MICROBIAL QUALITY OF IRRIGATION WATER AND VEGETABLES GROWN IN KIBAHA TOWNSHIP, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN PUBLIC HEALTH AND FOOD SAFETY OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

Vegetables are important integral part of the human diet. Although fresh vegetables provide good health, they also harbour a wide range of microbial pathogens. The purpose of this study was to assess the microbial quality of vegetables and water used for irrigation in Kibaha Township. A total of 60 samples collected from different vegetable types, namely *Amaranthus spp*, sweet potato leaves and spinach, and 20 water samples from different categories including rivers, drainage, shallow wells, and tape water were collected. These samples were cultured in Nutrient and MacConkey agars and analysed for total viable count (TVC), total coliform count (TCC) and total faecal count (TFC) using pour plate count technique (PPCT). In fresh vegetables the mean values ranged from 6.53 to 6.78 log_{10} CFU g^{-1} for TVC, 5.30 to 5.81 log_{10} CFU g^{-1} for TCC and 4.45 to 5.13 log_{10} CFU g^{-1} for TFC. In water samples the mean values were 5.75 log_{10} CFU ml^{-1} for TVC, 4.90 log_{10} CFU ml^{-1} for TCC and 4.5 log_{10} CFU ml^{-1} for TFC. Vegetable samples yielded significant higher ($P<0.05$) TVC, TCC and TFC than water samples collected from different locations in the study area. In addition river water samples had higher TVC, TCC and TFC than any other water type in Kibaha Township. Findings from this study indicate that water and vegetables from Kibaha Township are highly contaminated by microbial pathogens and that consumers are at high risk to acquire food borne related diseases. There is need for behavioural change with regards to food preparation and consumption in order to reduce the risky. WHO intervene to reduce health risky from uses of water with low quality is recommended.

DECLARATION

I, Akwinatha Marcus Haule, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is the result of my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Akwinatha Marcus Haule
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04/11/2014
Date

The above declaration is confirmed by:

Prof. R.H. Mdegela
(Supervisor)

04/11/2014
Date

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DEDICATION

To Adventina, Fransisca, Ester and Sabina my beloved daughters, Atukuzwe and Herbert my sons and the only great full loved husband Rupert.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABREAVIATION AND SYMBOLS

CFU	Colony Forming Unit
%	Percentage
>	Less than
°C	Degree Centigrade
COTC	Clinical Officers Training College
Eg	Example
FAO	Food Agriculture Organisation
FDC	Focal Development College
G	Grams
HACCP	Hazard Analysis Critical Control Point
ICSMF	International Commission of Microbiological Specifications for Food
IFIC	International Food Information Council
IFPA	International Fresh –cut-produce Association
KEC	Kibaha Education Centre
PPT	Pour Plate Technique
RTE	Read-to-eat
Sq km	Square Kilometre
SSA	Sub- Sahara in Africa
SUA	Sokoine University of Agriculture
TB	Tuberculosis
TCC	Total Coliform Count
TFC	Total Faecal Coliform Count
TFDA	Tanzania Food and Drug Authority
TVC	Total Viable Count
US EPA	United State Environmental Protection Agency

USA	United State of America
USDA	United States Department of Agriculture
UTI	Urinary Tract Infection
WHO	World Health Organization.

CHAPTER ONE

1.0 INTRODUCTION

1. 1. Background information

Water plays a vital role in the development of communities (Shayo *et al.*, 2007). It is used for growing vegetables and fruits in urban and peri urban areas. Fruits and vegetables are recognized as important component of a healthy diet and there is an International move to increase their consumption (FAO/WHO, 2008). Regular daily consumption of fruits and vegetables in sufficient amounts reduces prevalence of non-communicable diseases such as cardiovascular diseases and certain cancers. All fruits and vegetables contribute to this benefit significantly and leafy vegetables such as lettuce, spinach, chard, mustard green and cabbage make an important contribution (Hung *et al.*, 2004). Despite being beneficial vegetables can be contaminated with microorganisms still on plant on farm, Post-harvest contamination is considered as a minor source of contamination compared to contamination at farm level (Amoah *et al.*, 2007).

In all cases agricultural water is drawn either from streams, drainages, rivers, lakes, ponds or manmade reservoirs. Animal faeces are the main source of pathogens in these water sources (Converse *et al.*, 1999). Fresh vegetables and herbs including those of the leafy variety have been implicated as vehicles for transmission of microbial food borne diseases worldwide (Beuchat, 2006). Water related diseases continue to be one of the major health problems globally. For instance in 2002 about 4 billion cases of diarrhoea were reported annually and represented 5.7% of the global disease burden (WHO, 2002). About 5-10% of deaths in developing countries are due to water related diseases. Discharges of sewage and industrial wastes are carried to the rivers, ponds and springs. Southern Africa face a serious water supply challenge and projections suggest that by 2025 Mozambique, Namibia, Tanzania and Zimbabwe will face a significant and acute water stress (Shayo *et al.,* 2007).

Problems linked with pathogens in fresh produce, including the associated public health and trade implications have been reported in a number of countries worldwide (FAO/WHO, 2008). Safe fruits and vegetables from microbial contaminations are essential to maximize the health benefit of the produce. Consumer's awareness on the dangers of consuming pathogen contaminated foods and the need to insist on properly processed and stored produce need to be re awaked (Eni *et al.*, 2010). The report of the FAO/WHO (2007) meeting also provides an overview of the pathogens most commonly associated with fresh fruits and vegetables. Outbreaks associated with consumption of contaminated leafy vegetables and herbs have notably been reported. Outbreak of food borne diseases varies between countries (FAO/WHO, 2008). Waterborne diseases caused by viral, bacterial or parasitic pathogens occur in every region of the world. The use of low quality water containing pathogens in the farm environment may result in contamination of the crop. The risk associated with water used in production of leafy vegetables and herbs that are eaten raw must be identified (FAO/WHO, 2008). In most urban centres in Sub-Saharan Africa (SSA) sanitation infrastructures are poor or inappropriate to cope with the urbanization rate (Amoah *et al.*, 2007).

Health impacts are mainly due to pathogens and other organic and inorganic toxic substances which are likely to exceed health protection standards (WHO, 2006). Throughout the world association between the consumption of fruits and vegetable irrigated with raw wastewater and many food borne diseases, gastroenteritis, cholera and toxic chemicals has been demonstrated (Sou *et al.*, 2011). However, such studies are limited in most of the developing countries including Tanzania.

1.2 Justification and problem statements

The quality of irrigation water used in vegetables production in urban areas in developing countries is poor due to contaminations resulting from inadequate sanitary services. Improperly treated water used for irrigation form important sources of contamination of fruits and vegetables before harvesting. Thus consumers need to be informed on how to handle fresh and fresh-cut leafy vegetables safely and understand their roles and responsibilities in protecting them from exposure to contaminations and causative agents of food borne illness (FAO/WHO, 2008).

As in many areas in Tanzania, insufficient water source is also a big challenge in Kibaha Township and as a result most of the people use unsafe water for agriculture and other domestic purposes. Vegetable production in Kibaha Township is among major informal source of income to farmers. The surface Irrigation system that may encourage contamination of vegetables is highly done in the area. Since there have been no studies to assess health risks associated with irrigation water and vegetables in Kibaha Township, there is a need to assess microbiological quality of irrigation water from different sources and vegetables grown in Kibaha Township, examine the awareness and perception of farmers and consumers about availability, quality of water and vegetables as well as to visit different water sources used by vegetables farmers. This will help to identify and measure extent of risks to vegetable consumers and find ways to reduce them.

1.3 General objective

The overall objective of the study was to assess the extent of microbial contamination in water and vegetables, irrigation water sources and community awareness and perception toward water and vegetables quality.

1.4 Specific objectives

The following were the specific objectives:

(i) To assess the awareness and perception of community on quality of water used for irrigation,

(ii) To identify common sources of water used for vegetables production in the study area.

(iii) To determine the total viable count, total coliform count and total faecal coliform count in irrigation water and vegetables in the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water quality and contamination factors

Water is indispensably and intricately connected to life without which there is no life. This is the reason for which water must be given the necessary attention at all time (Adetunde *et al.,* 2010). Water quality refers to all attributes of water which make it acceptable to the people. The quality criteria can generally be classified as microbiological potential and chemical (FAO, 1993). Water quality indicates safety and possible threats to human health and environment (Tista *et al.*, 2007). Overall, river water contains higher level of organic matter than pipe water.

Water derived from different sources may greatly differ in quality. Rainwater collects impurities which pass through air, while stream and river collect impurities from surface run off. Discharge of sewage and industrial waste is carried to the rivers, ponds and springs (Jiwa *et al.,* 1991), this serving as major source of pollution. The construction operations, supervision of water supply reservoir and distribution system therefore should exclude any possible pollution of water by discharges from the sewerage and industrial wastes. Water pollution is caused by many factors, which as a result favour the growth of microorganisms and increases level of toxic minerals and other inorganic compounds which directly affect health of human population (Shayo *et al.*, 2007).

Polluted water can be used to irrigate gardens and in so doing it may create health hazards for those who mostly use these agricultural products. Vegetables constitute an important part of the human diet since they contain carbohydrates, protein, vitamins, minerals and fibbers required for human health. They also act as neutralizing agents for acidic substances formed during digestion. Microorganisms play a major role in water quality and the microorganisms of major concern are those which cause water borne diseases such as typhoid fever, diarrhoea, dysentery and gastroenteritis (Brimingham *et al.*, 1997). The most dangerous form of water pollution occurs when faeces enter the water supply. Many diseases are perpetuated by the faecal-oral route in which the pathogens are shed in human faeces. *Escherichia coli* are the only valid index organisms for monitoring food containing pathogens of faecal origin. Most of the large pollutes are Government and Private institutions with poor sanitary facilities. The ownership by the Government makes the prosecution of individual or private establishment difficult task (Amoah *et al.*, 2007). Many people rely on the streams for irrigation farming and others even domestic use (Amoah *et al.*, 2005).

2. 2 Faecal coliform in water and vegetables

Faecal coliform are Gram-negative bacili not sporulated, oxidase negative, optional aerobic or anaerobic, able to multiply in surface agents that have equivalent properties and are able to ferment lactose with acid and gas production in 48 hr at the temperature of 44+/-0.5°C. Excessive amounts of faecal bacteria in sewage and urban run-off have been known to indicate risk of pathogen-induced illness in humans (Fleisher *et al.*, 1998). High level of faecal coliform count above the common acceptable standard of 1 x 10^3 ml^{-1} in pipe water is not recommended for irrigation (Amoah *et al.*, 2007).

