	M	-	-	-	-	-	-
	W	39	6	18	5	40	6

Key: M=Men, W= Women

Comparing Maili Saba and Kibera, common crops grown included Kales (*Brassica oleracea*), Spinach (*Spinacea oleracea*), Amaranthus (*Amaranthus caudatus)*, Black Night Shade (*Solanum nigrum)* and Maize (*Zea mays*). On average the vegetables were ranked higher i.e. Kales (*Brassica oleracea*), Spinach (*Spinacea oleracea*), Amaranthus (*Amaranthus caudatus)* and Black Night Shade (*Solanum nigrum)*. Comparing the men from both areas, it was found out that the common crops they preferred to grow were Kales (*Brassica oleracea*), Cow pea (*Vigna unguiculata)*, Amaranthus (*Amaranthus caudatus*) and Black Night Shade (*Solanum nigrum)*. The differences were Kibera men preferred onions (*Allium cepa*) and beans (*Phaseolus vulgaris*) while the Maili Saba men preferred Maize (*Zea mays)* and Black Night Shade (*Solanum nigrum)*. The women on the other hand preferred to grow the following crops commonly Kales (*Brassica oleracea*), Spinach (*Spinacea oleracea*), Black Night Shade (*Solanum nigrum)* and Amaranthus (*Amaranthus caudatus)*, while the difference was that the Kibera women preferred to grow Beans (*Phaseolus vulgaris*) and Maize (*Zea mays*) while the Maili Saba women preferred Cow pea (*Vigna unguiculata)* and Pumpkin (*Cucurbita maxima)*.

4.1.7. Animals kept

Farmers according to the questionnaire survey (n=232) kept various types of livestock. Chicken were the most common livestock kept by farmers at 189 (81.5%), this was followed by cattle at 70 (30.1%), goats at 61 (26.3%) and ducks at 61 (26.3%).

Livestock kept

From the group focus discussions the livestock kept was ranked as follows. Maili Saba men ranked cattle as number one and the reason was that cattle were providers of milk. All other animals except the duck were kept for income generation and because of a readily available market. Other reasons why animals were kept was for the provision of manure or other products such as eggs, however ducks were kept without reason. The reason for this was that ducks had no market (Table 4.8.).

Table 4.8: Results of proportional ranking of livestock in Maili Saba.

Animal kept	Gender	Stones piled n=300	Av. Score	Ranking
Cattle	M	104	17.5	1
	W	28	4.6	5
Goats	M	72	12	2
	W	59	9.8	2
Pigs	M	22	3.6	5
	W	30	5	4
Chicken	M	57	9.5	3
	W	116	19.3	1
Sheep	M	46	7.6	4
	W	-	-	-
Ducks	M	0	0	6
	W	-	-	-
Dogs	M	-	-	-
	W	26	4.3	6
Cats	M	-	-	-
	W	41	6.8	3

Key: M=Men, W= Women

Livestock kept by men in Maili Saba was ranked as follows in the order of importance; Cattle, Goats, Chicken, Sheep, Pigs and Ducks. Livestock kept by women were as follows in order of importance Chicken, Goats, Pigs and Cattle. Pets were mainly kept by women. They included Dogs and Cats, Cats being the more preferred pets. In the overall ranking for all animals on the farm kept by women, cats ranked number 3, higher than the pigs and cattle.

In Kibera, men kept the following livestock ranked in decreasing order of importance: Cattle, Goats, Chicken, Sheep, Pigs and Ducks. Women only kept Chicken and Goats as livestock. Here, pets were also kept mainly by women; they included dogs and cats, cats being the preferred pets. During the ranking of all the animals kept, cats ranked number 2, higher than the goats. Comparing both areas the men ranked the livestock kept similarly. There was a difference in the type of animals kept by women in two areas. While in both areas the most preferred animal was the chicken followed by the goat. Kibera women kept only these two types of animals. Maili Saba women kept in addition pigs and cattle. These were ranked as number 3 and 4. Thus, while keeping of cattle was ranked number one by men in both areas, it seems not to be the women's choice, maybe due to the handling risks involved. Chicken seem to be the preferred animals in most areas, to both men and women, they were however ranked highest (Number 1) by women. Ducks were kept mainly in Kibera by men. They were however ranked last (Number 6). Interestingly, ducks did not seem to be valued by the people since their market value and turnover was considered low (Table 4.9, Figure 4.4).

Table 4.9: Results of proportional ranking of livestock kept in Kibera.

Animal kept	Gender	Stone piled	Av. Score	Rank
Cattle	M	54	13.5	1
	W	-	-	-
Goats	M	45	11.25	2
	W	20	2.85	3
Sheep	M	28	7	4
	W	-	-	-
Pigs	M	18	4.5	5
	W	-	-	-
Chicken	M	37	9.25	3
	W	47.5	6.78	1
Duck	M	18	4.5	6
	W	-	-	-
Cats	M	-	-	-
	W	32.5	4.64	2
Dogs	M	-	-	-
	W	5	0.71	4

Key: M=Men, W= Women

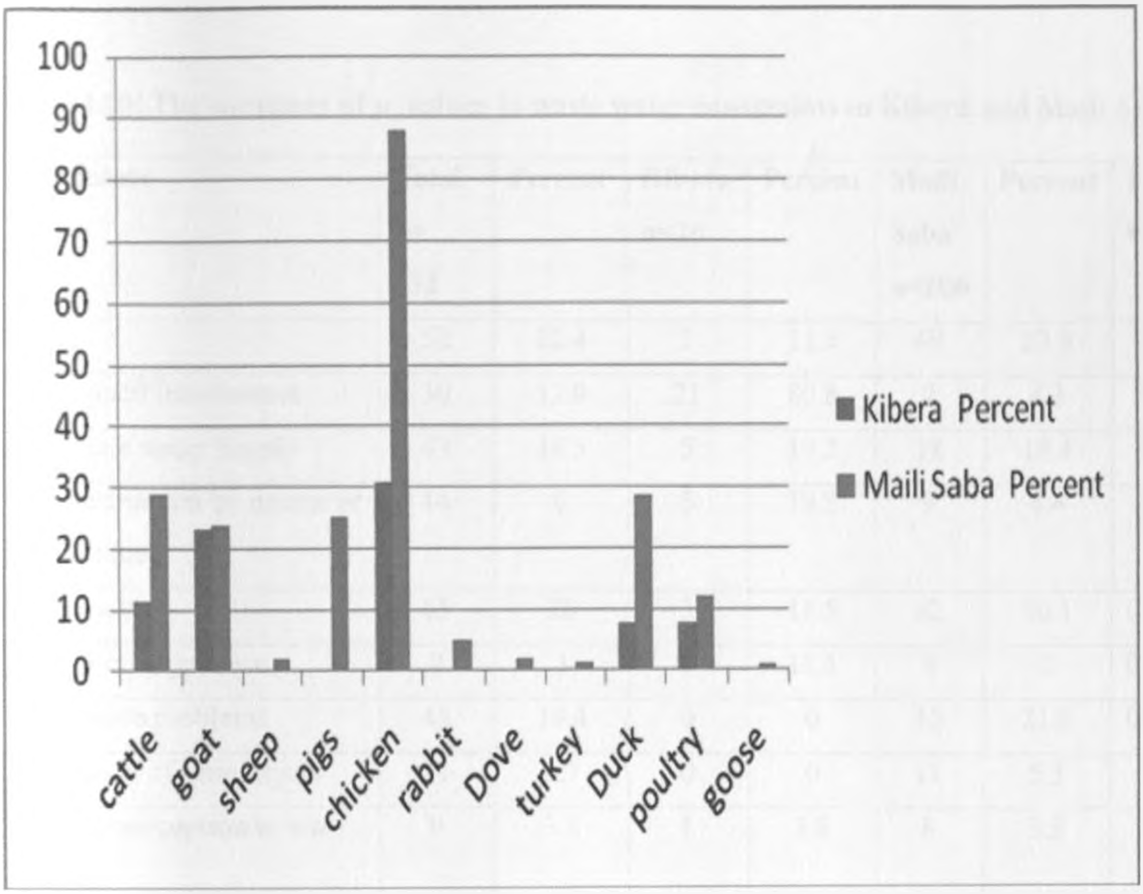


Figure 4.4: Comparison of animals kept in the two study sites from the questionnaire.

The reason for Kibera men ranking cattle first was that they provided milk and therefore a daily source of income. Women on the other hand ranked chicken top as they provided household food. Pigs were not kept in Kibera due to confiscation by the city council as the city by laws do not allow for keeping of livestock in the urban centres.

4.1.8. Constraints of wastewater farming experienced

Constraints were reported in the questionnaire survey were as follows. The highest ranked constraint to wastewater farming was health risks at 65 (28%), there was statistical significant difference (p=0.046) between the two sites. An additional constraint was that of inadequate water supply at 43 (18.5%). Others that had statistical significant were theft of crop produce and land tenure problems. The rest of the constraints are as summarized (Table 4.10.).

Table 4.10: The summary of p_values in waste water constraints in Kibera and Maili Saba.

Constraints	Total n= 232	Percent	Kibera n=26	Percent	Maili Saba n=206	Percent	P value
None	52	22.4	3	11.5	49	23.8	0.87
City council interference	30	12.9	21	80.8	9	4.3	0.06
Inadequate water supply	43	18.5	5	19.2	38	18.4	0.99
Crop destruction by excess or lack of water	14	6	5	19.2	9	4.4	0.03
Health risks	65	28	3	11.5	62	30.1	0.046*
Theft of crop produce	7	3	3	11.5	4	2	0.008*
Land tenure problems	45	19.4	0	0	45	21.8	0.008*
Inadequacy of farm inputs	11	4.7	0	0	11	5.3	0.22
Negative perception to ww farming	9	3.8	1	3.8	8	3.9	0.98
Small farm sizes	13	5.6	0	0	13	6.3	0.19
Lack of extension services	1	0.4	0	0	1	0.5	0.72
Quality of ww encourages pests and diseases	3	1.3	0	0	3	1.5	0.53
Lack of access to market	4	1.7	0	0	4	2	0.47
Destruction due to change of weather	1	0.4	0	0	1	0.5	0.72
Much labor in farming	1	0.4	0	0	1	0.5	0.72
Poor policies in waste water farming	1	0.4	0	0	1	0.5	0.72
Missing	9	3.8	0	0	9	4.4	0.28

Key: *p<0.05 therefore statistically significantly different, ww = wastewater

Table 4.10: The summary of p_values in waste water constraints in Kibera and Maili Saba.

Constraints	Total n= 232	Percent	Kibera n=26	Percent	Maili Saba n=206	Percent	P value
None	52	22.4	3	11.5	49	23.8	0.87
City council interference	30	12.9	21	80.8	9	4.3	0.06
Inadequate water supply	43	18.5	5	19.2	38	18.4	0.99
Crop destruction by excess or lack of water	14	6	5	19.2	9	4.4	0.03
Health risks	65	28	3	11.5	62	30.1	0.046*
Theft of crop produce	7	3	3	11.5	4	2	0.008*
Land tenure problems	45	19.4	0	0	45	21.8	0.008*
Inadequacy of farm inputs	11	4.7	0	0	11	5.3	0.22
Negative perception to ww farming	9	3.8	1	3.8	8	3.9	0.98
Small farm sizes	13	5.6	0	0	13	6.3	0.19
Lack of extension services	1	0.4	0	0	1	0.5	0.72
Quality of ww encourages pests and diseases	3	1.3	0	0	3	1.5	0.53
Lack of access to market	4	1.7	0	0	4	2	0.47
Destruction due to change of weather	1	0.4	0	0	1	0.5	0.72
Much labor in farming	1	0.4	0	0	1	0.5	0.72
Poor policies in waste water farming	1	0.4	0	0	1	0.5	0.72
Missing	9	3.8	0	0	9	4.4	0.28

Key: *p<0.05 therefore statistically significantly different, ww = wastewater

Table 4.10: The summary of p_values in waste water constraints in Kibera and Maili Saba.

Constraints	Total n= 232	Percent	Kibera n=26	Percent	Maili Saba n=206	Percent	P value
None	52	22.4	3	11.5	49	23.8	0.87
City council interference	30	12.9	21	80.8	9	4.3	0.06
Inadequate water supply	43	18.5	5	19.2	38	18.4	0.99
Crop destruction by excess or lack of water	14	6	5	19.2	9	4.4	0.03
Health risks	65	28	3	11.5	62	30.1	0.046*
Theft of crop produce	7	3	3	11.5	4	2	0.008*
Land tenure problems	45	19.4	0	0	45	21.8	0.008*
Inadequacy of farm inputs	11	4.7	0	0	11	5.3	0.22
Negative perception to ww farming	9	3.8	1	3.8	8	3.9	0.98
Small farm sizes	13	5.6	0	0	13	6.3	0.19
Lack of extension services	1	0.4	0	0	1	0.5	0.72
Quality of ww encourages pests and diseases	3	1.3	0	0	3	1.5	0.53
Lack of access to market	4	1.7	0	0	4	2	0.47
Destruction due to change of weather	1	0.4	0	0	1	0.5	0.72
Much labor in farming	1	0.4	0	0	1	0.5	0.72
Poor policies in waste water farming	1	0.4	0	0	1	0.5	0.72
Missing	9	3.8	0	0	9	4.4	0.28

Key: *p<0.05 therefore statistically significantly different, ww = wastewater

4.1.9. Health risks:

Activities around the farm that may contribute to health risks were reported as: hand weeding, watering of the plots and inadequate protective clothing while farming. There was no gender difference in farming activities such as watering and seed sourcing, while the children were seen to play a minimal role in farming activities as they were mostly in school. However produce from wastewater farms was fed to all age groups of farmers and the non farmers. The produce was also sold to markets within the city centre.

4.1.9.1 Perceived health issues experienced

Overall thirty four point five percent (80) of respondents perceived that they experienced health issues as a result of using wastewater. In Kibera 2 (7.7%) and Maili Saba 78 (37.8%) this perception had statistically significant different (p=0.002) between the study sites.

The following were the wastewater related diseases listed by the farmers: internal worms, typhoid, amoeba, allergies, malaria, skin infections and Rift Valley Fever (RVF). However Malaria and RVF could not be easily authenticated given their differing etiologies and pathogenesis. Others included symptoms of diseases such as stomach pains, diarrhoea, common cold, body weakness and back aches.

A child was defined for the purposes of this section of the household survey as being less than 13 years old. A youth was defined as between 13-25 years. An adult was above 26 years.

Of the respondents who had perceived that their families had experienced health issues. The commonest ailment was skin infections reported experienced by (22) female adults, (10) male adults, (4) youths and (1) child. Internal worms were reported to have been experienced by (9) youth, (10) children, (4) female adults and (4) male adults. Diarrhoea was experienced most by the (6) adult females, (6) children, (4) male adults and (2) youth. Typhoid was reported to be experienced by (8) adult females (7) adult males (5) youth and (3) children (Table 4.11).

Table 4.11: Perceived health ailments experienced by the different gender in wastewater using areas.