Levels of faecal coliform contamination in most cases differ by season, being higher in rain than in dry seasons (Amoah *et al.*, 2007). Crop contamination also takes place under irrigation with piped water and the already contaminated soil with faecal coliform levels of 1 x 10^4 g^{-1} in the upper soil (5cm top layer soil) (Amoah *et al.*, 2005). Some previous studies demonstrated that poor sanitary condition in post harvest handling and marketing have no much influence on contamination of vegetables at farm gate effect (Amoah *et al.*, 2007).

Watering cans and buckets are the most common means of irrigation in the urban area in which water is applied on the crop. Where over head irrigation with polluted water is common, vegetables may end up with high levels of contamination. In cases where the soil and water are contaminated, the faecal coliform levels usually exceed the recommended standard levels (Amoah *et al.*, 2006). Any of individual sample followed from farm to retail on the various sampling dates confirmed that the contamination of vegetables with pathogenic microorganisms does not significant increase through post harvest handling and marketing (Amoah *et al.*, 2006). As a better wastewater treatment is not likely to be available in the near future and government authorities give opportunities to improve their alternative strategies for health risk reduction are vital. Identification where and how much contamination occurs along the production consumption pathway and who finally consume the contaminated crops is also important (Amoah *et al.*, 2007).

2.3 Risk factors for vegetables contaminations

Fertilization with animal manure increases the risk for *E. coli* contamination (Mukherjee, 2007, Edmonds *et al.*, 2004, Beuchat., 2006). Other potential sources for *E.coli* contamination are wildlife, livestock, human activity and wastewater, soil type, floods and topographical features of growing fields (FAO/WHO, 2008).

Domestic and wild animals as well as humans are potential sources of microorganisms that are commonly associated with illness attributed to leafy vegetables and herbs. Faecal waste, urine, and hair from live animals and carcasses of dead animals in the field may directly contaminate produce while growing in the field (FAO/WHO, 2008). Human waste may also be a source of direct contamination if deposited in growing field. Environmental contamination with pathogen from sources may be transferred indirectly to produce via contaminated water, insects, workers, or formites such as dust, tools and equipments (FAO/WHO, 2008). *Escherichia coli* 0157 become an important cause of illness attributed to leafy vegetables and herbs. Ruminant animals are among the most common reservoir species for this pathogen (Hancock *et al.*, 2001). Hence utilization of manure may serve as an important risk factor of contamination.

Growing leafy vegetables and products can be contaminated by indirect means such as landfills and wastewater (Nesse *et al.*, 2005). Workers and contaminated equipments may also be vehicle of pathogens from contaminated locations to the growing field. Increase in temperature can also increase the rate of microbial growth and influence the population of pathogens on leafy vegetables (FAO/WHO, 2008).

Flooding can affect the microbial contamination of leaf vegetables through the spread of faecal waste onto growing area or through contaminated soil and water. The manure type, method of application, application rate, frequency of application and time period between application and planting or harvesting may also influence the risk of pathogen transfer from manure to leafy vegetables and herb crops (FAO/WHO, 2008). Enteric bacteria like *E. coli* 0157:H7 and Salmonella have the ability to persist for extended period in manure with survival times ranging from several weeks to months and even up to nearly 2 years (Franz *et al.*, 2005).

2.4 Risk factors for water contamination

The production of leafy vegetable is water intensive and production requirements met by irrigation with water drawn directly from natural sources such as streams/drainages, river, lakes or ponds, canals or irrigation ditches with water collected in catchment basins, including rain water/run-off from urban, ground water captured in wells or with potable water sources. The microbiological quality of water and their risk of crop contamination vary with water source and agronomic practice (FAO/WHO, 2008). A range of microbiological hazards can be transmitted to humans through contact with or the ingestion of contaminated water. Excreta-related bacterial species such as *E. coli* 0157:H7 and salmonella, intestinal helminths such as *Ascaris lumblicolders*, amoebae such as *Entamoeba coli* and protozoa such as *Giandia intestinalis* are associated with outbreaks of diseases in different parts of the world (WHO, 2006).

The interval between final irrigation and harvest influences the extent of contamination as pathogens have been shown to decline with time following cessation of irrigation before harvest (Amoah *et al.*, 2005, Keraita *et al.*, 2007). The likelihood of the eatable parts of a crop becoming contaminated during irrigation depends upon a number of factors including location, type of irrigation and nature of surface of the produce (Gerba and Choi, 2006).

2.5 Risk and awareness of consumers and farmers

There is a wide gap between what people know about safe food handling practices and their own behaviour (IFIC, 2008). Consumers remain an important group for food safety education since opportunities to eliminate microbial contamination is not possible once present on leafy vegetables. It is widely recognized by food microbiologists that washing cannot guarantee the removal of microbial contamination from produce.

Furthermore, pathogen contamination early in the supply chain will have a much larger impact due to a magnification effect, such high incidence of food borne illness linked to wider distribution of product (FAO/WHO, 2008). Consumers (target group) should be involved during development and pre-testing of food safety information and materials (Godwin *et al.*, 2006). Clear consistent messages on handling leaf vegetables and safety should be communicated to consumers by all stakeholders, industry, government, consumer organizations and media to avoid giving contradictory advice and causing confusion (Cuite *et al.*, 2007).

Research has shown that washing will remove soil and loosely attached microorganisms but has only a minor effect on those organisms that are attached. One to two log reduction of microbial load on leafy vegetables can be achieved through washing in the commercial setting. Current guidance is for consumer to use clean, potable running tap water for washing and rinsing leafy vegetables before use (FAO/WHO, 2008). There is potential for cross-contamination and transfer of pathogens from fresh leafy vegetables to cooked and Ready-to-eat foods (RTE) (Wachtel *et al.*, 2003).

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 The study area and duration

This study was conducted in Kibaha Township in Coast Region from February to May 2012. Kibaha Township is located 40 km away from Dar es Salaam city, with about750 sq. km and lies between 6·8° South and 38·2° to 38·5° East. As per 2002 census, the estimated human population in the area is about 78,294, and 70% of people depend on agriculture. Selected field sites for microbial assessment were Mkuza River in Mkuza ward, drainage system of Kibaha Education Centre in Tumbi ward, shallow wells in Mailimoja ward and pipe water in all three wards.

3.2 Study design

A cross sectional study design was used in this study and all together it included, 30 farmers and 30 consumers selected randomly to which a structured questionnaire was administered. In addition water and vegetable samples were collected and analysed to determine microbial contamination using total viable count (TVC), total coliform count (TCC) and total faecal coliform (TFC), indicators.

3.3 Farmers and consumers survey

Structured questionnaires were used to interview 30 farmers and 30 consumers during sampling operations. During interviews awareness and perception of community on quality of water used in irrigation and the safety of vegetables consumed were assessed (Appendix 1).

3.4 Physical observation

Physical observation were done to assess sources of water, field sites condition, general sanitation along the irrigation water system, and vegetables' irrigation (watering) system practice.

3.5 Sample size determination for microbial analysis

The sample size was determined as described by (Fisher *et al.*, 1991) formula:

$$n = \frac{Z \times P(1-P)}{L^2}$$

Where, n = estimated sample size

Z = 1.96 at 95% according to Fisher *et al.*, (1991)

P = Prevalence is 86% (Mdegela *et al.*, 2010)

L = 5% selected accepted error (precision)

$$n = \frac{(1.96 \times 0.86(1-0.86)}{0.05 \times 0.05}$$

$$n = 185$$

Due to shortage of resources and time only 43% of this sample size was included in the study.

3. 5 .1 Sampling procedure

A total of 60 vegetable (*Amaranthus spp*, sweet potato leaves and spinach) samples and 20 water samples were collected from four water sources in Kibaha Township.

3.5.2 Water samples

Over a period of 3 months starting February to May 2012 water samples were collected from different sites. Sampling was done according to procedure described by (Harrigan and Muance, 1976). At each site sterile glass bottles were used to collect five (5) water samples from the irrigation sources that are Mkuza River in Mkuza ward, Kibaha Education Centre (KEC) wastewater drainage system in Tumbi ward, shallow wells in Mailimoja ward and pipe water within these three wards. Sampling at all sites were carried out between eight and ten in the morning in keeping with farmer's irrigation practice and collected samples were transported to the laboratory in cool box with ice packs (Amoah, *et al.*, 2007). A total of 20 water samples were analyzed for total viable count, total coli form and faecal coli form counts.

3.5.3 Vegetable samples

Vegetable samples were collected from the same site where water samples were also collected. A minimum of three bunches of spinach, *Amaranthus spp* and sweet potato leaves were collected in each of the selected farm site randomly using sterile disposable gloves just before harvesting for sale at the market (Amoah *et al.*, 2007). Samples were stored into separate sterile polythene bags and transported on ice to the laboratory where they were analysed immediately or stored at 4°C until analysis within 24 hours, for total viable count, total coliform and total faecal coliform. A total of 60 samples were used for this study.

3.6 Laboratory procedures

3.6.1 Sterilization of equipment and materials

To avoid contamination, materials used for microbiological analysis were sterilized under laboratory conditions using standard procedures. Test tubes, motors, pestles, scissors and tips were washed with liquid soap and sterilized in autoclaves at 121°C for 15 minutes before use. Disposable Petri dishes were used and after use they were sterilized in the autoclave at 121°C for 15 minutes before discarding. Pipettes which were used during dilution and transferring samples to the Petri-dish were sterilized by spirit after every use using sterile cotton wool. Test tubes were tied with stoppers or aluminium foil during autoclaving. Working tables were cleaned with liquid soap and sterilized by spirit or ethanol using sterile cotton wool before use.

3.6.2 Media preparation

Twenty three grams of Nutrient agar powder was dissolved in 1 litre of distilled water, swirled to dissolve then sterilized in autoclave at 121°C for 15 minutes. Similarly 52g of MacConkey agar powder (Laboratorios Conda S.A, PRONADISA$^{(R)}$) was weighed and dissolved in 1litre, swirled to dissolve and sterilized in autoclaves at 121°C within 15 minutes.

3.6.3 Normal saline preparation

Normal saline was prepared by dissolving 8.5g of sodium chloride crystals in 1 litre of distilled water, from which 9 ml of solution were transferred to test tubes and autoclaved at 121°C for 15 minutes before being used for serial dilution.

3.6.4 Microbiological examination

All vegetable and water samples were analyzed at the Faculty of Veterinary Medicine Laboratories for microbial quality. One gram of each vegetable sample was weighed and grinded in 9 ml sterile saline using sterile motor and pestle. About 1ml of the mixture and water sample was serially diluted in sterile saline solution. Further ten-fold serial dilutions were made in the normal saline and 1ml of each fold was transferred in sterilized Petri- dishes.

Pour plate technique (PPT) was used to determine total viable count (TVC), total coliform count (TCC) and total faecal coliform (TFC). Fifteen ml of molten Nutrient and MacConkey agar (45°C) (Laboratorios Conda S.A, PRONADISA$^{(R)}$) were poured in Petri dishes contain samples for TVC determination and TCC or TFC respectively then swirled thoroughly to allow even distribution and solidification. Petri-dishes for determination of TVC and TCC were inverted and incubated at 37°C for 24 hours and those for TFC determination were incubated at 44°C for 24-48 hours. Petri-dishes with colonies between 30 to 300 were counted using light microscope for microbial load determination. The number obtained provided the statistical representation of bacteria in the undiluted sample. The counts were converted into log_{10} CFU/g or ml (Eni *et al.*, 2010).

3.7 Data handling and analysis

Data from questionnaire were entered and stored in Excel Spread Sheet 2007 and imported to Epi info Statistical Packages version 3.4.3 whereby the frequencies and percentages were determined. All bacteria counts were normalized to Colony

Forming Unit per millilitre or per gram (CFU/g or ml) and converted into Log_{10} values. Means and standard deviation as well as ANOVA were computed using of statistical software Stat view. The differences between the means were compared by Duncan's Multiple Range Test (DMRT) at ($P < 0.05$).

CHAPTER FOUR

4.0 RESULTS

4.1 Questionnaire survey to farmers and consumers

4.1.1. Age, sex and education characteristic of respondents

During this study 70% and 63.5% were female farmers and consumers respectively. The age of the respondents ranged between 18-60 years and education level ranged from informal to degree (Table 1).

Table 1: Sex, Age and Education levels of respondents

Variables	Categories	% of farmers (n=30)	% of consumers (n=30)
Sex	Male	30	36.5
	Female	70	63.5
Age	Between 18-40	76.7	43.3
	Between 41-60	23.3	50
	Above 60	0	6.7
Education	Informal	10	0
	Primary	80	33.3
	Secondary	10	26.7
	Others (Degree)	0	40

4.1.2 Awareness and perception of community on quality of irrigation water and vegetables

4.1.2.1 Risk factor and awareness of farmers on vegetable quality

In the study it has been observed that 93.3% of the farmers were producing vegetables throughout the year, January to December. The common vegetables grown depended on customers' preference at the market. Most of farmers grew vegetables for sale and this was the only source of income. The most common vegetables were *Amaranthus spp*, sweet potato leaves and spinach (Fig.1).

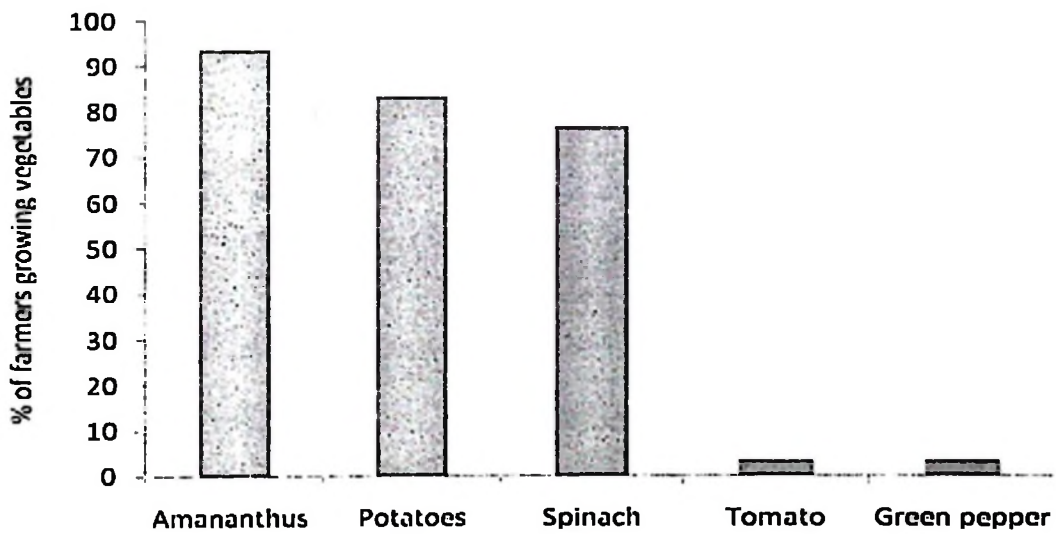

Figure 1: Type of vegetables grown in Kibaha Township (n=60)

In addition, harvesting time of vegetables depended on type of vegetables. *Amaranthus spp* was harvested after 3 weeks while for spinach and sweet potato leaves the first harvest started after one month.

In the study it has been found that the common sources of water for irrigation were rivers, wells, drainages and tape water (Fig.2).

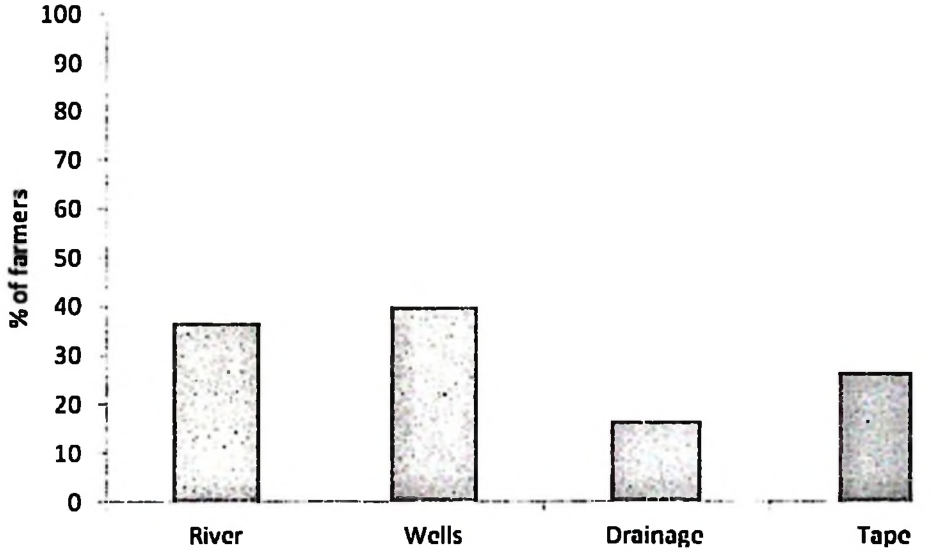

Figure 2: Source of water for irrigation (n=20)

Overhead irrigation system was the common method used to apply water to the vegetables, in which 83.3% used buckets, 13.3% watering cans, 6.7% watering tubes and only 3.3% used motorized pump (Fig.3).

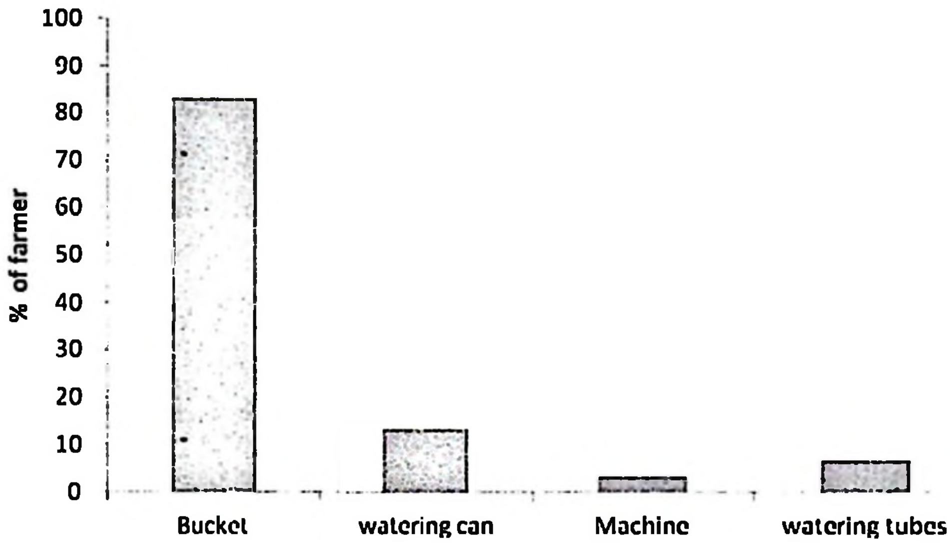

Figure 3: Types of irrigation equipments used to irrigate vegetables by surface irrigation

Due to high environmental temperature, 83.3% of farmers were irrigating vegetables twice per day and the remaining only once per day.

The results showed that 63.3% of farmers were washing vegetables after harvest. This depended on availability of water on the site. Different water types were used to wash vegetables including 47.4% that used tape water, 26.3% river, 21% well water and 5.3% drainage water (Fig.4).