Health risk	Male Adult (26 yrs and above)		Female Adult (26 yrs and above)		Youth (13-25 yrs)		Children (< 13 yrs)	
	%	No.	%	No.	%	No.	%	No.
Internal worms	29	4/14	29	4/14	64	9/14	71	10/14
Stomach pains	38	6/16	56	9/16	50	8/16	38	6/16
Diarrhoea	40	4/10	60	6/10	20	2/10	60	6/10
Skin infection	34	10/29	76	22/29	14	4/29	3	1/29
Malaria	26	5/19	63	12/19	26	5/19	37	7/19
Allergy	0	0	100	2/2	0	0	0	0
Typhoid	50	7/14	57	8/14	36	5/14	21	3/14
Common cold	14	1/7	57	4/7	14	1/7	29	2/7
Body weakness	0	0	100	1/1	0	0	0	0
Back ache	0	0	100	2/2	0	0	0	0
Amoeba	0	0	100	3/3	0	0	0	0
Bronchitis	0	0	100	2/2	0	0	0	0

Adult females were reported suffering from more ailments (allergy, body weakness, back ache, amoeba and bronchitis) compared to any other category of people. However 111(47.8%) of the respondents thought that there could be health risks due to consumption of animal products from animals fed with fodder grown using wastewater.

4.1.9.2 Perceived health risks associated with urban livestock keeping.

Overall 111 (47.8%) farmers associated consumption of animal products obtained from animals fed with fodder grown using wastewater with any health risk.

rs were asked to rank perceived health ailments they had experienced that would be linked stock keeping. Overall the most highly ranked was Rift Valley Fever (RVF) at 40 (17.2%). cond in importance was internal parasites at 25 (10.8%). The others sited on diminishing ance were; diarrhoea at stomach pains, foot and mouth disease, bird flu, anthrax, losis, malaria, allergy, skin infection, typhoid, Tuberculosis (TB), leg swelling and ng (Table 4:12).

Table 4.12: Perceived health ailments linked to livestock keeping in the two study sites.

Health risk	Total n=232	Percent	Kibera n= 26	Percent	Maili Saba n=206	Percent
Internal worms	25	10.8	2	7.7	23	11.2
RVF	40	17.2	5	19.2	35	17
Stomach pain	6	2.6	1	3.8	5	2.4
Diarrhea	13	5.6	4	15.4	9	4.4
Anthrax	4	1.7	1	3.8	3	1.5
TB	1	0.4	1	3.8	0	0
Skin infection	3	1.3	1	3.8	2	1
Leg swelling	1	0.4	1	3.8	0	0
Foot and mouth	6	2.6	2	7.7	4	1.9
Fever/homa	3	1.3	3	11.5	0	0
Malaria	3	1.3	1	3.8	2	1
Allergy	3	1.3	0	0	3	1.5
Typhoid	2	0.9	0	0	2	1
Brucellosis	4	1.7	0	0	4	2
Belching	1	0.4	0	0	1	0.5
Bird flu	5	2.2	0	0	5	2.4
Blood pressure	1	0.4	0	0	1	0.5
Amoeba	2	0.9	0	0	2	1
Liver disease	1	0.4	0	0	1	0.5
New castle disease	1	0.4	0	0	1	0.5
Headache	2	0.9	0	0	2	1
Dont know the name	14	6	0	0	14	6.8
Missing	1	0.4	1	3.8	0	0

Key: T.B. = Tuberculosis, R.V.F. = Rift Valley Fever

Note: At the time of the data collection RVF outbreak was underway and a lot of media attention had the public aware.

The three most reported perceived threats to the Kibera farmers health associated with livestock keeping were RVF at 5 (19.2 %); diarrhoea at 4 (17.4%) and fever at 3 (11.5%). While the important ones for Maili Saba farmers were RVF at 35 (17%), internal worms at 23 (11.2%) and diarrhoea at 9 (4.4%). There was no statistical significant difference (p>0.05) between the two sites when any of the three conditions were compared.

4.1.9.3 Practice of wearing protective clothing

Overall 88 (38%) of respondent famers were not using any form of protective clothing. There was no statistical difference between the two study sites (p=0.62). Of those that wore protective clothing, gum boots were the most widely worn at 14 (61%) in Kibera and 102 (56%) in Maili Saba. Hand gloves and dust coats were worn by a small percentage of the farmers (Table 4.13 and Figure 4.6).

Table 4.13: Various protective clothing used by farmers in the two study sites, Kibera and Maili Saba.

	Kibera	Maili Saba	p Value
Wear protective clothing	57% (15/26)	62% (129/206)	0.62
Of those who wore protective clothing in the question above (23 Kibera, 181 Maili Saba), further elaborated the kind of protective clothing worn)			
Gum Boots	61% (14/23)	56% (102/181)	0.64
Hand Gloves	8.4% (2/23)	6.1% (11/181)	0.67
Dust Coats	8.4% (2/23)	3.3% (6/181)	0.23

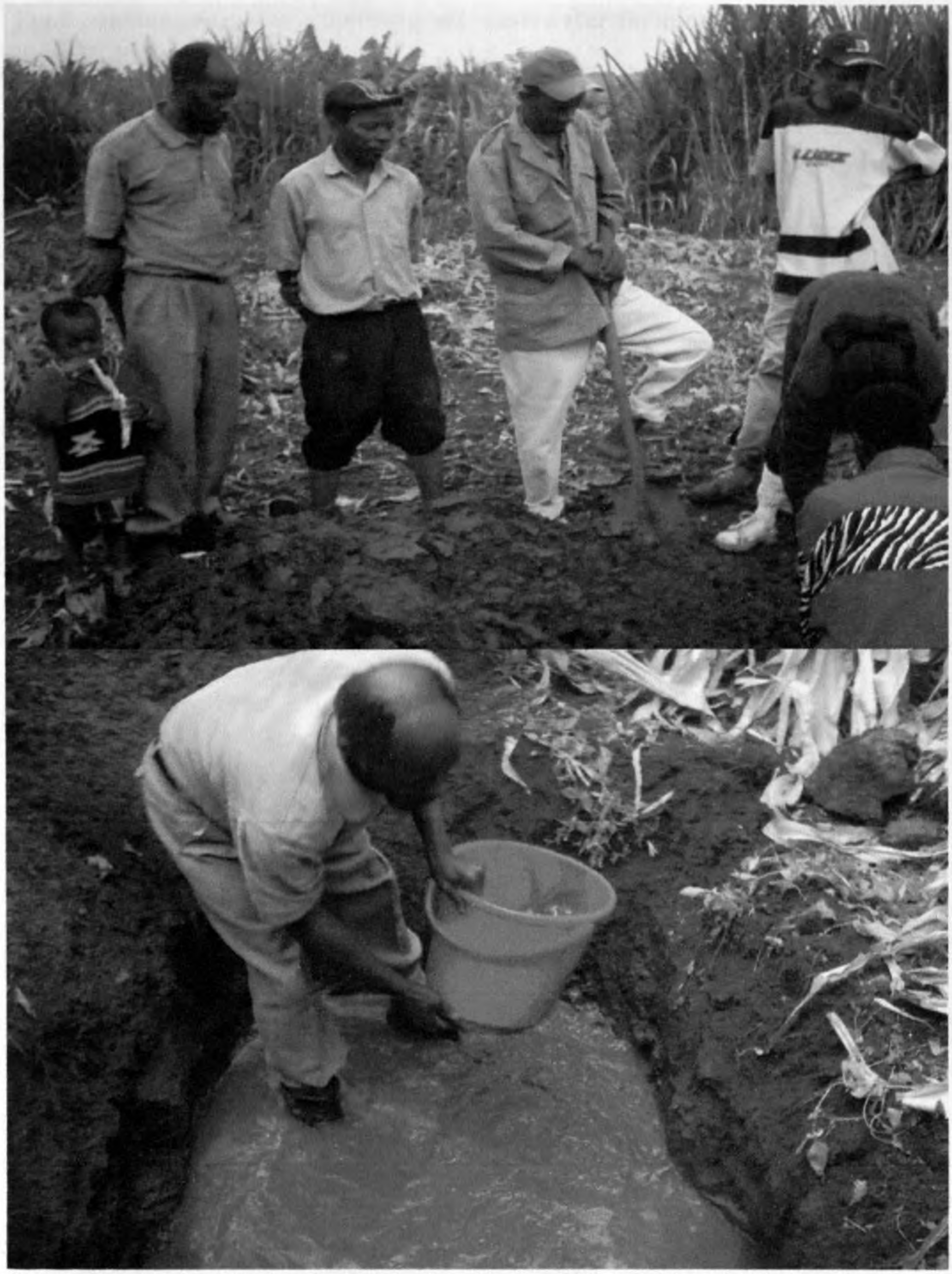
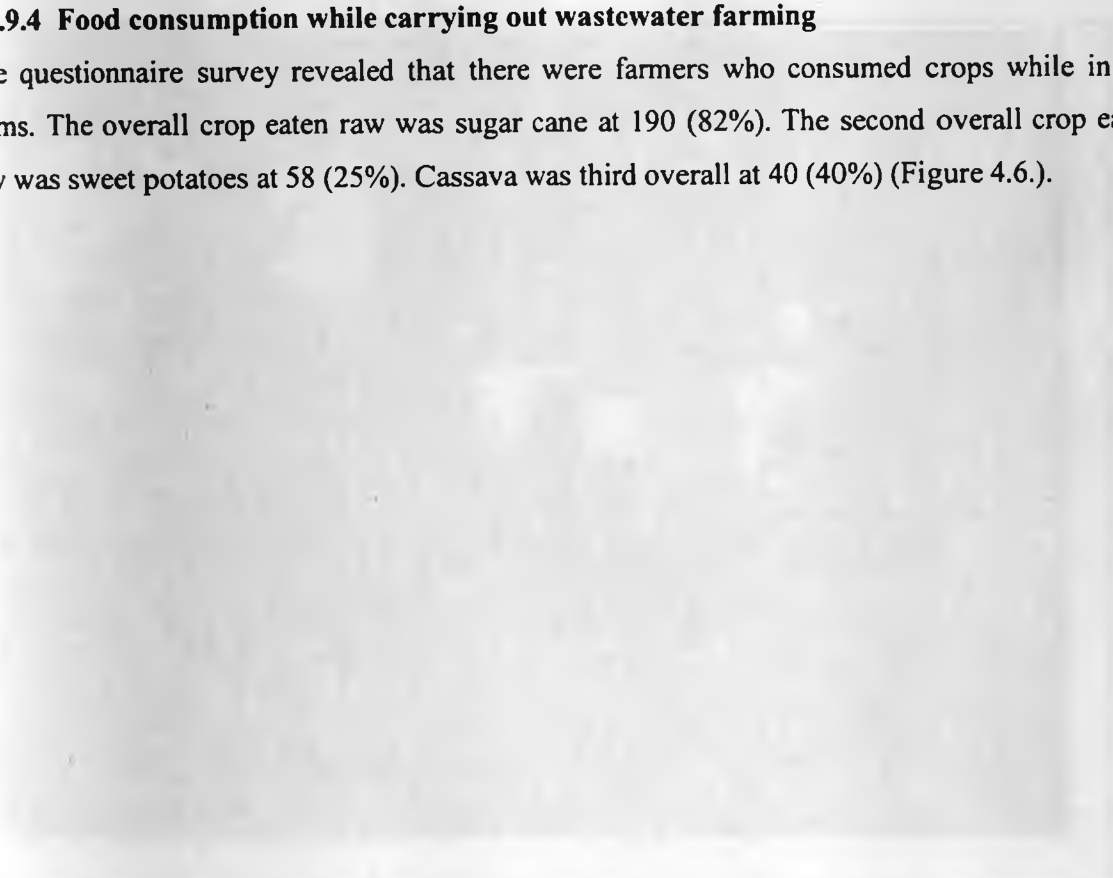


Figure 4.5: Farmers working with wastewater without protective clothing in Maili Saba.

4.1.9.4 Food consumption while carrying out wastewater farming

The questionnaire survey revealed that there were farmers who consumed crops while in the farms. The overall crop eaten raw was sugar cane at 190 (82%). The second overall crop eaten raw was sweet potatoes at 58 (25%). Cassava was third overall at 40 (40%) (Figure 4.6.).



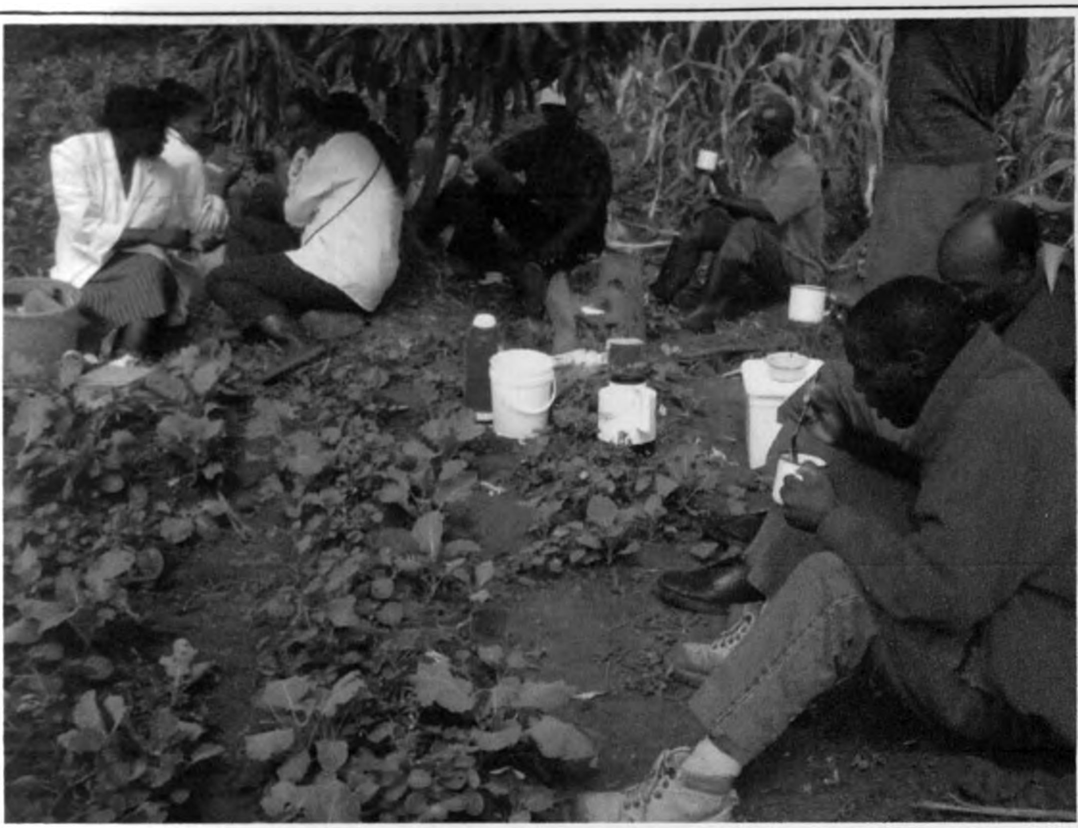


Figure 4.6: Consumption of food stuffs in the wastewater farms of Kibera.

4.1.9.5. Suggested mitigation strategies to minimize health risks due to use of wastewater for irrigation.

Mitigation strategies suggested by farmers were, washing food stuff before eating at 13 (50%) in Kibera and 61 (29.6%) in Maili Saba, statistically significant at ($p= 0.035$), others would seek medical help when sick. The rest of the mitigation strategies are as (Table 4:14).

Table 4.14: Possible mitigation strategies listed by farmers

Mitigation strategy By yourself	Total n=232	Percent	Kibera =26	Percent	Maili Saba =206	Percent	p_ value
None	31	13.4	3	11.5	28	13.6	0.76
Wear protective clothing	111	47.8	11	42.3	100	48.5	0.55
Wash foodstuffs/hands before eating	74	31.9	13	50	61	29.6	0.035*
Use disinfectants e.g. dettol	7	3	2	7.7	5	2.4	0.13
Cooking food properly	22	9.5	2	7.7	20	9.7	0.74
Seek medical help when sick	36	15.5	3	11.5	33	16	0.55
Stop ww farming	21	9.1	1	3.8	20	9.7	0.32
Seek divine interventions e.g. pray	7	3	1	3.8	6	2.9	0.79
Creating awareness on health risks/research	1	0.4	0	0	1	0.5	0.72
People to make their own decisions	1	0.4	1	3.8	0	0	0.005*
Provide clean/treated water for irrigation	1	0.4	0	0	1	0.5	0.72
Provide land and other farming inputs	1	0.4	0	0	1	0.5	0.72
Provide medical facilities	1	0.4	0	0	1	0.5	0.72
Observe general cleanliness & hygiene	20	8.6	0	0	20	9.7	0.097
Have other people irrigate for you	1	0.4	0	0	1	0.5	0.72
Missing	1	0.4	0	0	1	0.5	0.72

*Significant values ($p<0.05$)

Table 4:15 gives a breakdown of mitigation measures that farmers suggested for authorities/ government to effect. Overall, the two main measures suggested were: provision of clean/treated wastewater for irrigation 151 (65.1%) and provision of land and other farming inputs 100(43.1%). When considered separately both Kibera and Maili Saba ranked provision of clean/ treated water as number one at 11 (42.3%) and 140 (68%), respectively. The second rating for

Kibera was creating awareness on health risks 6 (23%), while that of Maili Saba was provision of land and other farming inputs 97 (47%). Rated third in Kibera at 4 (15.4%) was provision of medical facilities, in Maili Saba it was provide any good solution at 18 (8.7%).

Table 4.15: Possible mitigation measures suggested for governments/ authorities

By authorities/government	Total (232)	Percent	Kibera (26)	Percent	Maili Saba (206)	Percent	P value
None	5	2.2	1	3.8	4	1.9	0.52
Wear protective clothing	14	6	2	7.7	12	5.8	0.7
Seek medical help when sick	3	1.3	0	0	3	1.5	0.52
Stop waste water farming	5	2.6	0	0	5	2.4	0.42
Forming farmer groups	2	0.86	1	3.8	1	0.4	0.06
Creating awareness on health risks/research	11	4.7	6	23	5	2.4	0.00*
Provide clean/treated water for irrigation	151	65.1	11	42.3	140	68	0.0096*
Allow farmers to use untreated sewage water for farming	4	1.7	3	11.5	1	0.4	0.09
Provide any good solution	19	8.2	1	3.8	18	8.7	0.38
Provide land and other farming inputs	100	43.1	3	11.5	97	47	0.0006*
Provide medical facilities	20	8.6	4	15.4	16	7.8	0.19
Provide security to farmers	2	0.86	1	3.8	1	0.4	0.06
Proper irrigation & crop husbandry practices	1	0.4	0	0	1	0.4	0.74
Missing	1	0.4	0	0	1	0.4	0.74

* Responses that differ significantly in the two study sites ($p<0.05$)

Kibera was creating awareness on health risks 6 (23%), while that of Maili Saba was provision of land and other farming inputs 97 (47%). Rated third in Kibera at 4 (15.4%) was provision of medical facilities, in Maili Saba it was provide any good solution at 18 (8.7%).

Table 4.15: Possible mitigation measures suggested for governments/ authorities

By authorities/government	Total (232)	Percent	Kibera (26)	Percent	Maili Saba (206)	Percent	P value
None	5	2.2	1	3.8	4	1.9	0.52
Wear protective clothing	14	6	2	7.7	12	5.8	0.7
Seek medical help when sick	3	1.3	0	0	3	1.5	0.52
Stop waste water farming	5	2.6	0	0	5	2.4	0.42
Forming farmer groups	2	0.86	1	3.8	1	0.4	0.06
Creating awareness on health risks/research	11	4.7	6	23	5	2.4	0.00*
Provide clean/treated water for irrigation	151	65.1	11	42.3	140	68	0.0096*
Allow farmers to use untreated sewage water for farming	4	1.7	3	11.5	1	0.4	0.09
Provide any good solution	19	8.2	1	3.8	18	8.7	0.38
Provide land and other farming inputs	100	43.1	3	11.5	97	47	0.0006*
Provide medical facilities	20	8.6	4	15.4	16	7.8	0.19
Provide security to farmers	2	0.86	1	3.8	1	0.4	0.06
Proper irrigation & crop husbandry practices	1	0.4	0	0	1	0.4	0.74
Missing	1	0.4	0	0	1	0.4	0.74

* Responses that differ significantly in the two study sites ($p<0.05$)

4.1.10 Fodder sourcing by the wastewater farmers

All the available crop residues were reported utilized for various purposes on the farms. This was done through selling, feeding to livestock or preparing compost manure in pits. Majority of the respondents 118 (50.9%) sourced fodder for their livestock; Kibera farmers did it at 10 (38.5%) while Maili Saba at 108 (52.4%). More farmers grew their own fodder at 110 (47.4%). Overall 114 (49.1%) of fodder that was being fed to animals was grown using wastewater. Overall 31 (13.4%) of the farmers reportedly used substantial amount of income to source for fodder. For a summary of the fodder sourcing (Table 4.16)

Table 4.16: Fodder sourcing among the respondents.

	Total n=232	Percentage	No. Kibera n=26	Percentage	No. Maili Saba n=206	Percentage	P Value
Source of Fodder	118	50.9	10	38.5	108	52.4	0.43
Grew own fodder	110	47.4	9	34.6	101	49	0.16
Fodder grown using wastewater	114	49.1	9	34.6	105	51	0.11
Farmers that bought fodder	31	13.4	5	19.2	26	12.6	0.35

4.1.10.1 Mitigation Strategies for health risks associated with urban livestock keeping.

Overall the two main measures suggested to curb health risks were, proper cooking of animal products 118 (50.9%), while others would avoid consumption of the animal products 28 (12.1%). Other responses on mitigation strategies included 40 (17.2%) who would do nothing to avert any health risks associated with urban livestock keeping. Treatment or prevention of animal diseases was suggested by overall 27 (11.6%) of farmers and 17 (7.3%) would consume only inspected animal products.

The role of Government and Local authorities on health risks due to wastewater grown fodder for livestock was as follows; the main measures were for the government to take responsibility for treating and preventing animal diseases, at 66 (28.4%) and provision of veterinary services by the government 58(25%). When considered separately in the case of treating and preventing animal diseases Maili Saba 53 (11.2%) and Kibera 13(50%) had statistically significant differences ($p=0.001$). In the second case of provision of veterinary services by the Government, the Kibera group had no responses to it. Other responses 27 (11.6%) were that the government should do nothing. Others felt that there should be a provision of land for uncontaminated pasture production 27 (11.6%), this was only so from the Maili Saba side. Creation of awareness on consumption of animal products was overall 23 (9.9%) in Maili Saba 18 (8.7%) and Kibera 5 (19.2%). A total of 68 (29.3%) of the respondents kept dogs while 83 (36%) kept cats.

4.1.11 Marketing of the produce.

Responses from the focus group discussions showed that women were mostly involved in the marketing of farm produce. The Maili Saba farmers sold their produce to Wakulima, Gikomba, Korogocho markets within Nairobi and also within the villages where they lived. The Kibera farmers mostly marketed their produce in the expansive Kibera slums (Laini Saba, Toi and hawking along the estates) and in some of the neighbouring estate shops. This information was used to determine the markets that would be sampled for Kales ((*Brassica oleracea*)). They were Kibera, Gikomba, Korogocho and Wakulima.

4.2. RESULTS OF LABORATORY ANALYSIS

4.2.1. Wastewater analysis

The average total faecal coliform count for the wastewater used for irrigation in Kibera was 1.89 $X\ 10^7$per 100 ml.

When the sample mean of 1.89 $X\ 10^7$ per 100 ml of wastewater was compared (using a one sample t test) to the WHO guidelines (1989) of 1 $X\ 10^3$ cfu/ 100 ml of water for irrigation, the wastewater was found to be statistically significantly contaminated ($p<0.01$ for general irrigation and $p<0.02$ for leaf crop irrigation) at 1 $X\ 10^4$ cfu/100 ml of water.

Thirty wastewater samples were tested for *Vibrio cholerae* and *Salmonella* Typhi. There was one confirmed case of *Vibrio cholerae* isolated.

Parasitological analysis of wastewater (30) recovered *Balantidium coli* 26 (86%) as the most common type of pathogenic parasite isolated from Kibera (Table 4:17). The second commonest type was the parasitic type of larvae at 16 (53%); others included non parasitic larvae 4 (13%), *Entamoeba coli* 2 (6%), and Parasitium – a pupa or a caterpillar 1(3%).

Table 4.17: Summary of the parasites per litre of wastewater isolated from wastewater used for irrigation in Kibera farms

n=30.

H. W. Larvae		*Ascaris eggs*		*Strongy Loides*		*Ent. Coli*		*B. coli*		Parasitium	
No	%	No	%	No	%	No	%	No	%	No	%
16	53.3	0	0	0	0	2	6.7	26	86.7	1	3.3

Key: *Ent. coli = Entamoeba coli, B. coli = Balantidium coli, %*= percentage

4.2.2. Vegetables analysis

The data below represents analysis carried out on farm vegetables (kales) from farms and markets. The farms were located in Kibera while the markets were Kibera, Korogocho, Wakulima and Gikomba.

4.2.2.1 Farm Vegetables

The kales contained an average of 3.8 X 10^5 cfu/100 ml. Of these 21(38.2%) were coliforms of faecal origin, of which (14) 66.7% were *Eschericia coli*. The total results for vegetable bacteriology analysis were from a total of fifty five (55) samples.

The kales' parasitological results were as follows; *Entamoeba histolytica* 9(14%) was the most commonly found parasite. This was followed by *Entamoeba coli* 4 (14%). Others included, hook worm larvae at 6 (9.3%), *Balantidium coli* 4 (6%) and *Schistosoma* eggs 2 (3%) The total results for the vegetable parasitology analysis were from a total of sixty four (64) samples. (Table 4.18)

Table 4.18: Parasite results of Kibera farm vegetables.

(n= 64; (%).

H.W. Larvae		*Ascaris eggs*		*Strongy Loides*		*E. Histolytica*		*B. coli*		*Taenia eggs*		*Schisto Somes*		*Ent. coli*	
No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
6	9.3	0	0	3	4.7	9	14.1	4	6	1	1.6	2	3.1	4	6.3

Key: H.W. larvae= Hook worm larvae E. *histolytica*= *Entamoeba histolytica*

B. *coli* = *Balantidium coli*   E. coli= *Entamoeba coli,* Schistos= *Schistosome* species.

4.2.2.2 Market Vegetables

Table 4.19 gives the bacteriology results for vegetables obtained from various markets. Key () = Percentage

Table 4.19: Bacteriology results for the various market vegetables.

	Gikomba (n=21)	Wakulima (n=21)	Korogocho (n=21)	Kibera (n= 21)
MPN Index Sum	$1.08X10^8$	$8.5X10^7$	$8.8X10^8$	$1.7X10^{10}$
Average	$5.2X10^6$	$4.0X10^6$	$5.2X10^8$	$8.5X10^8$
Std. Dev	$7.0X10^6$	$6.2X10^6$	$1.1X10^8$	$3.4X10^9$
Faecal Coliforms	6 (28.6)	9 (42.9)	3 (14.3)	13 (61.9)
Esc. Coli	0(0)	(n= 9)6 (66.7)	(n=3) 1 (4.8)	(n=13) 11 (52.38)

*The SD are quite high as the samples tended to vary over different season and period of time.

Kales from Gikomba market yielded an average of $5.2 X 10^6$ cfu/100 ml. When the Gikomba market vegetable samples were compared with the farm (Kibera) gate samples. The findings were that there was a statistically significant difference in total coliforms (t- value) ($p=0.00$). The Gikomba market vegetables were thus more contaminated compared to the farm gate vegetables at Kibera.

Kales from Wakulima market yielded an average of $4.0X10^6$ cfu/100ml. Fourty two percent of these were of faecal origin and of the faecal coliforms, 66.6% were *Eschericia coli*. When the Wakulima market samples were compared to the farm gate (Kibera) samples. The finding was that there was statistically significant difference in total coliforms ($p=0.01$). The Wakulima market samples were thus more contaminated compared to the Kibera farm samples.

On average kales in Kibera markets yielded $8.5 X 10^8$ cfu/100 ml. Of these 62% were of faecal origin and 52% of the faecal coliforms were *Eschericia coli*. When the Kibera market samples were compared to the farm gate (Kibera) samples the findings were that there was no statistically significant difference in total coliforms ($p=0.06$).

Kale samples from Korogocho market yielded an average of $5.2X10^7$ cfu per 100 ml. Of these 14% were coliforms of faecal origin and 5 % of the faecal coliforms were *Escherichia coli.*
When the Korogocho market samples were compared to the farm gate (Kibera) samples. It was found that there was a significant difference in total coliforms (p=0.0000). Korogocho market samples had more contaminant coliforms compared to the farm gate produce at Kibera.

The parasitological results of the market vegetables are presented Table 4.20.

Table 4.20: Parasitology results for the various market vegetables.

	Gikomba (n=37)		Wakulima (n=39)		Korogocho (n=21)		Kibera (n=21)	
	No.	%	No.	%	No.	%	No.	%
Hook worm Larvae	3	8.1	2	5.1	0	0	0	0
N. P. Helminth Larvae	2	5.4	2	5.1	1	4.8	0	0
Ascaris Lumbricoides	4	10.8	2	5.1	3	14.3	1	4.8
Strongyloides	0	0	0	0	4	19	2	9.5
Entamoeba coli	9	24.3	9	23.1	2	9.5	2	9.5
Balantidium coli	1	2.7	1	2.6	2	9.5	1	4.8
Taenia eggs	1	2.7	0	0	2	9.5	1	4.8

Key: No. of sample (n) is shown for each market, (%)= percentage, N. P. Helminth larvae= Non Parasitic Helminth larvae.
The most prevalent parasite isolated from Gikomba market (37) kales was the *Entamoeba coli* at 9 (24 %), followed by *Ascaris lumbricoides* eggs at 4 (11%) and parasitic larvae at 3 (8%).
The most prevalent parasite in Wakulima (39) market was *Entamoeba coli* at 9 (23%). This was followed by parasitic larvae 2 (5%), non parasitic larvae 2 (5%), *Ascaris* eggs 2 (5%) and *B. coli*

1 (2%). Vegetables from Kibera market (21) had both *Entamoeba coli* and *Strongyloid* eggs at 2 (9.5%). Others were: *Taenia* Species, *Balantidium coli* and *Ascaris lumbricoides* at 1 (4.8%) each. The most prevalent type of parasite in Korogocho market (21) was *Strongyloides* eggs at 4 (19 %). *Ascaris lumbricoides* eggs followed at 3(14%) and others at 2 (9.5%), each, were *Entamoeba coli*, *Balantidium coli* and *Taenia* Species.

The vegetables were tested for parasites. Hook worm larvae were found in Kibera farm vegetables 6(9%), in Gikomba market 3(8%) and in Wakulima market 2(5%). When the market samples were compared with farm samples, it was found that there was no statistical significant difference between Kibera farm and Gikomba markets (p=0.86), Kibera farms and Wakulima markets (p=0.45). In fact, the Kibera and Korogocho markets did not have any hook worm larvae isolated.

When the vegetable samples were analysed for *Ascaris* species only the market samples had *Ascaris* species eggs on their surface. This could be indicative of post harvest handling contamination.