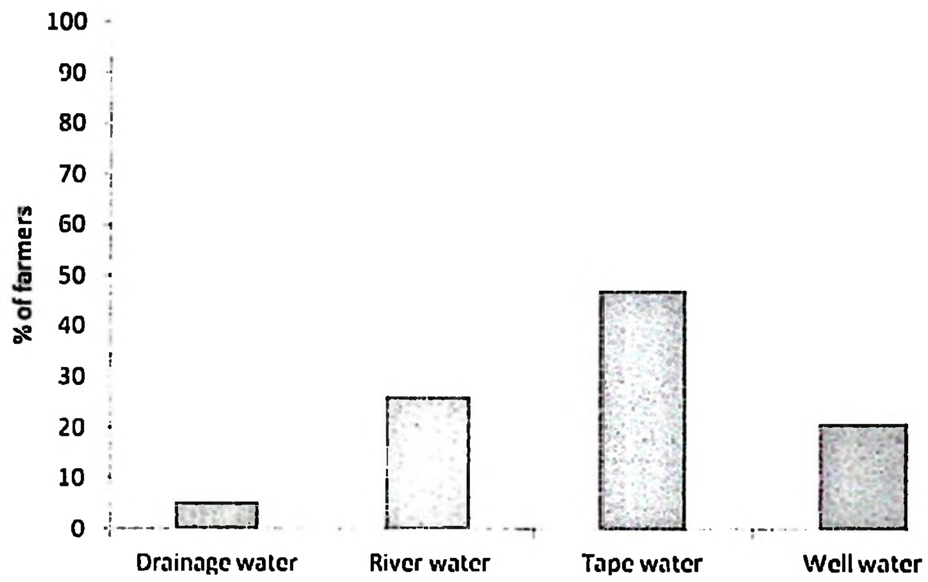

Figure 4: Source of water used for washing vegetable

In the study it has been revealed that 87% out of 30 farmers agreed that water was safe and the rest disagreed. The reported reasons for not being safe were dirty water sources (75%) and others stated that water used was stagnant and could cause bilharzias.

Reasons like, water used was clean, no effect observed from the use of water, water was from tape and the sources were far from toilet, water was from good sources like ground and spring water were stated by farmers to support their perception that the water used was safe (Fig.5).

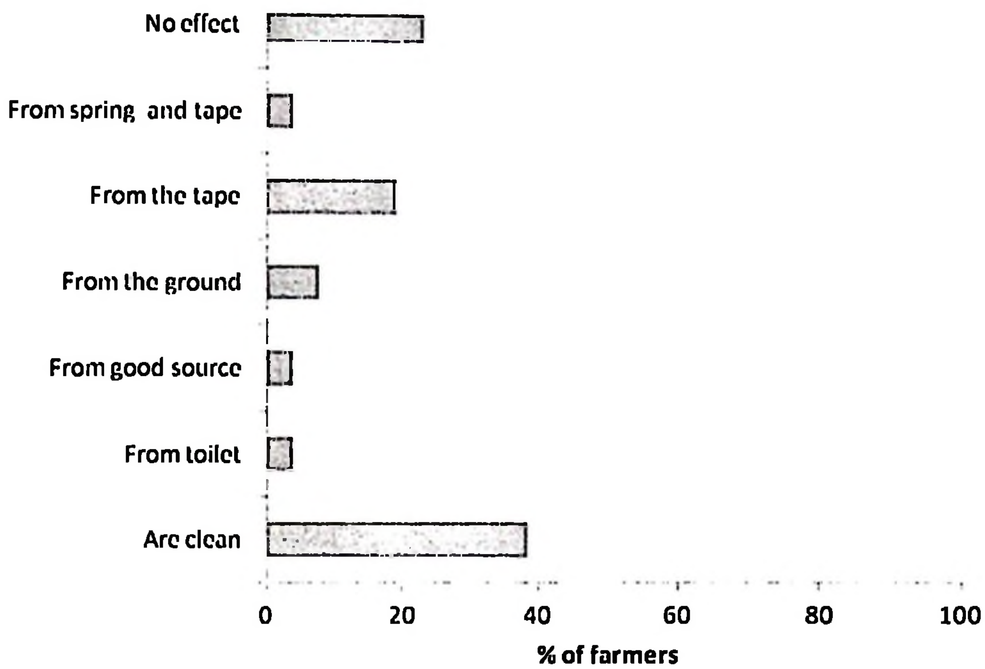

Figure 5: Farmers reasons on safety of water used for irrigation

About 46.7% of farmers used water for domestic purposes. Furthermore, the results showed that 70% of the farmers experienced some health problems. Only 46.7% of the farmers attended medical check up and 53% of farmers did not (Fig.6). Among those who checked their hearth status 20%, 67% and 13% did more than once per month, after every 3 months and every month respectively.

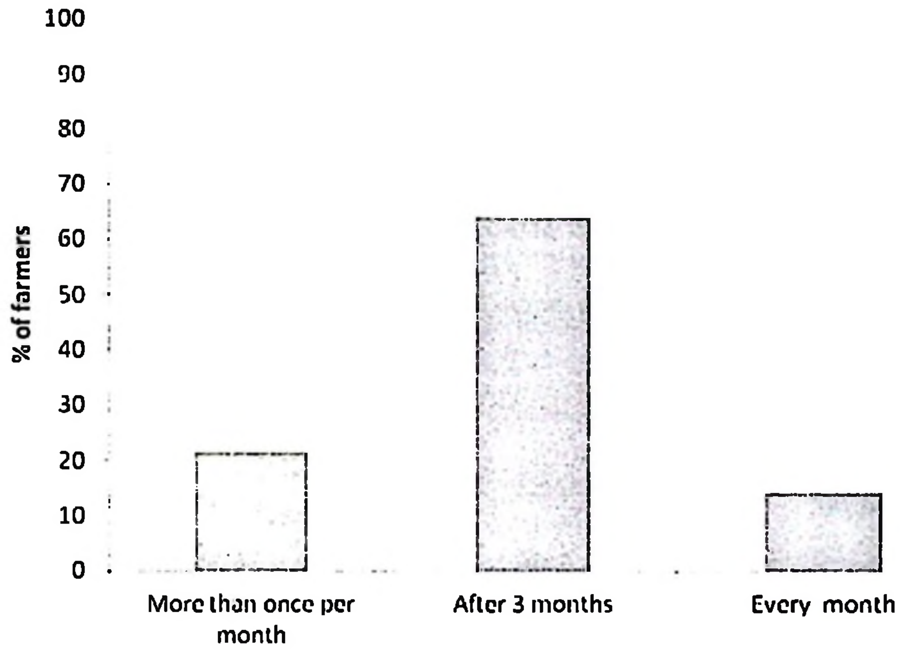

Figure 6: Frequency of health status check up

4.1.2.2 Risk factors and consumers awareness on vegetable quality

All interviewed consumers used vegetables as food in their main dishes twice or once per day, because vegetables are important for their health. The common vegetables preferred by consumers were *Amaranthus spp* 93.3%, spinach 93.3% and sweet potatoes leaves 80%, in addition to cassava leaves, cabbage and pumpkin leaves (Fig 7).

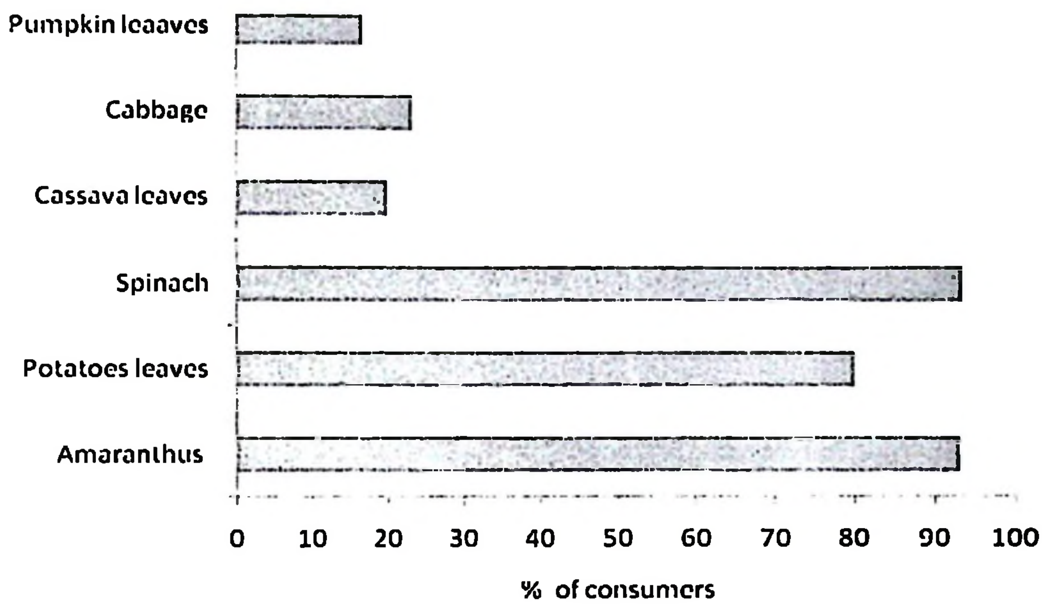

Figure 7: Type of vegetables commonly eaten by consumers

The results revealed that about 60% of consumers got vegetables from open markets, 56.7% from street vendors, 10% own garden and 3.3% nearby farmers (Fig 8).

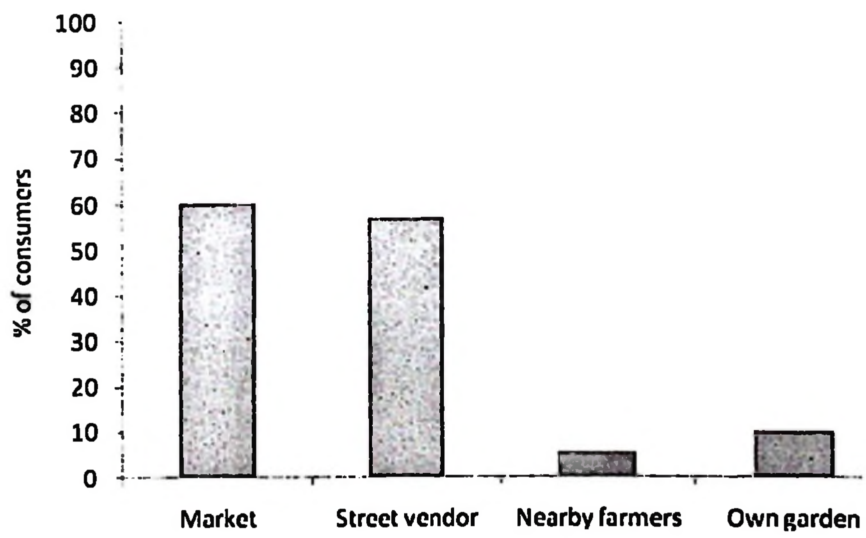

Figure 8: Source of vegetables

Moreover 56.7% of consumers accepted that the vegetables consumed were safe while 43.3% rejected. The reasons fur why vegetables are unsafe were irrigation water was from dirty areas and also farmers used dirty water for irrigation. About 60% of consumers knew some water sources including wells, streams, ponds, sewages, tape water, rivers and rain water (Fig.9).