Strongyloides eggs were only isolated in Kibera farms at 3(4.6%) and markets at 2(9.5%). There was, however, no statistical significant difference (p=0.41) between the two sites. All samples tested positive for *Balantidium coli,* however, when compared to the Kibera farm samples, there was no statistical significant difference for Kibera, Gikomba, Wakulima and Korogocho market samples (p=0.8, p=0.42, p=039 and p=61, respectively).

All market samples tested positive for *Taenia* species. However there was no significant difference indicated when results of Kibera, Gikomba, Wakulima and Korogocho market samples were compared to those of the Kibera farm samples (p=0.4, p= 0.69, p=0.4 and p= 0.08), respectively. All market samples tested positive for *Entamoeba coli*. There was also no significant difference between the Kibera, Gikomba, Wakulima and Korogocho markets and Kibera farm samples (p=0.61, p=0.38, p=36 and p=0.38, respectively).

The Kibera farm vegetables yielded *Schistosoma* eggs and *Entamoeba histolytica*. These were however not found on any of the market vegetables. Below is a comparison between farm samples and market samples (Table 4.21)

Table 4.21: Summary of parasite results from vegetable farms and markets.

	H. W. Larvae	***Ent. Coli***	***Ascaris eggs***	***Taenia eggs***	***Strogyle ggs***	***B. coli***
Kibera Farms (n=64)	6 (9.4)	4 (6.3)	--	1 (1.6)	3 (4.7)	4 (6.3)
Kibera Markets (n= 21)	-	2 (9.5) p=0.61	1(4.8)	1 (4.8) p=0.40	2 (9.5) p=0.41	1 (4.8) p=0.8
Gikomba Market (n=37)	3 (8.1) p=0.82	9 (24) p=0.38	4 (10.8)	1 (2.7) p=0.69	--	1 (2.7) p=0.42
Wakulima Market (n=39)	2 (5.1) p=0.43	9 (23.1) p=0.36	2 (5.1)	1(4.8) p=0.40	--	1 (2.6) p=0.39
Korogocho Market (n=21)	-	2 (9.5) p=0.38	3 (14.3)	2 (9.5) p=0.08	--	2 (9.5 p=0.61

Key: ( ) = Percentage, Ent. = *Entamoeba* Strong= *Strongyloides.* H.W. = Hook Worm larvae. *B. coli= Balantidium coli, Ascaris =Ascaris lumbricoides.*

4.2.3. Soil analysis

Below are the results of the parasites found in the soils analysed from wastewater farms. (Table 4.22)

Table 4.22: Summary of parasite eggs and larvae results in Kibera Farms

n= 64

	H.W. Larvae/Kg	**Np. Larvae/ Kg**	**EPG**
Sum	2960	2300	800
Average	46.25	35.9375	12.5
Std. Dev	52.23	54.53	60.42

KEY: H.W. Larvae = Hookworm Larvae, Np. Larvae = Non Parasitic Larvae, Kg= Kilogram, EPG= Eggs Per Gram

There was no statistically significant difference in the number of larvae isolated, whether hookworm or non parasitic, at 95 confidence interval using a t two paired test ($p=0.27$). The average *Ascaris* species eggs found were 12.5 eggs per gram.

4.2.4. Faecal sample analysis.

These are shown on Table 4.23.

Table 4.23: Faecal sample results in Maili Saba and Kibera wastewater farming community.

Location	Gender	Age Groups	*Trichuris eggs*		*Anchylostoma eggs*		*Strongyloides eggs*		*Taenia eggs*		*Ascaris eggs*		*Schist. eggs*		*Ent. coli*		*Ent. histolytica*	
			No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Maili Saba	Women	<18 Years (n=29)	5	17.2	4	13.8	1	3.5	1	3.5	2	6.9	0	0	2	6.9	0	0
		>18 years (n=51)	13	25.5	20	39.2	2	3.9	5	9.8	9	17.7	0	0	7	13.7	0	0
	Men	< 18 years (n=29)	5	17.2	4	13.8	1	3.5	0	0	3	10.3	1	3.5	5	17.2	0	0
		>18 years (n=22)	2	9	4	18.2	0	0	0	0	4	18.2	0	0	4	18.2	2	9.1
	O. tot	131	25		32		4		6		18		1		18		2	
Kibera	Women	<18 Years (n=1)	1	100	1	100	0	0	0	0	1	100	0	0	1	100	0	0
		>18 years (n=7)	1	14.3	2	28.6	0	0	2	28.6	0	0	0	0	1	14.3	0	0
	Men	< 18 years (n=4)	0	0	1	25	0	0	0	0	2	50	0	0	0	0	0	0
		>18 years (n=6)	0	0	0	0	0	0	0	0	2	50	0	0	2	33	0	0
	O. tot	18	2		4		0		2		5		0		4		0	

Key: (%) =percentage O. Tot= Overall total, Maili Saba n= 131 and Kibera n= 18 Anchylos= A*nchylostoma duodenale, Ascaris = Ascaris lumbricoides, Strongylo =Stronglyloides stercolaris, Schist. = Schistosoma mansoni, Ent. Coli = Entamoeba coli, Ent. histolytica= Entamoeba histolytica, Trichuris= Trichuris trichura.*

4.2.4.1 Faecal sample analysis of wastewater users

There were a total of eighty (80) sampled women farmers in Maili Saba. Of these 36% were below 18 years. The most prevalent infections were *Ancylostoma* (hookworm) infestations 24 (30%), followed by 18 (22.5%) *Trichuris trichura* infections. The bulk of the infections were carried by those over 18years old. For example 20 out of the 24 hook worm infections were in the over 18 year group, which was statistically significantly different from the under 18 year group ($p=0.017$).

There were a total of fifty one (51) men sampled from Maili Saba. Fifty six percent of these were below 18 years of age. The most prevalent infections in the men were protozoa infections (*Entamoeba coli*) 9 (17.6%), followed by *Anchylostoma spp* 8 (15.7%) and *Ascaris lumbricoides* 7 (13.7%). One case of *Schistosoma mansoni* was noted in a boy.

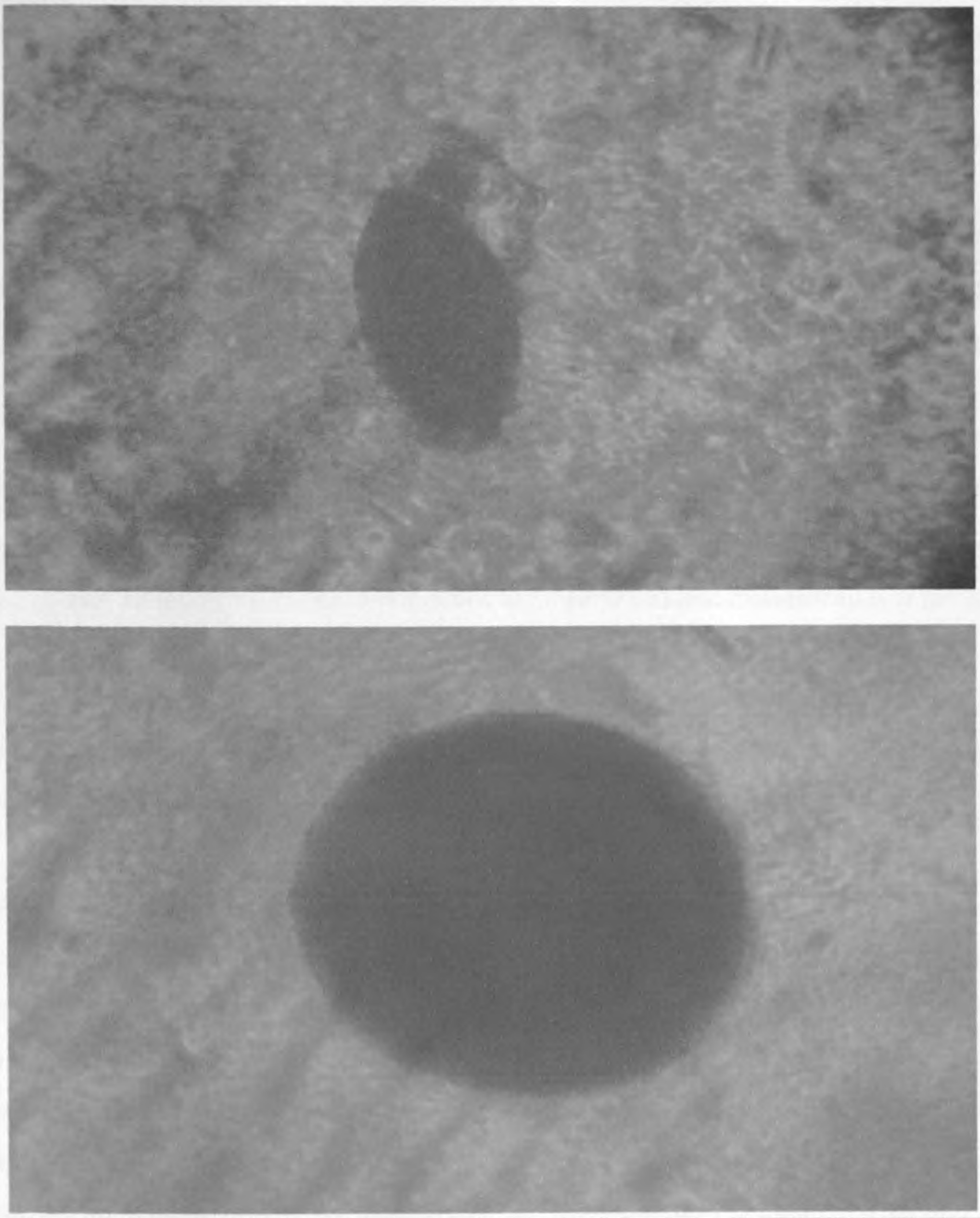


Figure 4.7: ***Trichuris trichura egg*** **(Top) and** ***Taenia*** **egg (Bottom) isolated from a faecal sample. Magnification (X 400)**

In Kibera the number of women sampled was eight. Of these 87% were over 18 years old. The most prevalent parasitic infections detected in adult women were *Anchylostoma infestations* 2 (28.6%) and tapeworms 2 (28.6%). The under 18 year old sampled were 1(100 %) positive for *Ancylostoma* (hookworm), *Ascaris lumbricoides* and protozoa.

Of the ten men from Kibera sixty percent were above 18 years of age. The most prevalent infections were *Ascaris* 4(40%) followed by protozoa 2(20%) and *Ancylostoma* (hookworms) 1(10 %).

There were no significant differences in the women in the two communities. The p values were as follows; *Anchylostoma* spp infestation (p=0.66), *Trichuris trichura* (p=0.87), *Strongloides spp* (p=0.57), *Taenia spp* (p=0.1), *Ascaris lumbricoides* (p=0.95) and *Entamoeba coli* (p=0.26).

The Maili Saba men had a higher variety of parasites including *Schistosoma mansoni*. There was a statistically significant difference between the infestation rates of *Ascaris lumbricoides* in men between the Maili Saba 7 (13.7%) and Kibera 4(40%) group (p = 0.04).

4.2.4.2 Faecal sample results in non wastewater users (Maili Saba).

Women non farmers sampled were 18 in total with the below 18 year olds being 39%. The non farming community experienced mainly *Ancylostoma* (hook worm) and *Ascaris* infestations. The men volunteers from the non farming community were six. Eighty three percent (5/6) were below the age of eighteen. The men were infested with *Trichuris trichura*, *Ancylostoma* species (hook worm) and *Ascaris*. There was statistically significant difference when *Ancylostoma* hook worm infestation in Kibera men using wastewater for irrigation was compared with that of the non farming community men (p= 0.01). The non farming community had higher Hook worm infestation.

Faecal sample results for those not using wastewater are shown on Table 4.24.

Table 4.24: Faecal sample results of non farming community

	Gender	Age	*Trichuris eggs*		*Ancylostoma. eggs*		*Ascaris eggs*	
			No.	*%*	*No.*	*%*	*No.*	*%*
Non Farmers	Women	<18yrs (n= 7)	0	0	1	14.3	1	14.3
		>18yrs (n=11)	1	100	6	54.5	1	9
		18	1	5.6	7	38.9	2	11.1
	Men	< 18 yrs (n= 5)	1	20	2	40	0	0
		>18 yrs (n=1)	0	0	1	100	1	100
		6	1	16.7	3	50	1	16.7
	O. T.	24	2	8.3	10	41.7	3	12.5

Key: Percentage = (%), n= Sample and O.T. = Overall Total

Maili Saba farming and non farming Community

There was no statistically significant difference between the Maili Saba women using wastewater for irrigation and the non farming group with respect to *Trichuris trichura, Ancylostoma* (Hook worm) and *Ascaris* infestations. However the Maili Saba wastewater-using women had a higher variety of infestations. They had *Taenia* species and *Entamoeba coli* which the non farming women did not have.

There was a statistically significant difference between the Maili Saba males using wastewater for irrigation and the non farming group, with respect to *Ancylostoma spp* (hook worm) infestations ($p=0.04$). The isolation rate for wastewater-using Maili Saba males' was 8 (15.7%); that for the non farming community males was higher, at 3 (50%).

CHAPTER FIVE:

DISCUSSION

Two hundred and thirty two households interviewed relied on wastewater for irrigation. The Maili Saba households studied were 206 while those for Kibera were 26. Each household had an average of six persons. This was comparable to other slum areas of Nairobi where other studies have been carried out, namely: Kariobangi and Korogocho - they had an average of seven persons per household (Ngome and Kimiywe 2006). This was however higher than the country's average household number which stood at 4.2 persons per household and 3.3 persons in urban areas (Central Bureau of Statistics 2003, MoPND and Vision 2030, 2009). The UN Habitat study of 2005 documented that, in Kenya, 60-70% of the urban population lived in slums (UN-Habitat 2008). This explains why the average households in the study sites were above the national averages, but within similar ranges for similar studies. The education level of the farmers would influence any suggested mitigation strategy. It would also play a role in the understanding of health risks involved but also in the seeking of alternatives for wastewater farming such as employment.

Majority 142 (62%) of the studied household members had attained a primary school level of education. This trend was similar for the two study sites. It was also similar for other slum areas of Nairobi i.e. the Kariobangi and Korogocho slums (Ngome and Kiminywe 2006). The study also showed those that had attained secondary level of education were 54 (23.6%). This was below the 32 % frequency for other slum areas of Nairobi. There is an under representation of those with secondary school education. Twelve percent did not have any form of education. In Faisalabad, Pakistan farmers were found to be mainly illiterate and aged between 45-60 years old (Amerasinghe et al, 2009).

Land Tenure system in the two study sites was temporarily offered, rented or public land. Few people own land elsewhere or for farming. This seems to be a common phenomenon in other areas that practice wastewater farming. In Pikine region of Dakar Senegal land tenure is precarious, and many use land without title, fifty four percent of the 380 farmers farm without any right to the land – a risky proposition, therefore putting minimal inputs (Keraita *et al*, 2010).

Among the respondents, 99(43.2%) had lived in Nairobi between 10-19 years. This is consistent with previous studies by Foeken and Mwangi (2000), which showed that most farmers had lived in Nairobi for over fourteen years.

Kales (*Brassica Oleracea*) were the most grown vegetable in the two study sites. This is consistent with findings on urban agriculture by Foeken and Mwangi, (2000) in Nairobi, Korogocho and Pumwani. This finding has been widely documented in Kumasi, Accra, Ghana; Dakar, Senegal; Hyderabad, India; Faisalabad and Pakistan that vegetables constitute a majority of what is grown in the urban and peri-urban areas due to the availability of the wastewater and the proximity to markets (Buechler *et al*, 2002, Jacobi *et al*, 2009, Amerasinghe, 2009, Amoah *et al*, 2007, Keraita *et al*, 2010).

Poultry was the most important (for the women) and frequently kept type of livestock in the study sites. This was consistent with findings in Korogocho and Pumwani, Nairobi by Foeken and Mwangi (2000). Chicken and pig farming was practiced in the urban and peri urban areas of Nairobi as commercial entities, due to market proximity (Mireri, 2002). In Addis Abba, Ethiopia cattle and poultry are the most important economic enterprises in urban and peri-urban areas (Tegegne, 2004).

The benefits of wastewater farming in urban agriculture were seen as mainly food security and nutrition. This was consistent with earlier studies by Foeken and Mwangi (2000) in the Korogocho and Nairobi slums, where urban agriculture is practiced for the same reasons. In Lagos, Nigeria, food security and increase of the social economic status of the urban poor are identified as important reasons for urban agriculture (Anosike *et al,* 2005). The finding of food security being constantly being the most important comes with the view that one billion of the six billion people on earth are food insecure; this includes 3.8 million people in Kenya (Republic of

Kenya, 2010). This is usually worse for the urban slums across the country. The Millennium Development Goal (MDG) number 1 addresses the eradication of extreme hunger and poverty (UN, 2010) and the Kenya food security policy (Republic of Kenya, 2009) emphasizes the need for persons to be food sufficient. In this light, wastewater farming plays an important role.

Health risks associated with wastewater farming were ranked highest in the questionnaire survey of farmer's perceptions. The two study sites were however statistically significantly different in this perception ($p= 0.04$). This perception was higher in Maili Saba than in Kibera. Other constraints such as theft of crop produce were experienced. This was more so in Kibera than Maili Saba ($p=0.008$). This brought about an added cost of a watch man. This is also reported in other studies in Nairobi where it is a major constraint (Foeken and Mwangi, 2000). Although this study found that health risks were ranked highest, studies elsewhere showed other unrelated issues and risks being given more prominence compared to those associated with wastewater (Weldesilassi *et al.*, 2010; Obuobie *et al.*, 2006; Ouedraogo, 2002). This study also found that there was a list of ailments such as Rift Valley Fever, malaria, allergies, bronchitis, and back ache among others which were not directly attributed to wastewater. A similar trend was noted in other studies, where other ailments took prominence over those related to wastewater reuse (Weldesilassi *et al.*, 2010; Obuobie *et al.*, 2006; Ouedraogo, 2002). In Pikine, Senegal, farmers reported malaria, parasitic infection, dermatitis and fatigue as the top four illnesses they had experienced in the previous year. About 70% of the farmers in another study claimed not to have suffered any illnesses related to wastewater (Chaudhuri, 2008); however, hospital records showed diarrhoea to be a major complaint among the population. Women in the Maili Saba study complained of more ailments compared to any other category of farmers. In Accra and Ouagadougou the farmers saw no significant difference in using wastewater and using clean water (Gbewonyo, 2007; Gerstl, 2001). In this study, 80 (34.5%) of the farmers perceived they experienced health issues as a result of using wastewater and 144 (62%) used some form of protective clothing. This was not the case in other countries where despite the farmers being aware of health risks they seldom adopted the use of protective measures (Keraita, 2002; Obuobie *et al*., 2006). Protective clothing was in most cases perceived to be unsuitable in hot conditions and not necessary, given the low level of perceived risk (Weldesillassi *et al*, 2010).

This study showed that (22) of adult women and (10) adult men identified skin infections as the commonest health issue (Table 4.11.) This is not surprising since other studies have shown dermatitis, skin irritation, to be a major complaint by persons involved in sewerage treatment works or in wastewater farming all over the world. Theories (swimmers itch, contact dermatitis and allergies) have been advanced on the cause but no real evidence has been cited (Hoek *et al*, 2005).

Zoonotic disease-causing organisms, such as *Vibrio cholera, Balantidium coli* and *Taenia* spp were isolated from wastewater, and/or stool samples. This corresponded with several studies that showed that the greatest risk for farm workers in wastewater-irrigated agriculture was intestinal nematode infections and for produce-consumers, bacterial infections (Shuval *et al*., 1986, Blumenthal and Peasey, 2002, WHO, 2006).

Isolation of *Vibrio cholerae* in the wastewater used to irrigate vegetables proved that there is indeed a risk of contracting the disease. The WHO fact sheet on cholera estimates that there are 3-5 million cholera cases and 100,000 -120,000 deaths every year, due to cholera globally. People who are immune-compromised are at the greatest risk of death if infected. The main reservoirs of cholera are people and brackish water (WHO, 2010). Use of wastewater for irrigation, therefore, increases possibility of contracting and spreading of the cholera organism.

Balantidium coli was found in 86% of the wastewater samples analysed. This may be an indication that the wastewater was contaminated with farm or animal waste as *Balantidium coli* organisms are commensals in the caecum and colon of pigs and may cause infections in humans if they contaminate drinking water supply. In humans infection manifests as bloody diarrhoea, and this is a significant infection in immune-compromised individuals. *Balantidium coli* have been regarded as a neglected pathogen with limited research being under taken, but seen as an emerging protozoan pathogen (Garcia, 2008). This is the first report of the parasite in wastewater, in Kenya. *Entamoeba coli* were found in 2 (6%) of the wastewater samples investigated. *Balantidium coli* were isolated in 4 (6%) of the farm vegetable samples (64) irrigated with wastewater. *Balantidium coli* were found in all market vegetables. *Entamoeba histolytica* was, however, found more in the farm vegetables 9(14.1%). *E. histolytica* was not isolated in the irrigating wastewater. This may be indicative of accumulative effects or other sources such as manure and faecal contamination as the area has no latrine facilities and therefore prone to open defecation. Although infectious doses of *Giardia*, *Cyclospora*, *Cryptosporidium*, *Entamoeba* spp. tend to be generally low they have been found to survive long in the environment to pose health risks (WHO, 2006).

Taenia species eggs were found in irrigated farm vegetables and in the market vegetables. This means that there was a possibility of completing the lifecycle of the parasite. When ingested, the parasite could then lead to Taeniosis or Cysticercosis. Taeniosis, caused by *Taenia solium* and or *Taenia saginata,* and cysticercosis, caused by *Cysticerci cellulose*, have been reported to have a prevalence of 10 % in Kenya and other African countries (Phiri., *et al* 2003). Fifty one percent of the respondents fed their livestock wastewater irrigated fodder or crop residues. This also gives the opportunity for the completion of the *Taenia* lifecycle. Wastewater irrigation could serve as a way of further spreading the diseases of public health importance. More research is, therefore, indicated in this area as little has been done since taeniosis is one of the Neglected Tropical Diseases (NTD).

Wastewater irrigation practices of furrow irrigation were observed for most food crops whether vegetables, fodder or maize. Nursery crops, however, experienced bucket irrigation. Flood and furrow irrigation were found to expose field workers to the greatest risk, especially if earth moving was done by hand and without protection (Blumenthal, *et al,* 2000). However, in many developed and middle-income countries, such as the USA, Tunisia, Spain, France, Israel and Jordan, wastewater is effectively treated before application to agricultural fields (Jiménez and Asano, 2008). In these countries, wastewater irrigation is formal, well regulated and controlled by well-established agencies. This is not the case in Kenya and other developing nations. A recent survey suggests that wastewater without any significant treatment is used for irrigation purposes in and around four out of five cities in the developing world (Raschid-Sally and Jayakody, 2008). Of most concern in developing countries are excreta-related pathogens and skin irritants (Blumenthal *et al.*, 2000; van der Hoek *et al.*, 2005). These risks affect the sustainability of wastewater irrigation and need to be addressed. There was generally a higher variety of infestation among the wastewater farmers compared to the non wastewater farmers. It was observed that the wastewater irrigation fields did not have latrine facilities and there was the practice of open defecation.

The Maili Saba men had a higher variety of parasitic infestations including *Schistosoma mansoni* compared to their counterparts in Kibera. There was no significant difference between infestation rates in the women in the two study sites. The MDG number 6 speaks of combating, HIV/AIDs, malaria and other diseases such as schistosomiasis, (UN, 2010), however the use of wastewater may have a negative contribution to this. The Nairobi west district development plan, where one of the study sites (Kibera) falls, identifies diarrhoea (9.3%), skin diseases (4.9%) and intestinal worms (14%) among the five most prevalent diseases in the district, after respiratory diseases (30.1%) and malaria (41.7%) (MoPND and Vision 2030, 2009) This is consistent with the ranking by farmers of diseases in this area.

Amerasinghe and others (2009), in a study in Faisalabad, Pakistan, found no significant differences in the parasite infestation of wastewater farming communities and the non wastewater farming communities. This was attributed to general poor hygiene and sanitation measures by those surveyed. The only significant difference was in the hook worm infestation, being higher in the wastewater farming village.

Post harvest contamination of vegetables along the marketing value chain was noted to be the reason why the market vegetables had higher counts and farm vegetables had less average counts of faecal coliforms ($3.78 x 10^5$). Market vegetables from Gikomba market had $5.18x\ 10^6$

organisms per 100ml; those from Wakulima market had 4.0×10^6 organisms per 100ml and those from Korogocho market had 5.2×10^8 organisms per 100ml. ($p=0.000$, $p=0.001$ and $p=0.000$, respectively). This is consistent with findings in Ghana and Faisalabad, Pakistan (Ensink *et al*, 2007). Studies in Morocco showed a great variety of bacterial and parasite contamination of wastewater irrigated vegetables (Ibenyassine *et al*, 2007).

Findings from vegetable parasitic analysis showed the presence of parasitic larvae, *Ascaris lumbricoides, Balantidium coli, Taenia* species, *Entamoeba coli, Entamoeba hystiolytica, Schistosoma hematobium* and *Stronglyloides* eggs. These results were consistent with findings from Dakar, Senegal, where recently harvested wastewater-irrigated plants for sale were found to be contaminated with amongst other pathogens, *Amoeba*, *Ancylostoma*, and *Ascaris* which cause amoebic dysentery, hookworm, and roundworm, respectively (Faruqui, *et al.*, 2004). In Faisalabad, Pakistan and Hydarabad, India it was noted that market vegetables were a major point of contamination and thereby required intervention (Amerasinghe, *et al*, 2009). Vegetable contamination was reported to increase progressively through the market chain: from farm, through storage to market, as was in this study. The market vegetables of Hydarabad, India, were seen to have higher than recommended levels of coliforms. This was important in crops eaten raw such as mint and coriander (Zeeuw and Lock, 2000, Ensink *et al* 2007).

A risky behaviour reported in this study was that farmers ate in the farms while carrying out farming activities. They ate raw crops in the farms, such as sugar cane 190 (82%), sweet potatoes 58 (25%) and cassava 40 (17.2). The farmers suggested the following ways of countering health risks in wastewater irrigation; wearing protective clothing 111 (47.8%), washing foodstuffs and hands before eating 74 (31.9%), seeking medical help when sick 36 (15.5%), and do nothing 31 (13.4 %).

The average parasitic larvae per kilogram of soil was 46. The average Egg Per Gram (EPG) for *Ascaris* eggs was 12.5. Soil contamination does not have any set standards for evaluating whether a health risk exists or not. However it has been found that farm workers may involuntarily ingest a certain amount of soil through the activities being carried out in the farm. This would therefore

show that a certain health risk would ensue in such a case where the soil was contaminated as such (Blumenthal, *et al*, 2000).
There are generally no policies in place in Kenya addressing wastewater reuse. The city council of Nairobi considers it to be illegal. There is no agricultural extension or any form of government recognition of the reuse of wastewater in irrigation in the urban and peri-urban areas. Government extension services are limited to rain fed agriculture in other parts of Nairobi. However the Nairobi West District Development plan 2008-2012 notes that the city by laws do not allow farming in the district and recognizes the urgency to develop a policy regarding the same and designate certain areas for farming. This is within the 2008-2012 planning period. (MoPND and vision 2030, 2009).

This trend is similar in other countries where the urban councils and governments turn a blind eye to the practice of wastewater reuse for irrigation. However in Zimbabwe the city council of Bulawayo is involved in the pumping and distribution of the wastewater. They also enforce restriction of crops that are grown using the wastewater (Mubvami *et al* 2008). Studies have shown that the use of wastewater for irrigation was more profitable to households compared to those that use fresh water (Amerasighe, 2009). However, those that used the wastewater experienced more sick days per year compared to those that used fresh water (Amerasighe, 2009).

The wastewater reuse practices, such as food production, irrigation, environmental issues, wastewater production and treatment, public health issues are scattered among various government ministries in Kenya such as the Ministry of Agriculture, Ministry of Water and Irrigation, Ministry of Environment, Ministry of Local Government and the Ministry of Public Health and Sanitation. This may have similar and duplicating policies on the same or conflicting and contradicting policies at points of implementation. There is a general lack of coordination in this sector that is multi disciplinary and interrelated.

In the event of development of legislative measures use of metrics for disease measurements of disease such as Disability Adjusted Life Year (DALYs) per person per year or the absence of a specific disease related to that exposure would be important. Health-based targets would be set at the national level, feasible to implement in the local circumstances and part of the overall regulatory framework.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

CONCLUSIONS

The study has clearly shown that:

1. That it was beneficial to practice wastewater farming for the farmers. This was especially for the purposes of food security. However few of the farmers were ready to recognize the other side of the coin whether there may be serious health implications to contend with.
2. That wastewater used for irrigation was contaminated with faecal coliforms above recommended WHO guidelines.
3. Nematode eggs were not common in the wastewater analyzed. The WHO only provides guidelines for nematode eggs and not for protozoa.
4. *Balantidium coli* was the most commonly isolated protozoan parasite in the wastewater.
5. Vegetables were contaminated with both bacteria and parasites. A significant finding was *Schistosoma* eggs in a vegetable sample.
6. Levels of contamination of market vegetables were significantly different from the farm vegetables.
7. Market Vegetables had higher levels of contamination which could be linked to post harvest contamination.
8. Soils were relatively contaminated with *Ascaris* eggs and parasitic hook worm larvae.
9. That some farmers were aware that there could be health risks in the reuse of wastewater for irrigation. However others had been involved in the practice of wastewater farming for such a long time they "saw" no health risks associated with the wastewater reuse.
10. Risk factors and Mitigation strategies were identified as limited use of protective clothing and eating raw foods in the wastewater farms

RECOMMENDATIONS

From the study the following recommendations were made.

1. To sufficiently address wastewater health risks issues a health risk assessment or environmental assessment with a strong health impact component should be incorporated in the planning and development of projects for the use of wastewater, excreta and grey water in agriculture and aquaculture.
2. I) Research and policy issues regarding wastewater reuse should be handled by multidisciplinary teams. Such teams would then translate into harmonized sectoral policies that would ensure adequate handling of all the important aspects. The sectors involved would be the health sector, agricultural sector, the water sector and the research councils. Such cooperation would result in saving in the health sector with a reduced health burden.

   II) Other areas of common interest would be conservation of natural resources. Environmental protection agencies are responsible for environmental impact assessment and the ensuing environmental management plans. These would then be in line with public health issues arising from wastewater reuse and management. In the conduction of extension and good communication the established systems in the agricultural sector would be useful for relaying health messages.
3. Though as a developing nation Kenya may not have had adequate resources to treat all wastewater generated, however enforcement of any regulations is yet to be under taken. Domesticated policy guideline for wastewater reuse needs to be set up to suit the Kenyan scenario.
4. Creation of awareness of the health risks involved in wastewater farming. This would include educating the users of the wastewater and the consumers of the produce on proper cooking and eating of inspected products.