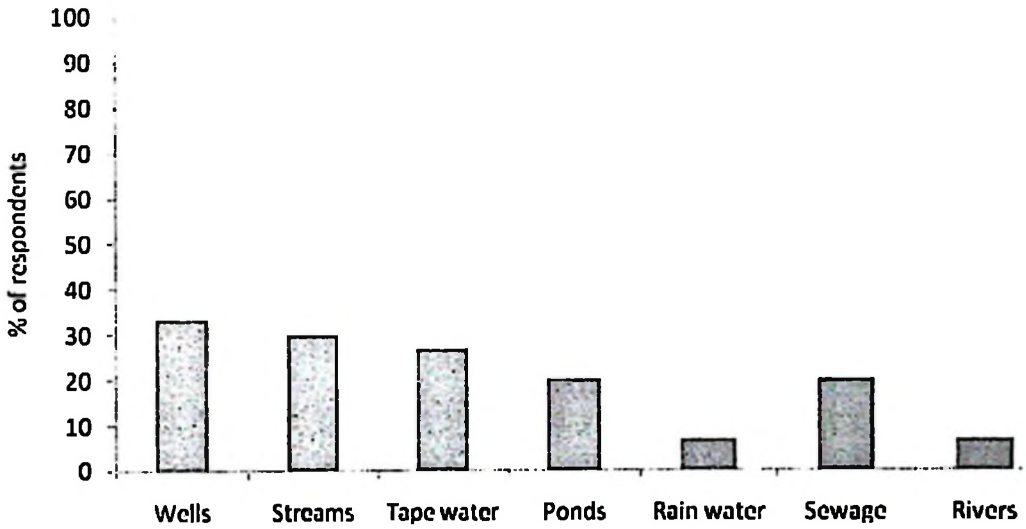

Figure 9: Consumers knowledge about sources of water for irrigation

The common method of cooking vegetables was boiling. It was observed that 53.3% of consumers boiled vegetables for about 5 minutes to the point of ready to eat (Fig.10).

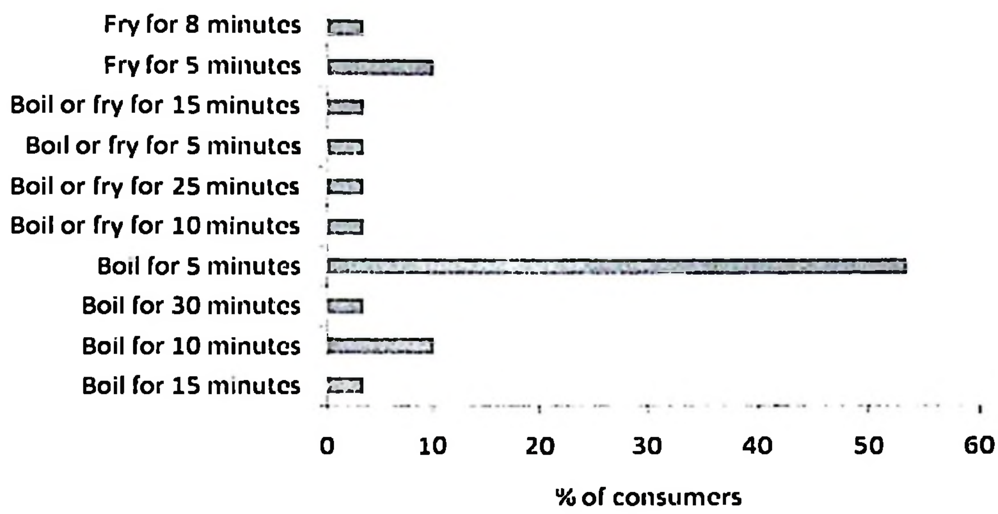

Figure 10: Duration and methods of cooking vegetables at home

Overall, consumers of vegetables grown in Kibaha Township are at high risk of acquiring food borne diseases. About 76% of consumers had experienced health problem related to food borne diseases. Common food borne diseases were stomach fever, dysentery, typhoid, helminthiosis (worms) and amoebiasis (Fig 11).

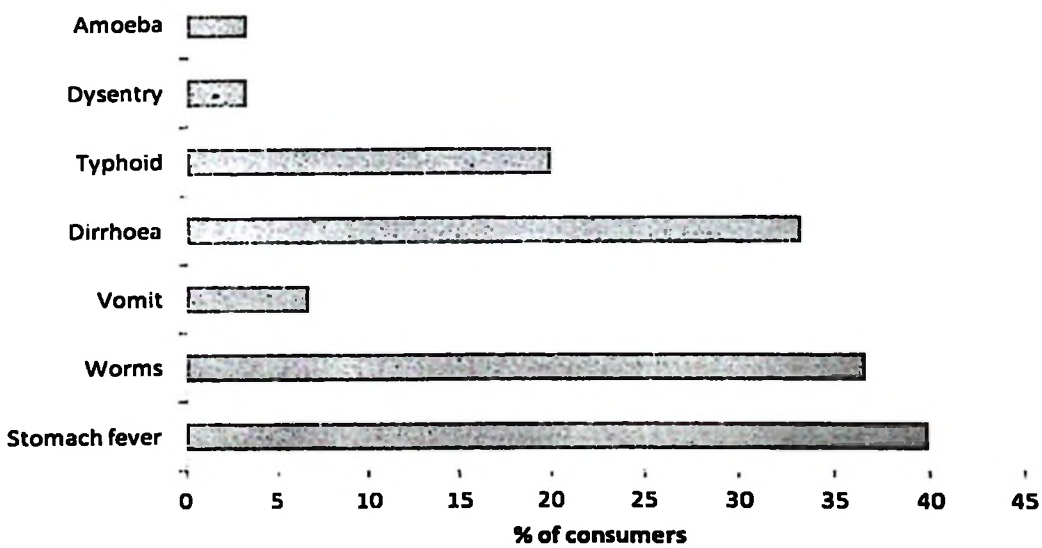

Figure 11: Consumers' health problems

Apart from food borne diseases malaria was also a reported burden to Kibaha Township community. Other diseases like cancer, coughing, tuberculosis (TB), and urinary tract infection (UTI) were also reported. About 50% of the consumers' families visited Hospital once per month, 40% twice per month and 10% once after every three months.

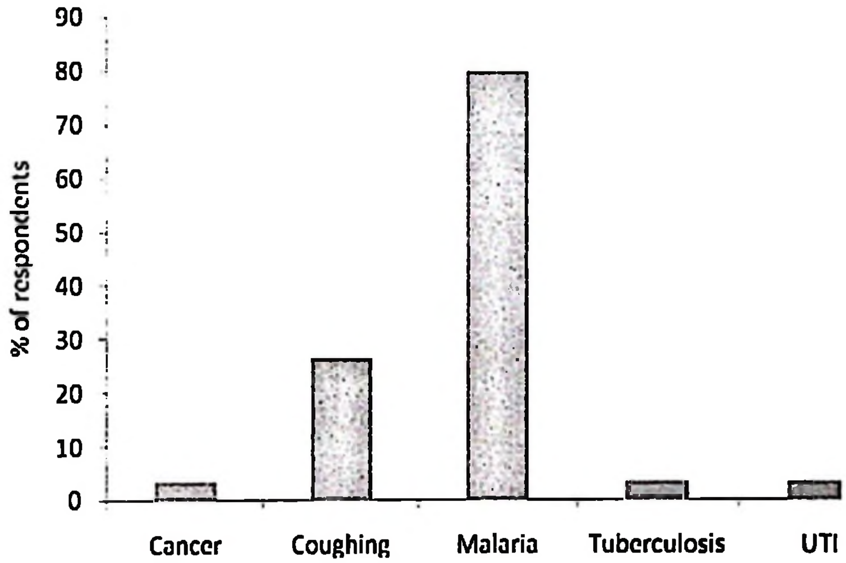

Figure 12: Other human health problem as reported by consumers in Kibaha Township

4.2 General overview of microbial quality of vegetables and irrigation water

In Kibaha Township water and vegetable samples specifically the *Amaranthus spp*, spinach and sweet potato leaves were collected from Mkuza River, Kibaha Education Centre (KEC) drainage system, shallow wells of Mailimoja and pipes within the three wards. The level of faecal coliform counts in *Amaranthus spp* was higher compared to the levels in other two vegetable types (Table 4).

All water and vegetable samples collected in different sites in Kibaha Township were contaminated with microbial pathogen as demonstrated by then Total viable counts (TVC), Total coliform counts (TCC) and Total faecal coliform (TFC) (Table 2). Mean level of TVC, TCC and TFC exceeded the recommended levels (FAO/WHO, 2008). There were no significant differences ($P>0.05$) in contamination levels of vegetables and water (Table 4). The overall results for microbial quality of vegetable and water samples demonstrated that, vegetable samples had higher microbial loads for TVC, TCC and TFC than water samples.

4.3 Contamination level within site as demonstrated by TVC, TCC and TFC

The table below indicates the mean, standard deviation and p-value for irrigated water and vegetables in Kibaha Township. Drainage had high faecal contamination compared to other sites.