   The following health protection measures would have an impact on product consumers: wastewater treatment, crop restriction, wastewater application techniques that minimize contamination (e.g. drip irrigation), withholding periods to allow pathogen die-off after the last wastewater application, hygienic practices at food markets and during food preparation,

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Wastewater use activities may lead to the exposure of workers and their families to excreta-related diseases (including schistosomiasis), skin irritants and vector-borne diseases (in certain locations). Wastewater treatment is a control measure for excreta related diseases, skin irritants and schistosomiasis but may not have much impact on vector-borne diseases. Other health protection measures for workers and their families include: use of personal protective equipment, access to safe drinking-water and sanitation facilities at farms, health and hygiene promotion, chemotherapy and immunization, disease vector and intermediate host control, reduced vector contact.

Local communities are at risk from the same hazards as workers, especially if they have access to wastewater-irrigated fields. If they do not have access to safe drinking water, they may use contaminated irrigation water for drinking or for domestic purposes.

Children may also play or swim in the contaminated water. Similarly, if wastewater irrigation activities result in increased vector breeding, then local communities may be affected by vector-borne diseases, even if they do not have direct access to the irrigated fields. To reduce health hazards, the following health protection measures for local communities may be used: wastewater treatment, restricted access to irrigated fields and hydraulic structures, access to safe recreational water, especially for adolescents, access to safe drinking-water and sanitation facilities in local communities, health and hygiene promotion, chemotherapy and immunization, disease vector and intermediate host control, reduced vector contact.

Post-harvest interventions would comprise an important component of a multiple-barrier approach for health-risk reduction of wastewater-irrigated crops.

A joint coordinated effort was necessary for proper handling of public health concerns. All stakeholder players from the farmers, to the researchers and the policy makers and implementers should be involved.

5. Crop restriction may be practiced in conjunction with wastewater treatment so that lower quality effluents can be used to irrigate non-vegetable crops.

6. Further research is recommended to address the information gaps in; wastewater reuse in aquaculture, vector borne diseases and viral diseases which has not been researched in Kenya.

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APPENDICES

APPENDIX I:
HEALTH GUIDELINES FOR WASTEWATER IRRIGATION

1.1 The 1989 WHO guidelines for the use of treated wastewater in Agriculture[a]

Category	Reuse Conditions	Exposed group	Intestinal Nematode[b] (Arithmetic mean no. eggs per liter)[c]	Fecal coliforms (Geometrical mean no per 100ml)[c]	Wastewater treatment expected to achieve the required microbiological guideline.
1	Irrigation of crops likely to be eaten uncooked, sports field, public parks[d]	Workers, consumers, Public	< or =1	< or= 1000	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment.
2	Irrigation of cereal crops, Industrial crops, Fodder crops, pasture and trees[e]	Workers	< or =1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal.
3	Localized irrigation of crops in category B if exposure to the workers and the public does not occur	None	Not Applicable	Not Applicable	Pretreatment as required by irrigation technology, but not less than one primary sedimetation.

[a]In specific cases, local epidemiological, social cultural and environmental factors should be taken into account and guidelines modified accordingly.

[b]*Ascaris* and *Tricuris* Species and Hookworms

[c]During the irrigation period

[d]A more stringent guideline (<= 200 faecal coliforms per 100ml) is appropriate for public lawns, like hotel lawns with which the public may come into contact.

[e]In the case of fruit trees irrigation should stop two weeks before the fruit is picked and No fruit should be picked from the ground. Sprinkler irrigation should be used.

Table adopted from (Kilelu 2004)

1.2 Summary of health risks associated with the use of wastewater in irrigation.

Health threats as summarized by Carr *et al* 2005

Group exposed	Nematode infection	Bacteria/Viruses	Protozoa
Consumers	Significant risks of *Ascaris* infection for both adults and children with untreated wastewater; no excess risk when wastewater is treated to < 1 nematode egg/l expect where conditions favor survival of eggs	Cholera, typhoid and Shigellosis outbreaks reported from use of untreated wastewater: Sero positive responses for *Helicobacter pyroli* (untreated); increase in non specific diarrhoea when water quality exceeds 10^4 FC/100 ml	Evidence of parasitic protozoa found on wastewater irrigated vegetable surface but no direct evidence of disease transmission.
Farm Workers and their families	Significant risk of *Ascaris* infection for both adults and children with contact with untreated wastewater; risks remain, especially for children when wastewater treated to <1 nematode egg/l; increased risk of hook worm infection to workers.	Increased risks of diarrhoea disease in young children with wastewater contact if water quality exceeds 10^4 FC/100ml; elevated risk of *Salmonella* infection in Children exposed to untreated wastewater; elevated seroresponse to Norovirus in adults exposed to partially treated wastewater	Risk to *Giardia intestinalis* infection was insignificant for contact with both untreated and treated wastewater. Increased risk of amoebiasis observed from contact with untreated wastewater.
Nearby communities	*Ascaris* transmission not studied for sprinkler irrigation but same as above for flood or furrow irrigation with heavy contact.	Sprinkler irrigation with poor quality water 10^{4-6} FC/100ml or less in sprinkler irrigation not associated with increased viral infection rates.	No data for transmission of protozoan infections during sprinkler irrigation with wastewater.

Sources: Blumenthal and Peasey, 2002; Blumenthal *et al.*, 2000a.

1.3 Recommended revised microbiological guidelines for treated wastewater use in agriculture[a]

Category	Reuse conditions	Exposed group	Irrigation technique	Intestinal Nematodes[b] (Arithmetic mean no of eggs per liter[c])	Faecal coliforms (Geometrical mean no per 100mld)	Wastewater treatment expected to achieve required microbiological quality
A	Unrestricted irrigation Vegetable and salad crops eaten uncooked, sports fields, public parks[c]	Workers, consumers, public	Any	<0.1[f]	$<10^3$	Well designed series of waste stabilization ponds (WSP), Sequential batch fed wastewater storage and treatment reservoirs (WSTR) or equivalent treatment (e.g. conventional secondary treatment supplemented by either polishing ponds or filtration and disinfection)
B	Restricted irrigation- cereal crops, industrial crops, fodder crops, pasture and trees[g]	B1 Workers (but no children <15 years), nearby communities	(a) Spray/ Sprinkler	<1	$<10^5$	Retention in WSP series inc. one maturation pond or in sequential WSTR or equivalent treatment (e.g. conventional secondary treatment supplemented either by polishing ponds or filtration)
		B2 As B1	(b) Flood/ furrow	<1	$<10^3$	As for Category A
		B3 Workers including children < 15 years, nearby communities	Any	<0.1	$<10^3$	As for Category A
C	Localized irrigation of crops in category B if exposure of worker and the public does not occur	None	Trickle, drip or bubbler	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

Table adopted from (Carr *et al* 2005).

1.3 Recommended revised microbiological guidelines for treated wastewater use in agriculture[a]

Category	Reuse conditions	Exposed group	Irrigation technique	Intestinal Nematodes[b] (Arithmetic mean no of eggs per liter[c])	Faecal coliforms (Geometrical mean no per 100mld)	Wastewater treatment expected to achieve required microbiological quality
A	Unrestricted irrigation Vegetable and salad crops eaten uncooked, sports fields, public parks[c]	Workers, consumers, public	Any	<0.1[f]	$<10^3$	Well designed series of waste stabilization ponds (WSP), Sequential batch fed wastewater storage and treatment reservoirs (WSTR) or equivalent treatment (e.g. conventional secondary treatment supplemented by either polishing ponds or filtration and disinfection)
B	Restricted irrigation-cereal crops, industrial crops, fodder crops, pasture and trees[g]	B1 Workers (but no children <15 years), nearby communities	(a) Spray/ Sprinkler	<1	$<10^5$	Retention in WSP series inc. one maturation pond or in sequential WSTR or equivalent treatment (e.g. conventional secondary treatment supplemented either by polishing ponds or filtration)
		B2 As B1	(b) Flood/ furrow	<1	$<10^3$	As for Category A
		B3 Workers including children < 15 years, nearby communities	Any	<0.1	$<10^3$	As for Category A
C	Localized irrigation of crops in category B if exposure of worker and the public does not occur	None	Trickle, drip or bubbler	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

Table adopted from (Carr *et al* 2005).

[a]In specific cases, Local epidemiological, sociocultural and environmental factors should be taken into account and the guidelines modified accordingly.

[b]*Ascaris* and *Trichuris trichura* species and hookworms; the guideline is also intended to protect against risks from parasitic protozoa.

[c]During the irrigation season (if the wastewater is treated in WSP or WSTR which have been designed to achieve these egg numbers, then routine effluent monitoring is not required).

[d]During the irrigation season (faecal coliform counts should preferably be done weekly, but at least monthly)

[e]A more stringent guideline (< 200 faecal coliforms per 100ml) is appropriate or public lawns, with which the public may come into direct contact.

[f]This guideline can be increased to <1 egg per liter if (i) Conditions are hot and dry and surface irrigation is not used, or (ii) if wastewater treatment is supplemented with anthelmintic chemotherapy campaigns in areas of wastewater reuse.

[G] In the case of fruit trees, irrigation should cease two weeks before fruit is picked and o fruit should be picked off the ground. Spray/sprinkler irrigation should not be used.

1.4 Summary of Hazards that may arise from wastewater reuse.

Hazard	Exposure route	Comments
Excreta-related pathogens Bacteria (*Escherichia coli*, *Vibrio cholerae*, *Salmonella* spp., *Shigella* spp.)	Contact Consumption	Bacteria die off more rapidly on crops than some other pathogens (e.g. helminths) but may still present a health risk. Disease outbreaks of cholera, typhoid and dysentery have been associated with the use of wastewater, excreta or greywater for irrigation of vegetables. As these pathogens can survive in the environment sufficiently long to pose health risks, produce disinfection/washing and cooking are important health protection measures.
Helminths- Soil-transmitted helminths (*Ascaris*, *Ancylostoma*, *Necator*, *Hymenolepis*, *Strongyloides*, *Toxocara*, *Trichuris*, *Taenia* spp.)	Contact Consumption	Major risk in agriculture, especially where untreated wastewater and excreta are used and sanitation standards are low. Eggs can survive in the environment for a long time. Hookworm infections (*Ancylostoma duodenale*, *Necator americanus*) are common in some areas where farmers do not wear adequate shoes or boots.

- Trematodes (*Clonorchis*, *Opisthorchis*, *Fasciola*, *Schistosoma* spp.)	Contact Consumption	Major risk in aquaculture where trematode parasites are present. Distribution is limited to certain geographic areas. Foodborne trematodes are transmitted through food consumption (especially the consumption of raw, unprocessed fish); schistosomiasis is spread through skin contact with contaminated fresh water
Protozoa (*Giardia*, *yclospora*, *Cryptosporidium*, *Entamoeba* spp.)	Contact Consumption	Have been found on wastewater-irrigated vegetables at the point of harvest and in the market. Protozoa can survive in the environment long enough to pose health risks.
Viruses (hepatitis A and E viruses, adenovirus, rotavirus, norovirus)	Contact Consumption	Viruses are present in high numbers in wastewater and excreta, and some types can survive in the environment long enough to pose health risks. Contamination of crops has led to disease outbreaks.
Vector-borne pathogens (*Plasmodium* spp., dengue virus, *Wuchereria bancrofti*, Japanese encephalitis virus)	Vector contact	Risk for any water resource development activities in relevant geographic areas where vector-borne diseases are present. Most insect vectors breed in clean water, with the exception of vectors of lymphatic filariasis, which breed in organically polluted water.
Skin irritants	Contact	The causes of skin irritation such as contact dermatitis (eczema) are likely due to a mixture of microbial and chemical hazards.

Sources: WHO (1995, 1999); BGS-CNA (1998); Chorus & Bartram (1999); Blumenthal *et al.* (2000a, 2000b); Gilroy *et al.* (2000); van der Hoek *et al.* (2005).

1.5 Summary of Health risks associated with the use of wastewater for irrigation

Group exposed	**Health threats**		
	Helminths	**Bacteria/viruses**	**Protozoa**
Consumers	Significant risks of helminth infection for both adults and children with untreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 104 thermotolerant coliforms per100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risks of helminth infection for both adults and children in contact with untreated wastewater;	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 104 thermotolerant coliforms	Risk of *Giardia intestinalis* infection reported to be insignificant for contact with both

	increased risk of hookworm infection to workers who do not wear shoes; risks for helminth infection remain, especially for children, even when wastewater is treated to <1 helminth egg per litre; adults are not at increased risk at this helminth concentration	per 100 ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	untreated and treated wastewater; another study in Pakistan estimated a threefold increase in risk of *Giardia* infection for farmers using raw wastewater compared with irrigation with fresh water; increased risk of amoebiasis observed from contact with untreated wastewater
Nearby communities	Transmission of helminth infections not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor water quality (106–108 total coliforms/100 ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (104–105 Thermotolerant coliforms/100 ml or less) in sprinkler irrigation is not associated with increased viral infection rates	No data for transmission of protozoan infections during sprinkler irrigation with wastewater

Sources: Shuval, Yekutiel & Fattal (1984); Fattal *et al.* (1986); Shuval *et al.* (1989); Blumenthal *et al.* (2000a); ; Blumenthal & Peasey (2002); J.H.J. Ensink, W. van der Hoek & F.P. Amerasinghe (unpublished data, 2005).

1.6 Health based targets and helminth reduction tartgets for treated wastewater use in agriculture

Type of irrigation	Health-based target for viral, bacterial and protozoan pathogens	Microbial reduction target for helminth eggs
Unrestricted	≤10-6 DALY per person per year[a]	≤1 per litre (arithmetic mean)[b,c]
Restricted	≤10-6 DALY per person per year[a]	≤1 per litre (arithmetic mean)[b,c]
Localized (e.g. drip irrigation)	≤10-6 DALY per person per year[a]	(a) Low-growing crops:[d] ≤1 per litre (arithmetic mean) (b) High-growing crops:[d,e] No recommendation

[a] The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction.
[b] When children under 15 years of age are exposed, additional health protection measures should be used.
[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre.
[d] High-growing crops include fruit trees, olives, etc.
[e] No crops to be picked up from the soil.

1.7 Verification monitoring[a] (*E. coli* numbers per 100 ml of treated wastewater) for the various levels of wastewater treatment in Options A–G

Type of irrigation	Option (Figure 2.1)	Required pathogen reduction by treatment (log units)	Verification monitoring level (*E. coli* per 100 ml)	Notes
Unrestricted	A	4	$\leq 10^3$	Root crops
	B	3	$\leq 10^4$	Leaf Crops
	C	2	$\leq 10^5$	Drip irrigation of high-growing crops
	D	4	$\leq 10^3$	Drip irrigation of low-growing crops
	E	6 or 7	$\leq 10^1$ or $\leq 10^0$	Verification level depends on the requirements of the local regulatory agency[b]
Restricted	F	3	$\leq 10^4$	Labour-intensive agriculture (protective of adults and children under 15 years of age)
	G	2	$\leq 10^5$	Highly mechanized agriculture
	H	0.5	$\leq 10^6$	Pathogen removal in a septic tank

[a] "Verification monitoring" refers to what has previously been referred to as "effluent standards" or "effluent guideline" levels.
[b] For example, for secondary treatment, filtration and disinfection: five-day biochemical oxygen demand (BOD5), <10 mg/l; turbidity, <2 nephelometric turbidity units (NTU); chlorine residual, 1 mg/l; pH, 6–9; and faecal coliforms, not detectable in 100 ml (State of California, 2001).