Table 2: Mean values for TVC, TCC, and TFC (log $_{10}$ CFU/ g or ml) in irrigation water and vegetables grown in Kibaha Township (n=5)

Sources of Irrigation water	Sample types	Unit	Microbial population (mean log $_{10}$ CFU/ g or ml)		
			TVC	TCC	TFC
River	Water	Ml	6.79 ±1.73^{a}	5.97±1.41^{a}	5.28±1.59^{a}
	Amaranthus spp	G	7.01±1.47^{a}	5.98±1.26^{a}	4.59±2.64^{a}
	Potato leaves	G	6.42±1.37^{a}	5.43±1.11^{a}	3.74±2.52^{a}
	Spinach	G	7.22±0.45^{a}	6.26± 0.05^{a}	5.44±0.66^{a}
	P-Value(river)		**0.811**	**0.688**	**0.543**
Drainage	Water	Ml	6.06±1.19^{b}	5.27±1.98^{b}	5.28±1.59^{a}
	Amaranthus spp	G	7.35 ± 0.10^{a}	6.62±0.62^{ab}	5.86±0.64^{a}
	Potato leaves	G	6.99±0.89^{ab}	5.70±0.79^{ab}	5.10±1.30^{a}
	Spinach	G	7.34±0.06^{a}	7.08±0.24^{a}	5.18±0.71^{a}
	P-Value(drain)		**0.047**	**0.079**	**0.717**
Shallow Wells	Water	Ml	4.88±1.11^{b}	4.25±1.08^{ab}	3.55±1.37^{a}
	Amaranthus spp	G	7.15±1.09^{ab}	6.43±1.04^{a}	5.92±1.31^{a}
	Potato leaves	G	7.40±1.87^{a}	6.33±1.70^{ab}	5.94±2.28^{a}
	Spinach	G	6.38±2.41^{ab}	3.78±3.11^{b}	3.27±3.37^{a}
	P-Value(wells)		**0.129**	**0.091**	**0.139**
Tape	Water	Ml	5.26±0.04^{bc}	4.12±0.12^{b}	3.95±0.14^{b}
	Amaranthus spp	G	5.60±.52^{ab}	4.31±0.53^{b}	4.14±0.57^{b}
	Potato leaves	G	5.96±0.39^{a}	5.01±0.43^{a}	4.74±0.60^{a}
	Spinach	G	5.17±0.11^{c}	4.07±0.07^{b}	3.91±0.09^{b}
	P-Value(tape)		**0.006**	**0.002**	**0.024**

^{abc} Means with the same superscripts are not significant different (P>0.05). Duncan's Multiple Range Test was used to compare different of mean between types of samples for each category over source of irrigation water.

4. 4 Water contamination levels by samples type as demonstrated by TVC, TCC and TFC

Table 3 showed that in different sites mean values of TFC contamination level for water, *Amaranthus spp*, sweet potato leaves and spinach samples are not significant difference (P>0.05).

Table 3: Mean values for TVC, TCC, and TFC (log $_{10}$ CFU/ g or ml) in irrigation water and vegetables grown in Kibaha Township (n=5)

Sample types	Sources of Irrigation water	Unit	Microbial population (mean log $_{10}$ CFU/ g or ml)		
			TVC	**TCC**	**TFC**
Water	River	Ml	6.79 ± 1.73^{a}	5.97 ± 1.41^{a}	5.28 ± 1.59^{a}
	Drainage	Ml	6.06 ± 1.19^{ab}	5.27 ± 1.98^{ab}	5.28 ± 1.59^{a}
	Shallow wells	Ml	4.88 ± 1.11^{b}	4.25 ± 1.08^{ab}	3.55 ± 1.37^{a}
	Tape water	Ml	5.26 ± 0.04^{ab}	4.12 ± 0.12^{b}	3.95 ± 0.14^{a}
	P-value		**0.092**	**0.132**	**0.114**
Amaranthus	River	G	7.01 ± 1.47^{a}	5.98 ± 1.26^{a}	4.59 ± 2.64^{a}
	Drainage	G	7.35 ± 0.10^{a}	6.62 ± 0.62^{a}	5.86 ± 0.65^{a}
	Shallow wells	G	7.15 ± 1.09^{a}	6.43 ± 1.04^{a}	5.92 ± 1.31^{a}
	Tape water	G	5.62 ± 0.52^{b}	4.31 ± 0.53^{b}	4.14 ± 0.57^{a}
	P-value		**0.043**	**0.004**	**0.206**
Potato leaves	River	G	6.42 ± 1.37^{a}	5.42 ± 1.11^{a}	3.73 ± 2.52^{a}
	Drainage	G	6.99 ± 0.89^{a}	5.69 ± 0.79^{a}	5.10 ± 1.30^{a}
	Shallow wells	G	7.40 ± 1.87^{a}	6.33 ± 1.70^{a}	5.94 ± 2.28^{a}
	Tape water	G	5.96 ± 0.39^{a}	5.01 ± 0.43^{a}	4.74 ± 0.60^{a}
	P-value		**0.322**	**0.326**	**0.334**
Spinach	River	G	7.22 ± 0.45^{a}	6.25 ± 0.05^{a}	5.44 ± 0.66^{a}
	Drainage	G	7.34 ± 0.06^{a}	7.08 ± 0.42^{a}	5.18 ± 0.57^{a}
	Shallow wells	G	6.38 ± 2.41^{ab}	5.01 ± 0.43^{b}	4.74 ± 0.60^{a}
	Tape water	G	5.17 ± 0.11^{b}	4.07 ± 0.07^{b}	3.91 ± 0.09^{a}
	P-value		**0.047**	**0.010**	**0.201**

^{ab} Means with the same superscripts are not significant different (P>0.05). Duncan's Multiple Range Test was used to compare means of different sources of irrigation water for each sample type.

4.5 Comparison for TVC, TCC and TFC levels in vegetables and water samples

Based on findings from this study *Amaranthus spp*, were highly contaminated followed by potato leaves, spinach then water samples as determined by TVC, TCC and TFC levels (Table 4).

Table 4: Mean values for TVC, TCC and TFC (log $_{10}$ CFU/ g or ml) in all vegetable and water samples from River, Drainage, Wells and Tapes (n=20)

Samples	Microbial population (mean log $_{10}$ CFU/ g or ml)		
	TVC	TCC	TFC
Water	5.75±1.02	4.90±1.15	4.51±1.17
Amaranthus	6.78±0.80	5.81±0.86	5.13±1.29
Potato leaves	6.69±1.13	5.61±0.98	4.88±1.68
Spinach	6.53±0.76	5.30±0.92	4.45±1.21
P-Value	**0.053**	**0.236**	**0.560**

CHAPTER FIVE

5.0 DISCUSSION

5.1. Practices contributing to health risk associated with vegetables consumption in Kibaha Township

5.1.1 Consumers and farmers awareness

Vegetable farming in Kibaha Township is an intensive activity throughout the year. This is due to the fact that is one of the main sources of income to farmers. The common vegetables grown are *Amaranthus spp*, sweet potato leaves and spinach. Based on findings from this study challenges to farmers and consumers of vegetables were the availability and good quality of water for agricultural practice. The common water sources used by farmers for irrigation are river, wells, drainage and tape water. Due to unreliable water supply farmers are forced to use contaminated water for irrigation and domestic purposes that subject farmers and consumers to food borne diseases.

In this study a survey was done to 30 consumers and 30 farmers to assess the awareness and perception to quality of water used for irrigation and vegetables grown in Kibaha Township through structured questionnaire. About 87% (n=30) and 57% (n=30) of farmers and consumers respectively perceive the water used for irrigation was safe and of good quality. About 47% of farmers used irrigation water for domestic purposes, as well as 63.3% (n=30) farmers were washing their vegetables with water available in the farm before sending to the market. All consumers interviewed consumed vegetables whose sources were open markets and street vendors. During preparation consumers wash vegetables with water and boil or fry, 53.3% of them boil vegetables for five minutes before eating. On the other hand numbers of illnesses were reported by consumers and farmers in the study group. Out of the 30 consumers interviewed 76.7% reported illness of at least once, twice or three times per month. The major food borne diseases reported by consumers were helminthiosis (worms), fungus, stomach fever, dysentery, amoebiasis and typhoid.

. These findings agree with what was previously reported in other studies. Poor quality water used for irrigation and eating contaminated vegetable were a threat to consumer's health. Food borne diseases are a persistent challenge and of great concern to health world-wide (Saria *et al.*, 2011). About 60% (n=30) of consumers mentioned wells, streams, ponds, sewerages, tape, river and run-off (rain) water as the common water sources used by farmers for vegetables irrigations. The common irrigation system used was overhead irrigation, where farmers use buckets 84% (n=30), watering canes 14% (n=30) and the rest used watering tubes or water pumps to irrigate vegetables once or twice per day. The human pathogens most often are transmitted by eating vegetables which cause infection and illness through faecal-oral route (Havelaar *et al.*, 2001, FAO/WHO, 2008).

An adequate training of farmers may lead to a positive impact towards reduction of microbial contamination. Awareness among consumers about the need of disinfection of vegetables eaten raw is essential. Bacterial and viral contaminants of fresh produce that are associated with outbreak of food borne illness include Salmonella, *E. coli* 0157, *Listeroa monocytogenes* and *Camplobacter jejuni* and viruses including Norovirus and Hepatitis A. Thorough cooking of produce have the potential to destroy all of these pathogens. To achieve this killing of bacteria by cooking require temperature up to 70°C and viruses at 80-90°C for few minutes (Monaghan and Hutchison, 2010).

Measures to minimize routes of faecal contamination in the production of vegetables even those that will be cooked are needed, since these can be a source of cross-contamination at home. There is a potential for cross-contamination and transfer of pathogens from fresh leafy vegetables to cooked and Ready-to-eat foods (RTE). Washing is not effective at removing pathogen contamination from the surface of produce (Wachtel *et al.*, 2003, Monaghan and Hutchison, 2010). In another study, food sellers washed vegetables with tape water and used disinfectants such as lemon, household bleach and vinegar sparingly during the preparation. These processes were therefore considered useful in reducing the microbial load. A 1 $\log_{10}$ reduction of pathogens can be achieved through washing with water an addition 2 $\log_{10}$ reduction of pathogen can be also achievable when a mild disinfectant is used. It can therefore assumed that, the combined effect of washing and disinfection during vegetable preparation may lead to a 3 $\log_{10}$ reduction of pathogens (WHO, 2006, Amoah., *et al* ., 2007).

Large surface area increases the chance of contamination of vegetables with micro-organisms present in water. Leafy vegetables with large surface area, such as spinach and *amaranthus spp* or those where the surface structure allows pathogens to adhere easily are at a greater risk of contamination from water. The risk can be further increased when the contact with contaminated water takes place near harvest time or during post- harvest handling (Mushobozi, 2010). In the study area, farmers do not cease irrigation before harvest as they want their vegetables to look fresh at the point of market. The closer to harvest irrigation increases the chance for survival of pathogens on produce. Where water quality is unknown or cannot be controlled, farmers should be advised to consider irrigation practices that minimize contacts between water and the edible portion of the crop. The likelihood of the eatable parts of a crop becoming contaminated during irrigation depends on a number of factors including growing location, type of irrigation applied and nature of the produce surface (Gerba and Choi, 2006).

Hazards associated with irrigation practices are influenced by water source, quality and amount of water applied on the produce. Buckets and watering cans are used to apply water directly to the crop, thereby increasing possibility of crop contamination (Fig 13).

Figure 13: Overhead irrigation system

Therefore preventing water pollution and creating awareness through education are practical ways that would reduce waste water-related negative impacts. Other suggestion is to stop farmers to use polluted water, establish self-assessment and risk control procedures. Hazards which threaten food safety should be identified in order to introduce control measures to avoid, reduce or eliminate contamination based on the Hazard Analysis Critical Control Point (HACCP) methods (Keraita *et al.*, 2003, Mushobozi, 2010)

Tanzania Food and Drug Authority (TFDA) recognize that food safety is an essential component of sustainable development as it contributes to the promotion of public health, adequate livelihood reduction of poverty through human productivity and reduce medical cost. Training of producers on good agriculture practice at every level of production chain and education of consumers is a key element in reducing hazards associated with fresh vegetables. Risk to farmers and consumers mainly depend upon the irrigation methods, quality of water, type of product consumed, and the degree of contact of wastewater with the product.

Food borne related diseases may be the source of high morbidity and mortality rate in Kibaha and other towns in Tanzania. The possibility for morbidity and mortality rate to increase is due to the fact that vegetables and water used in different human activities in the towns are faecal contaminated (Saria *et al.*, 2011).

5.1.2 Sources of irrigation water in Kibaha Township

Mkuza River, located in Mkuza ward, is one of sources of irrigation water in Kibaha Township. Mkuza is a temporary river, which depends much on surface water collected from run-off during rain seasons. Along this river, there are various activities including irrigation, cars washing, brick making and other domestic uses. During the dry season there is shortage of water and famers use small ponds located within the river for irrigation.

Figure 14: Vegetable grown at Picha ya ndege Street along Morogoro road

Urban waste water that runs off into streams influences water quality. Mkuza River water visibly dirty, turbid with allot of snails and there was a dump near the river. People living along and consumers of vegetables grown along this river have high health risk. There was a possibility of vegetables being contaminated with dusts and vehicles exhaust fumes and smock. Due to presence of risk factors, diseases like bilharzias, helminthiosis, stomach fever, typhoid, cholera and amoebiasis are likely to attack those people living along Mkuza River (Brown *et al.*, 1992, FAO/WHO, 2008).

Figure 15: Solid waste dump near vegetables garden in Picha ya ndege Street

There is possibility for pathogens to live in the soil and contaminate vegetables by wind dust or transferred to water sources during rainy season. The potential for survival of Salmonella in dust is 26 months and the survival of *E. coli* is recorded to be 10 months. Human pathogen may travel by water over a long distance and wind dust up to 1000 km (Davies *et al.*, 1996, Varma *et al.*, 2003, Baertsch *et al.*, 2007).

Figure 16: Mkuza River from which vegetables growth and car washing activities were taking place, these were machines used for cars washing

Drainage water from Kibaha Education Centre (KEC) in Tumbi ward was also among main sources of water for irrigation. Waste water and sewages are collection from KEC (Tumbi Hospital, Kibaha Secondary School, Clinical Officers Training College (COTC), Focal Development College (FDC), Sugar Research Station (SRS), Workers and Staff Houses). Wastewater is collected into three stabilization ponds and finally accumulated in a big pond owned by Sugar research station from which research activities, vegetable irrigations, rice farming and fishing take place. Farmers collected water from the outlet (stream) for irrigation purposes.

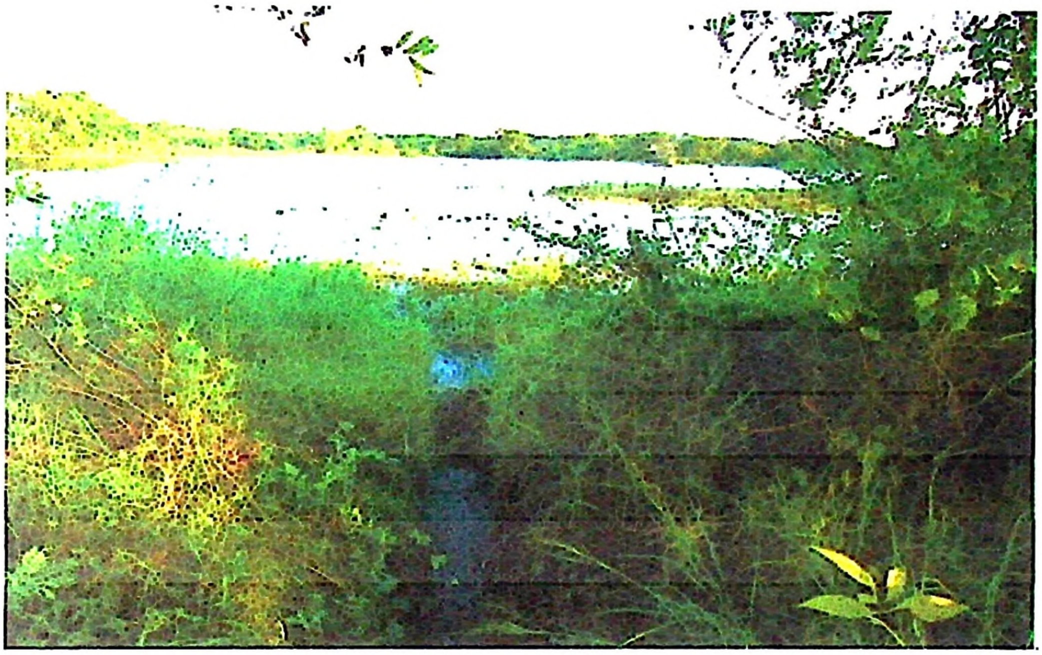

Figure 17: Sugar Research pond in KEC with a stream from which farmers collect water for vegetables irrigation

Figure 18: Vegetables and rice grown at KEC using wastewater from Sugar research pond

The use of this wastewater for vegetables production exposes consumers as well as farmers to various health risks. Unplanned use of land that received wastewater is high, pathogenic viruses, bacteria, protozoa and helminthus present in wastewater pose health problem to Kibaha Township community. Indirect use of wastewater was prevalent in several developing countries that lead to pathogenic risk to agricultural farmers, worker, and consumers of irrigated produce.

Figure 19: Sugar research pond offers fishing activities apart from vegetable irrigation

Shallow wells were also scattered within Mailimoja ward and most of them were hand-dig and found near residential areas. The main source of water was ground water but this water was interfered by surface water and activities going on within the surrounding areas, such as cars washing, garage and other community activities which make water to look dirty with snails and algae covered the surface. Farmers used dirty water for vegetables irrigation and therefore increasing health risk to farmers and consumers of vegetables. A rising water table and low-lying areas may also act as carrier of potential pathogens and contribute to microbial contamination in leafy vegetables (FAO/WHO, 2008).

Figure 20: Vegetables production using shallow well at Mkoani Street

The main source of tape water was Ruvu River along the Mlandizi Township. Various activities were going on along this river including irrigation farming, livestock grazing, domestic purposes and fishing. Water from Ruvu station is collected in tanks before being distributed to residents for domestic purpose. Distance travelled, age of pipes and extent of internal deposition in mains and conduits are the key factors for water contamination. Domestic, wild animals and human activities can present a risk both from direct contamination of the crop and soil as well as from contamination of surface water sources and other inputs. Tubes used for irrigation may influence contamination of vegetables as well.

Figure 21: Vegetables production at Mwanalugali Street using tape water

In Kibaha, the leakage in transmission or distribution system of water contributes to infiltration of sediments and contaminant into pipe water. This problem becomes severe when sewage and pipe water system interfere with each other. Determination of analytical test should be done to evaluate the assimilability of water for each intended use after consulting the water safety authorities (Napacho *et al.*, 2010).

5.2 Total Viable Count

After community and water sources survey in Kibaha Township, vegetables and water samples from river, drainage, wells and tape water irrigation sources were collected and analysed in the laboratory to assess the microbial quality. Most of the vegetable samples collected were highly contaminated by total viable count (TVC).

The mean values for vegetable samples irrigated by Mkuza River and those irrigated by shallow wells did not show a significant different ($P>0.05$). The mean of vegetable samples collected from drainage and tape water sites are significant different at ($P<0.05$) (Table 2). It has been reported that, generally fresh vegetables should not have a total viable count (TVC) exceeding 6.69 $\log_{10}$CFU/ g^{-1} (Ngunyen-the and Carlin, 1994). Food containing less than 4.4, 4.4 - 6.69, 6.69 -7.69 and greater than 7.69 $\log_{10}$CFUg-1TVC are rated good, average, poor and spoiled food respectively (Aycicek *et al.*, 2006). Based on these criteria findings from the present study indicate that 50% of vegetable samples analysed could be regarded as of poor quality (Table 2 and 3).

Several factors may influence the level and variation of contamination in most of the analysed vegetables. Among these are the uses of polluted irrigation water, sanitation of the growing environment, time interval from irrigation to harvest, the structure and size of the leaf surface and the irrigation system. Farmers use buckets for irrigation which apply water directly to leaf surface, this encourage the adherence of pathogens on leaves.

The result in Table 2 showed that, the mean value of TVC for water samples and sweet potato leaves samples collected from different sites are difference insignificantly ($P>0.05$). The difference were also noted in *Amaranthus spp* and spinach (Table 3). Therefore reducing the total count is a priority to ease the economic impact of such contamination.

However, it is also important to note that in Kibaha Township farm vegetables contamination also cause by irrigation using pipe water. The quality of ground water on other hand is relatively uniform throughout an aquifer. Changes in quality occur slowly due to the fact that it is not exposed to the air and is not subject to direct pollution and contamination from run-off as surface water. Due to natural filtering action of the aquifer, the ground water is relatively free from microbes than surface water. Quality of surface water (river and streams/drainages) is dynamic and can change within the catchments area (Amoah., *et al*., 2007, Napacho, 2010).

Figure 22: Mkuza River where cars washing and bricks making were also taking place

5.3 Total coliform count

During analysis total coliform counts (TCC) were also investigated. Their presence indicates that pathogens might be present due to faecal contamination by human, indicated that the level of coliform were high in all samples. The TCC mean value on sweet potato leaves irrigated by different water sources ranged from 5.01 to 6.33 log_{10} $CFUg^{-1}$ which was not significant different ($P>0.05$). The differences were observed in *Amaranthus spp*, spinach (Table 3). Also the difference for TCC in water samples collected from different sources was not significant ($P>0.05$). When observing sites, results indicated that only tape water samples showed statistical significant difference ($P<0.05$).