Option A: shows that the required pathogen reduction is achieved by the combination of (a) wastewater treatment, which provides a 4 log unit pathogen reduction (approximately equivalent to an *E. coli* level of 103/100 ml in unchlorinated effluents), (b) a 2 log unit reduction due to pathogen die-off between the last irrigation and consumption, and (c) a 1 log unit reduction due to normal household washing of the salad crops or vegetables with water prior to consumption. This option, which provides [a] 7 log unit pathogen reduction, is suitable when root crops that may be eaten uncooked are irrigated with treated wastewater.

Option B: has a lower degree of wastewater treatment than Option A (3 log units, rather than 4) combined with two post-treatment health protection control measures: a 2 log unit reduction due to die-off and a 1 log unit reduction due to washing the salad crops or vegetables with water prior to consumption. This option, which provides a 6 log unit pathogen reduction, is suitable for the irrigation of non-root salad crops (e.g. lettuce, cabbage) and vegetables eaten uncooked.

Option C: combines an even lower degree of treatment (2 log units) with drip irrigation of high-growing crops (such as fruit trees, olives), which achieves the required remaining 4 log unit pathogen reduction.

Option D: incorporates the drip irrigation of low-growing non-root crops (a 2 log unit reduction), so a greater degree of treatment (4 log units) is provided (a valid alternative would be, for example, a 2 log unit reduction by treatment followed by a 1 log unit reduction due to die-off and a 1-log unit reduction due to produce washing).

Option E: relies solely on wastewater treatment to achieve the required 6–7 log unit reduction. A typical sequence of wastewater treatment processes to achieve this would comprise conventional wastewater treatment (e.g. primary sedimentation, activated sludge, including secondary edimentation) followed by chemical coagulation, flocculation, sedimentation, filtration and disinfection (chlorination or UV irradiation). Such a sequence is used, for example, in California, USA, to ensure compliance with the state water recycling criteria for unrestricted irrigation (≤2.2 total coliforms per 100 ml and a turbidity of ≤2 NTU) (State of California, 2001). However, this option does not take into account pathogen reduction due to (a) natural die-off between final irrigation and consumption and (b) specific food preparation practices such as washing, disinfection, peeling and/or cooking. Moreover, the very high costs and operational complexity of the wastewater treatment processes required for this option will generally preclude its application in many developing countries.

Option F: in Figure 2.1 represents labour-intensive restricted irrigation; the health based target of an additional disease burden of ≤10-6 DALY loss per person per year is achieved by a 4 log unit pathogen reduction.

Option G: represents restricted irrigation using highly mechanized agricultural practices (e.g. tractors, automatic sprinklers, etc.); wastewater treatment to 10^5– 10^6 *E.coli* per 100 ml is required (i.e. a pathogen reduction of 3 log units).

Option H: illustrates a typical single-household or institutional situation: minimal treatment in a septic tank (0.5 log unit pathogen reduction) followed by subsurface irrigation via the soil absorption system for the septic tank effluent. There is no contact between the crop and the pathogens in the septic tank effluent, so the subsurface irrigation system is credited with the remaining 6.5 log unit pathogen reduction required for root crops.

As stated previously, each country can and should establish national criteria and procedures that suit its epidemiological, social and economic needs. These should allow for the optimal combination of risk reduction elements to be designed and implemented at the system level. The WHO Committee of Experts that reviewed and endorsed these guidelines felt that the in-depth risk analyses provided a sound epidemiological basis to conclude that options A, B, C and D provide a high degree of health risk reduction, which should meet the needs of most countries in a reasonably cost-effective manner. It concluded that these new risk assessment studies and the extensive review and evaluation carried out by the group generally validated the 1989 WHO recommended guidelines for unrestricted wastewater use in agriculture of 1000 *E. coli*/100 ml.

1.8 Pathogen reductions achievable by various health protection measures

Control measure	**Pathogen reduction (log units)**	**Notes**
Excreta storage without fresh additions	6	The required pathogen reduction to be achieved by excreta treatment refers to stated storage times without addition of fresh untreated excreta. Pathogen reductions for different treatment options are presented in chapter 5 of Volume 4.
Grey water treatment	1–>4	Values relate to the relevant treatment options. Generally, the highest exposure reduction is related to subsurface irrigation.
Localized (drip) irrigation with urine (high-growing crops)	2-4	Crops where the harvested parts have not been in contact with the soil
Materials directly worked into the soil	1	Should be done at the time when faeces or urine is applied as a fertilizer
Pathogen die-off (withholding time one month)	4–>6	A die-off of 0.5–2 log units per day is cited for wastewater irrigation. Reduction values cited are conservative to account for a slower die-off of a fraction of the remaining organisms.
Produce washing with water	1	Washing salad crops, vegetables and fruit with clean water
Produce disinfection	2	Washing salad crops, vegetables and fruit with a weak disinfectant solution and rinsing with clean water
Produce peeling	2	Fruits, root crops
Produce cooking	6–7	Immersion in boiling or close-to-boiling water until the food is cooked ensures pathogen destruction

Sources: Beuchat (1998); Petterson & Ashbolt (2003); NRMMC & EPHCA (2005).

1.9 Water quality monitoring parameters

Activity/exposure	Water quality monitoring[a] parameters	
Agriculture	*E. coli* per 100 ml[b] (arithmetic mean)	Helminth eggs per litre[b] (arithmetic mean)
Unrestricted irrigation		
Root crops	$\leq 10^3$	≤ 1
Leaf crops	$\mathbf{\leq 10^4}$	
Drip irrigation, high-growing crops	$\leq 10^5$	
Restricted irrigation		
Labour-intensive, high-contact agriculture	$\leq 10^4$	≤ 1
Highly mechanized agriculture	$\leq 10^5$	
Septic tank	$\leq 10^6$	

[a] Monitoring should be conducted at the point of use or the point of effluent discharge. Frequency of monitoring is as follows:
- Urban areas: one sample every two weeks for *E. coli* and one sample per month for helminth eggs.
- Rural areas: one sample every month for *E. coli* and one sample every 1–2 months for helminth eggs.

Five-litre composite samples are required for helminth eggs prepared from grab samples taken six times per day. Monitoring for trematode eggs is difficult due to a lack of standardized procedures. The inactivation of trematode eggs should be evaluated as part of the validation of the system.
[b] For excreta, weights may be used instead of volumes, depending on the type of excreta: 100 ml of wastewater is equivalent to 1–4 g of total solids; 1 litre = 10–40 g of total solids. The required *E. coli* or helminth numbers would be the same per unit of weight.

1.10 Summary of health risks associated with the use of wastewater for irrigation

Group exposed	Health threats		
	Nematode infection	**Bacteria/viruses**	**Protozoa**
Consumers	Significant risk of *Ascaris* infection for both adults and children with untreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 10^4 thermotolerant coliforms/100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risk of *Ascaris* infection for both adults and children in contact with untreated	Increased risk of diarrhoeal disease in young children	Risk of *Giardia intestinalis* infection was insignificant for contact with both

	wastewater; risk remains, especially for children, when wastewater treated to <1 nematode egg per litre; increased risk of hookworm infection in workers	with wastewater contact if water quality exceeds 10^4 thermotolerant coliforms/100 ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	untreated and treated wastewater; increased risk of amoebiasis observed with contact with untreated wastewater
Nearby communities	*Ascaris* transmission not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor water quality (106–108 total coliforms/100 ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (10^4–10^5 thermotolerant coliforms/100 ml or less) in sprinkler irrigation is not associated with increased viral infection rates	No data on transmission of protozoan infections during sprinkler irrigation with wastewater

APPENDIX II
PARTICIPATORY RESEARCH APPROACHES

Date / /2006, Name of moderator (s)

Place and Venue ....No of participants ....Gender of participants....Male.....Female

11. Introduction

Name of participants	**Where do you farm** (Same locality or other)	Plot No.	Plot size (M^2,Ft^2 or Acres)	Tenure system (Own, rented, public land **specify,** Institution **specify,** other **specify**)	Source of water for crop farming

12.) Daily activity profile.

Male and female persons in groups will be asked in separate sessions to explain in chronological order their usual activities during a day, the duration of these activities and the location of these activities. The difference in weekdays and during the weekend will be noted. They will also be asked to what extent the recorded day is representative or special.

Time	Activities	Location

A discussion will then be held on the division of labor between men and women, the peaks of their workload and the problems related to activities implemented during the day.

13.) Seasonal activity calendar (18 months).

This shall be done in gender-disaggregated groups in order to come up with seasonal patterns of household labor and hired labor grouped by gender and age. Other interpretations made from the seasonal calendar will include the number of harvest periods per year, time when irrigation is usually done and who grows and sells the main crops.

The participants will be let to describe their classification of months and seasons and symbols will be placed long the upper side of a square. The participants will then identify their main line of farming which will be listed vertically. For each of the main line of farming a chronological order of activities implemented through out the season and the character of involvement of men, women and children in each of these activities and the amount of time involved. The data are filled into the rows of squares using symbols or codes. Various types of crops and livestock will also be done in the same order. The results will then be discussed with the group.

Months	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	Who is doing most of the work
Rainfall																			(M)W
Kale																			
Tomato																			
Carrots																			
Chicken																			
Other																			

Abbreviations used will include W=weeding P=planting H=harvesting M=marketing

14.) Crops priority ranking

By asking a general question i.e. what types of crops do you grow will identify crops grown. The participants will then be asked to indicate which is the most important and why? A rank will be done using individual piling.

A.i) Crops grown with wastewater.

ii) List the type of livestock you keep

Product e.g. Tomatoes, Kale	Purpose for growing the crop		Reasons	Livestock e.g cattle, goats	Purpose for keeping livestock	
	% Home consumption	% Sale			% home consumption	% Security or sale
1						
2						
3						
Others 4-10						

B.

This is to rank the most important crops as listed above.

Crops	Farmers									
	1	2	3	4	5	6	7	8	9	10
1.										
2.										
Total										

9.15.) Trend line

This will be used to get general background information about a specific site.

A table and list of guiding information will be used. The population of wastewater farmers over the years, education levels, other occupation of the farming community, crops grown, livestock kept and health status will be evaluated.

Event	**Year**	**Remarks**

16.) Access and control of resources.

It will be explained to the participants the meaning of Access and Control.

The groups will be separated according to gender and asked questions to help them fill in the table. Tools that will be used to assist will be pieces of stones. A number such as 10 will be used to show the exact divisions.

This table will be according to men a similar one will be according to women.

Resources	Who has access to it?		Who controls it?			Reasons
	Men	Women	Men	Women	Other?	
Traditional Vegetables						
Kales						
Tomatoes						
Livestock						
Others						

17.) Problem (risk) analysis:

This will be used together with a problem tree where the key issue will be identified Then the underlying causes of the key issues and the effects of the key issues. Coping mechanism that the local people apply and how the problem can be solved by local people as well as by help from outside.

Problem or Risk	Cause	Effects by gender			Coping mechanism or (mitigations being applied by local people)	How can the problem be solved by local people
		M	W	C		

APPENDIX III
QUESTIONNAIRE.

Household survey:

2.1 Section one: IDENTIFICATION.

Enumerators name:

Estate   Household Number:

Respondent's name

Sex of respondent _______________ 1=male, 0=female

Age Category a) 20-35 b) 36-50 c) 51-70 d) Over 70

Relation to household head

Education level of respondent:

No formal education [ ] 2.) Primary [ ] 3.) Secondary [ ] 4.) College [ ] 5.) University. [ ]

Type of farming. 1.) Crop only [ ] 2.) Livestock only [ ] 3.) Crop and Livestock [ ] 4.) No farming at all [ ]

Date_______________ Start Time _____________End time ______ .

GPS Reading...

2.2 Section Two: Household Characteristics

2.1

Name of household member	Sex 1=Male 2=Female	Age 0=0-15 1=16-25 2=26-40 3= 0ver 40	Education level 1=Informal 2=Primary 3=Secondary 4=Technical college 5= University	Occupation 1=Informal sector 2=Formal sector 3=Business

2.3 Section Three: Benefits

Is the land you are using 1.) Rented 2.) Leased 3.) Bought 4.) Other (Specify)

What is the approximate size in acres?

How much does it cost to rent per year? 1.) Ksh 200-500 [ ] 2.) Ksh 501-1000 [ ] 3.) ksh 1000-2000 [ ] 4.) Ksh over 2000 [ ] how much 5) Not applicable

3.4)

Type of crop in order of importance	Type of inputs for each type of crop.			
	Land preparation	Planting	Protective clothing	Harvesting

Whom do you grow your crops for?

1.) Home consumption [ ] 2.) For market [ ] 3) For both [ ]

How much do you consume at home? 1) 0-20% [ ] 2.) 21-40% [ ] 3.) 41-60% [ ] 4.) 61-80% [ ] 5.) 81-100% [ ]

Who controls which products fill in the table? I.e. who decides what is to be marketed?

Crops	Control			
	Male	Female	Male child	Female Child

What proportion of each crop is marketed?

1.) Dry season 2.) Wet season

Crop	Season	
	Dry season	Wet season

Who decides how the money will be spent (Total income from all crops)?

Is wastewater irrigation/ farming profitable? Please explain how?

Save on food buying [ ] Get a profit of? [ ] State an approximate figure

What are your other sources of income?

1.) Part time job [ ]2.) Keeping livestock [ ] 3.) Other [ ](Specify)?

2.4 Section four: Health risks.

4.1) Does wastewater pose any health risk to you or your family?

1.) Yes [ ] 2.) No [ ] 3.) I don't know [ ]

What is the health problems experienced in your household in the last?

Health problem	House hold member that is sick	How long does it last?			What medical attention do you seek		
		2 weeks	1 month	1 year	Go to health center	Buy medicine from suppliers	Nothing
Diarrhoea							
Intestinal worms							
Stomach ache							
Skin irritation							
Others specify							

What protective clothing do you use?

1.) Wearing protective clothing [ ] 2.) Gumboots [ ] 3.) Gloves [ ] 4.) Nothing [ ]

Where do you source your drinking water?

1.) Water kiosks [ ]2.) Municipal water [ ] 3.) Borehole [ ] 4.) Other (Specify)

2.5 Section Five: Mitigation

What would you like to be done by stakeholders i.e. Government and non-governmental organizations to improve your living standards and to protect you?

What would you like to do as a community to help and protect yourselves i.e. for those in self-help groups?

What would you like to do as an individual to help yourself, your family and others around you?

What improvements would you like to see in the reuse of wastewater and marketing of your produce?

How has the recent ban on urban livestock keeping affected you, your family and community?

APPENDIX IV

GRAM STAINING, BIOCHEMICAL AND SEROLOGICAL TESTS FOR *SALMONELLA TYPHI* AND *VIBRIO CHOLERAE*

1.0 GRAM STAIN

Equipment; Bunsen burner, alcohol-cleaned microscope slide, water

Reagents; Crystal violet, Gram's iodine solution, acetone/ethanol (50:50 v:v), 0.1% basic fuchsin (carbol fusin) solution

Procedure;

Preparation of a Slide Smear:

A drop of the suspended culture is transferred on a slide with an inoculation loop or if from a solid culture a few loopful of water are added on the slide, and a minute amount of colony aseptically transferred from the Petridish to the slide. The culture was then spread with an inoculation loop to an even thin film over a circle of 1.5 cm in diameter, approximately the size of a dime. The culture was air-dried and fixed over a gentle flame, while moving the slide in a circular fashion to avoid localized overheating.

Gram Staining:

Crystal violet stain was added over the fixed culture. It was left to stand for 10 to 60 seconds. The stain was poured off and the excess stain gently rinsed with a stream of water from a faucet.

Iodine solution was added on the smear, enough to cover the fixed culture. It was left to stand for 10 to 60 seconds. It was then poured off and rinsed with running water. Excess water was shoken off from the surface.

A few drops of decolorizer (50:50Alcohol, Acetone) were added so the solution trickled down the slide. It was rinsed off with water after 5 seconds.

A Counterstain with basic (carbol) fuchsin solution for 40 to 60 seconds was carried. The solution was washed off with water. Excess water was blotted with bibulous paper or placed on a rack for air drying.

Examination of the finished slide under a microscope.

This was done using the oil emersion lens where bacteria were then observed and classified as either gram positive or gram negative depending on the colour retained. Gram positive cells retained the first colour (purple) while gram negatives took the second colour of pink. Other characteristics such as morphology were described.

Summary of the expected results of *Salmonella* and *Vibrio cholera* in biochemical tests.

Characterization features for *Salmonella Typhi* and *Vibrio cholera*.

		Colonial Morphology	Gram Reaction	Biochemical Tests											Serotyping	
				Oxidase	I	MR	VP	C	Urease	Lysine	Motility	H2S	glucose	Inositol	O	H
S. Typhi	Mac Conkey	Pale colonies	Negative, rods		–	+	–	±	+	+	±	+	G O	+	+	+
V. cholerae					String Test										Ogawa	
	TCBS	Yellow colonies	Negative, curved rods	+	Positive										+	

Key: I=Indole reaction, MR= Methyl Red Reaction, VP= Voges Proskaeur, C= Citrate, H2S= Hydrogen sulphide gas, + =Positive reaction, - = Negative reaction G= Gas, O= Vibrio Antigen Ogawa, H= Vibrio Antigen H

THE BIOCHEMICAL TESTS USED.

1. **Triple Sugar Iron (TSI) Agar** was used for the differentiation of *Enterobacteriacea* and other gram negative rods. The identification was based on the interpretation of multiple phenotypic tests. TSI contains three sugars Glucose (0.1%), Lactose (1%), Sucrose (1%) a PH indicator phenol red and ferrous sulfate to demonstrate Hydrogen Sulphate (H_2S) production by blackening of the medium. An Alkaline slant and acid butt occurred when only glucose was fermented. The procedure involved a small amount of growth (24 hour old), harvested with a sterile loop and slightly inoculated the surface of the agar slant and a single stab made into the butt of the tube. Tubes were inoculated under aerobic conditions at 37^0C with caps slightly loosened. Tubes should be examined and results recorded at 24 hours, 48 hours and 5-7 days, unless H_2S occurred sooner.

Results were reported as follows.

Hydrogen sulphide production Positive; Black colour along the streak or in the whole medium. Negative; No black colour. Hydrogen gas production; Positive; Gas bubbles or splitting of the agar Negative; No bubbles or splitting of the agar. Carbohydrate fermentation- Alkaline slant/ Alkaline butt; no sugars fermented. Alkaline slant/ acid butt- Only glucose fermented. Acid slant/ Acid butt- Glucose fermented along with lactose and or sucrose.

2. **Urea Test Media (Urea Agar)** was used to differentiate organisms based on urease activity. Organisms that produced urease split urea into carbon dioxide and ammonia. The ammonia combined with water to form Ammonium carbonate which raised the PH of the medium. This PH shift was indicated by the phenol red indicator. The procedure involved a small amount of growth (24 hours old) harvested with a sterile loop and lightly inoculated on the surface of the agar slant. Tubes were inoculated under aerobic conditions at 37^0C with caps slightly loosened. Tubes should be examined and results recorded at 24 hours, 48 hours and 5-7 days. Positive results were intense pink colour on the slant. While negative results had no colour change.

3. Motility-Indol-Ornithine (MIO) Agar. MIO agar is used to demonstrate Motility, Ornithine decarboxylase activity and Indole production. All the three are performed in a single tube following overnight incubation (18-24 hours). Motility and Ornithine decarboxylase activity are determined by visual inspection while indole results are interpreted after addition of Kovacs Indole reagent. The procedure involved harvesting a small amount of growth with an inoculating needle. A single stab was made straight into the Agar stopping approximately 1 cm from the bottom. Tubes are then incubated under aerobic conditions at 37^0C with caps loosened. Tubes were than examined and results recorded following overnight incubation.

Results were interpreted as follows;

Motility: Positive, Visible growth extending away from the stab line making the whole media turbid. Negative, Growth only along the stab line with the agar remaining clear.

Ornithine Decarboxylase: Positive the agar in the middle of the tube turned a light purple colour. Negative, The agar in the middle of the tube turned yellow.

Indole: As the Kovacs reagent turns the media yellow it was important that this be the last to perform. 3-4 drops of Kovac's reagent are added to the top of the tube. Positive; Kovac's reagent turned pink red. Negative; Kovac's reagent remained orange yellow.

4. Lysine Iron (LIA) Agar. LIA was used for the differentiation of Enterobacteriacea and other gram negative rods. Identification was based on the interpretation of multiple phenotypic tests. LIA Agar was utilized to detect hydrogen sulphide production, lysine decarboxylation and Lysine deamination of enteric organisms. The procedure involved harvesting a small amount of growth with an inoculating needle. A single stab was made straight into the Agar. Tubes were then incubated under aerobic conditions at 37^0C with caps loosened. Tubes were then examined and results recorded following overnight incubation at 24hrs, 48 hrs and 5-7 days Unless H_2S production occur soonest. Results were interpreted as follows; H_2S production was positive if there was black colour along the streak or throughout the medium. Negative reactions showed no black colour. Lysine decarboxylase examined for in the butt of the tube. A positive organism turned the agar in the butt of the tube purple. Negative organisms turned the agar in the butt of the tube yellow. Lysine deamination was examined for in the agar slant. Lysine deaminase positive organisms turned the agar slant red. Lysine deaminase negative organisms turned the agar slant purple.

5. Simmon Citrate Agar. Contains inorganic ammonium salts as a nitrogen source and simmon citrate as a carbon source. It was used to differentiate members of the *Enterobacteriaceae* based on citrate utilization. The procedure involved harvesting a small amount of growth with an inoculating needle. The surface of the agar slant was slightly inoculated. Tubes were then incubated under aerobic conditions at 37^0C with caps loosened. Tubes were then examined and results recorded following overnight incubation at 24hrs, 48 hrs and 5-7 days. Results were interpreted as follows. Positive reaction was an intense blue colour. Negative reaction the colour remained green.

***Vibrio Cholerae* CDC (1999)**

Twenty five ml of sample was placed into a tarred jar (capacity approximately 500 ml). 225 ml of Alkaline Peptone Water (APW) was added into the jar. The sample was thoroughly mixed to form a broth. The broth was incubated at 37 ± 2^0C for 6-8 hours. A dried plate of Thiosulfate Citrate Broth Salt (TCBS) was prepared. A 5 mm loopful was transferred from the APW broth to the surface of the TCBS agar and streaked in a manner to yield isolated colonies. The TCBS plate was incubated overnight (18-24 hours) at 37 ± 2^oC.

Typical colonies of *V. cholerae* on TCBS usually are large, smooth, yellow (occasionally late sucrose fermentors are green) and slightly flattened with opaque centers and translucent peripheries.

Further tests

1. Oxidase

The oxidase test was conducted with fresh growth from a Muller Hilton Agar plate (Sub cultured from TCBS) to avoid false-positive, or false negative results. Two to three drops of oxidase reagent (1% *N,N,N*N,*N*N-tetramethyl-*p*-phenylenediamine) were placed on a piece of filter paper in a petri dish. Using a wooden stick applicator a culture was smeared across the wet paper. In a positive reaction, the bacterial growth become dark purple immediately. While oxidase-negative organisms remained colorless or turned purple after 10 seconds. Color development after 10 seconds was disregarded. Positive and negative controls were tested at the same time.

2. String Test

The string test was carried out using fresh growth from nonselective Muller Hinton agar. This was useful for ruling out non-*Vibrio* spp., *Aeromonas* spp. The string test was performed on a plastic petri dish by suspending 18- to 24-hour growth from Muller Hinton Agar. A drop of 0.5% aqueous solution of sodium deoxycholate was mixed. In a positive result, the bacterial cells would be lysed by the sodium deoxycholate, the suspension would lose turbidity, and DNA will be released from the lysed cells, causing the mixture to become viscous. A mucoid "string" is formed when an inoculating loop is drawn slowly away from the suspension. *V. cholerae* strains are positive, whereas *Aeromonas* strains are usually negative. Other *Vibrio* spp. may give a positive or weak string test reaction.

SEROLOGY

1. Confirmation of *V. cholerae* O1 using Inaba and Ogawa antisera

Vibrio cholerae has been divided into three serotypes, Inaba, Ogawa, and Hikojima (very rare). Serotype identification was based on agglutination in monovalent antisera to type-specific O antigens (Cat no. BS3233 distributed by CDC for LRN labs).

Slide agglutination procedure

Agglutination tests for *V. cholerae* somatic O antigens were carried out in a petri dish. Using a sterile applicator stick, a portion of the growth on the Muller Hinton media was placed on the petridish. The growth was emulsified in two small drops of physiological saline and mixed thoroughly. An equal volume of antiserum was added to one of the suspensions. The suspension and antiserum were mixed thoroughly and then the petridish was tilted back and forth to observe for agglutination. A positive reaction showed, clumping within 30 seconds to 1 minute. The saline suspension was examined carefully to ensure that it did not show clumping due to autoagglutination.

Media and Reagents for *V. cholerae*

1. Alkaline peptone water (Oxoid contents, Peptone 10.0 g, NaCl 10.0 g,Distilled water 1000.0 ml)

   Add ingredients to the water and adjust to pH 8.5 with 3 N NaOH solution. Distribute and autoclave at 121°C for 15 minutes. Store at 4°C for up to 6 months making sure caps are tightly closed to prevent a drop in pH or evaporation. When inoculated into APW for quality control, *V. cholerae* O1 should show good growth at 6 to 8 hours.

2. Oxidase reagent; *N,N,N*N,*N*N-Tetramethyl-*p*-phenylenediamine dihydrochloride 0.05 g. Distilled water 5.0 ml,Dissolve the reagent in purified water (do not heat to dissolve). This was prepared fresh daily. Positive and negative controls were tested every time the reagent was prepared. *V. cholerae* is oxidase positive; *E. coli* is oxidase negative.

3. Sodium deoxycholate reagent (0.5%) for string test

   Sodium deoxycholate 0.5 g, Sterile distilled water 100.0 ml.

   Add sterile distilled water to sodium deoxycholate and mix well. A *V. cholerae* O1 strain should be used as positive control. E. *coli* may be used as a negative control.

4. Thiosulfate Citrate Bile salts Sucrose (TCBS) agar

   Follow manufacturer's instructions to weigh out and suspend the dehydrated medium. Heat with agitation. Medium should be completely dissolved. Cool agar in a water bath until cool enough to pour (50° to 55°C). Pour into petri plates, leaving lids ajar about 20 minutes so that the surface of the agar will dry. Close lids and store at 4°C for up to 1 week.

MEDIA PREPARATION PROCEDURES.

Medias were prepared according to the instructions on the Label. The common procedure involved mixing the weighed medium with the appropriate amount of water, heating to dissolve and then autoclaving at 121^{0}C for 15 minutes. The media would then be allowed to cool at a water bath 50^{0}C after which approximately 20 ml, would be dispensed into plastic plates under a hood and allowed to dry. This was used immediately or stored for about a week at + 4^{0}C. Medias that were broth would be dispensed into the various universal tubes, bottles or test tubes before being autoclaved.

Exceptions to the above procedure were TCBS, Tetrathionate, Urea and Alkaline Phosphate Buffered Water. TCBS involved measuring the media and water. Boiling to dissolve and dispensing the media onto plates. Tetrathionate involved measuring the media into the appropriate amount of water. Boiling to dissolve and adding 10% Iodine before inoculating the sample. Urea base agar was autoclaved at 115^{0}C for 20 minutes then the urea reagent added after cooling to 50^{0}C the media is quickly dispersed into binjol bottles and placed in a slanting position to dry.

APPENDIX V

NAMES OF THE MANUFACTURERS OF THE MEDIA AND EQUIPMENT USED.

MEDIA/ EQUIPMENT	MANUFACTURER
MEDIAS	
Lauryl Tryptose Broth (Lauryl Sulphate Broth) CM 0451	Oxoid LTD., Basingstoke, Hants., England
Brilliant Green Lactose Bile 20% (Broth) IVD	Oxoid LTD., Basingstoke, Hants., England
MacConkey Agar (CM0007)	Oxoid LTD., Basingstoke, Hants., England
M.R.V.P Medium (CM 43)	Oxoid LTD., Basingstoke, Hants., England
Simmon Citrate Agar (CM 155)	Oxoid LTD., Basingstoke, Hants., England
Tryptone Soya Broth (Soybean- casein digest) Medium U.S.P. (CM 0129)	Oxoid LTD., Basingstoke, Hants., England
Urease Agar Base (CM 53)	Oxoid LTD., Basingstoke, Hants., England
40% Urea	Oxoid LTD., Basingstoke, Hants., England
Triple Sugar Iron Agar (CM 0277)	Oxoid LTD., Basingstoke, Hants., England
TCBS Cholera Medium (CM 0333)	Oxoid LTD., Basingstoke, Hants., England
Buffered Peptone Water (CM 509)	Oxoid LTD., Basingstoke,

	Hants., England
Tetrathionate Broth Base (CM 0029)	Oxoid LTD., Basingstoke, Hants., England
EQUIPMENT	
Test tube	Pyrex, Germany
Universal bottle	Pyrex, Germany
Durham tube	Pyrex, Germany
Culture tube	Pyrex, Germany
Stomacher 400 Laboratory blender	Seward Medical, London
Stomacher Bags	Seward Medical Stomacher® Bags London, UK
Water bath	Memmert, 854 Schwabach, Germany.
Incubator	Memmert, 854 Schwabach, Germany.
Laminar Flow cabinet	ODD A. Simonsen A/S Oslo, (02) 291236
PH Meter3320	Jenyway Ltd, UK
Cryovial tubes sterile (freezing)	LAXBRO
Weighing Balance, Mettler PM 4600 Balance	Delta Range®
Schott Duran bottles	Made in Germany (00590801)
Measuring Cylinder 500ml	Jay Tec united Kingdom B.S. 604
Refrigerator	LG Best choice
Vortex Genie mixer 58223	McGaw park, Illinois 60085

	Distributed by scientific products
McMaster Slide	5004-228th Avese Issaquahwa 98027 USA Advanced equine products
Centrifuge (2000 rpm)	International equipment co Needham Hits mass USA Distributed by fischer scientific
Microscope	Leitz Wetzlar Germany
Microscope	Leitz, Laborlux 12 Germany
Binjol bottle	Pyrex, Germany
Sterile pipettes	Fischer brand-Nonpyrogenic
Pipete pump™	Pequannock. N.J. USA Bel-ART products®
Pipete pump™	Made in West Germany Glasfirn. pi. Pump
Diethyl ether	Magnate Agencies
Formalin	Analar® Prod. 103266T (BHD)
Cool box 28 liters	Prince®
Urine Jar	Pyrex, Germany
Centrifuge tubes (50 ml)	Greiner
Vibrio "O" anti sera	Cat no. BS 3233 distributed by CDC for LRN labs
Vibrio " H" anti sera	Cat no. BS 3233 distributed by CDC for LRN labs