River, drainage and wells samples had mean level for TCC that did not differ significantly ($P>0.05$) between sources (Table 2). Some related findings were reported by Halablab *et al.*, (2011), where coliform counts of vegetable samples ranged from 2.0 to 10.71$log_{10}CFUg^{-1}$. Moreover, Vishwanathan and Kaur (2001) reported coliform counts that ranged from 6.0 to 9.0 log_{10} $CFUg^{-1}$. In Taiwan study reported the contamination level of coliform in vegetables was reported to range from 2.3 to 7.55log_{10} $CFUg^{-1}$ (Fang *et al.*, 2003). In Zambia as study a range of total coliform counts on vegetable products were between 2.2 and 5.9$log_{10}CFUg^{-1}$ (Nguz *et al.*, 2005).Total coliform count on vegetable samples were also reported in the range of 3.0 to 6.9 log_{10} $CFUg^{-1}$ Aycicek *et al.*, (2006).

The high incidence of coliform in spinach, *Amaranthus spp* and sweet potato leaves may be due to the size of the leaves. Vegetables with large surface area have a higher risk of being contaminated. Structure of the leaf surface and the nature of the leaf surface may also influence the adherence of microbes on the surface (Amoah., *et al*., 2005, Gerba and Choi, 2006). Irrigation system and time interval from a day of manure application to harvesting may influence risk of pathogen to leaf vegetables (Amoah., *et al*., 2006, FAO/WHO, 2008).

Figure 23: Vegetable garden in which there was manure bags kept in the farm

5.4 Total Faecal Coliform

The availability of faecal coliform in food and the prevailing diseases like typhoid, amoebiasis and cholera indicate that the food or water used by that community were contaminated by faeces from human or animal origin. During the study vegetable consumers and farmers were complaining about high prevalence of typhoid and amoebiasis illnesses. The results from the current study indicated that all vegetable and water samples were contaminated by faecal coliform. There was no significant difference in mean contamination level (P>0.05) for samples collected from river, drainage and shallow wells (Table 2 and 3). The difference was observed between samples collected from tape water (Table 2). Contamination levels for TFC in water sample and vegetable samples showed statistically no significant different (P>0.05). for *Amaranthus spp,* sweet potato leaves and spinach (Table 3).

Samples irrigated using tape water were less contaminated compared to other sites but still higher number of pathogens than the International Commission on Microbiological Specification for Food (ICMSF) that recommend levels of 1×10^3 in100ml (Amoah *et al.*, 2006, Amoah *et al.*, 2007). Lower levels of faecal coliform populations were recorded in vegetable samples from shallow well and tape water than drainage and river. This could be due to the nature of the water sources. Shallow well water was from ground water which is better in quality than urban drainage water and river (Keraita *et al.*, 2002, Amoah *et al.*, 2007).

Among the three vegetables from all sites, *Amaranthus spp* had the highest level of TFC (Table 4), which could be due to the time range from planting to harvest. *Amaranthus spp* leaves are harvested three weeks after planting. A sufficient time interval between applying manure and harvesting the leafy vegetables can result in a sufficient decline of pathogen (James et al., 2010, FAO/WHO, 2008). About 90 days before harvesting an edible product that is not contact with the soil and to at least 120 days before harvesting an edible product that does come into contact with the soil (USDA, 2008). All water samples had contamination level that exceeded WHO (1989) recommended level of 1000 faecal per 100ml.

Figure 24: One of the irrigation water source along Mkuza River

The microbial quality of irrigation water from different sites selected in Kibaha Township supported the earlier reports of the usage of poor quality irrigation water for urban vegetables production in Tanzania cities (Napacho *et al* ., 2010).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Pollution is a major problem in urban areas of Tanzania and improper solid and liquid waste disposal are the major contributors to urban area pollution. The leakage in transmission or distribution system of the main pipe that supply water to residents of Kibaha and Dar es Salam and poor infrastructure for water supply can contribute to infiltration of sediments and contaminant into pipe water. Sometimes water with suspended soil particles are observed to flow from tape especially during rain seasons. This problem becomes severe when sewage and pipe water system interfere each other. Use of wastewater for irrigation and domestic purposes is associated with risks and negative impacts to users. Distance travelled, age of pipes and extent of internal deposition in mains and conduits are the key factor contributing towards water contamination.

Vegetables may be contaminated with pathogenic microorganisms during production in the field. Food borne diseases remain as an importance public health threat and one of the most importance food safety hazards associated with raw vegetable in Kibaha as well as in the World. The large number of total microorganisms and faecal contamination indicators detected in vegetables surveyed indicate potential health hazards to consumers of vegetables in Kibaha Township. In many countries wastewater used for irrigation of vegetables is based on the value of its contact. The major cause for contamination of vegetables is irrigation with wastewater. Sewage water is an alternative water source in arid and semi-arid areas where water is scarce. Pathogens transported from wastewater may survive in the soil and crops which will in turn be transported to consumers and cause numerous diseases. A range of microbiological hazards can be transmitted to humans through contact with or the ingestion of contaminated water. Excreta-related bacterial species e.g *E. coli* 0157:H7 and salmonella, intestinal helminths e.g. *Ascaris lumblicolders*, amoebae e.g. *Entamoeba coli* and protozoa e.g. *Giandia intestinalis* are associated with outbreaks of diseases in different parts of the world (WHO, 2006). Proper waste disposal and good management of water supply system should be considered by the authority to minimize the health risk to community.

6.2 Recommendations

Risk assessment should be conducted prior to farm establishment and planting. Protection of surface water and ground water resources from pollution (wildlife, waste from animal production, agricultural run-off, human activity, sewage and industrial effluent) is essential for production of safe leafy vegetables.

Routine and regular schedule for food safety awareness creation is required for all persons involved in leafy vegetables from farm to plate. Training and education of growers and handlers along the entire food chain continuum should be considered as a primary preventative control measures or risk mitigation strategy.

There is a need to create awareness among all workers associated with fresh produce production. This increased awareness is also required for consumers. The overall goal of education should be to encourage increased adoption of effective food safety behaviours. High-risk food safety practices and behaviour need to be targeted in education interventions.

Food safety programmes for leafy vegetables should pay special attention to controlling, reducing and eliminating potential faecal contamination from people and animals through the most likely conduits that is hands, water, manures and soil. Social and community support networks are important for sustainable action especial in rural communities of developing countries (WHO, 2007).

Training and education priority should focus farmers, field workers, consumers and should consider literacy and education levels. When growing fields have been contaminated or damaged, assessment should be carried out to establish measures to reduce the risk of pathogen (e.g. delayed harvesting, heat treatment) or to assure disposal (FAO/WHO, 2005).

Sociological and behavioural research is needed to inform pertinent and effective food safety messages that will result in behaviour changes. Consumer education is to raise awareness about microbial hazards and safety of leafy vegetables without causing alarm or damaging consumers confidences in nutritious foods. Leafy vegetables should be considered the highest priority in terms of fresh produce safety from global perspective. Each stage of waste handling needs to be considered to minimize chances of contamination. Farmers should take a hazard analysis control approach and be aware of the hazards for their crops. Food safety programme should be induced, from which studies will be conducted to get permanent solutions of public health risk to the community of Kibaha Township.

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APPENDICES

Appendix 1: Questionnaire for farmers

Tittle: Assessment of microbiological quality of irrigation water and vegetables grown in Kibaha Town Council

Introduction

Date of Interview ……………………………………………………………..

Questionnaire No……………………………………………………………

Village………………………………………………………………………

Wards………………………………………………………………………..

Division………………………………………………………………………..

Name of Interviewer………………………………………………………..

Name of interviewee…………………………………………………….

A. Individual Characteristics

1. Sex. 1. Male. 2. Female

2. What is your age?

i. 18- 30 years

ii. 31- 40 years

iii. 40- 60 years

iv .Above 60 years

3. What is your level of Education?

i. Non formal Education

ii. Primary Education

iii. Secondary Education

iv. Other (Specify)……………………….

4. How long have you been doing this work?

i. 0 - 4 years

ii. 5- 10 years

iii. 11- 20 years

B. General information on risk factor associated with use of contaminated water for irrigation

1. What are sources of water you are using for vegetables irrigation?
   i. Rivers
   ii. Shallow wells
   iii. Streams
   iv. Drainage system
   v. Pipe water
   vi. Others specify...
2. What other activities used with the water?
   a. Drinking
   b. Bathing
   c. domestic purposes
   d. Others specify...
3. What are means of irrigation you are using?
   a. watering cans
   b. buckets
   c. tubes
   d. watering channels
   e. others specify...
4. How many times per day you irrigate vegetables?
   a. Once per day
   b. Twice per day
   c. Triple per day
5. What are types of vegetables your are growing?
   a. Spinaches
   b. Cabbages
   c. Amaranthus
   d. Carrots
   e. Green paper
   f. Potato leaves
   g. Legume leaves

h. Others specify..

6. What is the proper time for vegetables growth?

a. At rain season

b. At dry season

7. What is the purpose of vegetables growth?

a. For sale

b. For food

c. Others specify..

C. Awareness about quality of water and vegetables safety.

1. Are the water safe for use? Yes, No, Not sure

2. If No, which means you use to make them safe before use?

a. Disinfecting

b. filtering

c. Others specify...

3. How long is it take to start to harvest your vegetables?

a. Less than one month

b. More than one month

4. Do you wash your vegetables after harvest? Yes/No

5. If Yes, do you use irrigation water? Yes/No

6. What problems you face?

1........................., 2......................., 3............................., 4.................................

7. What other activities you do? ....

8. Is there any health problem you get, which you thing related to this work? Yes/No

9.If yes, mention...

10. Are you attending medical check-up? Yes/No

11. How many times per month?

a. Once

b .More than once

12. What are your opinions about your work and problems facing?

....

....

Appendix 2: Questionnaires for consumers

Introduction

Date of Interview ....

Questionnaire No...

Village...

Wards...

Division..

Name of Interviewer...

Name of interviewee...

A. Individual Characteristics

1. Sex. 1. Male. 2. Female

2. What is your age?

   i. 18- 30 years

   ii. 31- 40 years

   iii. 40- 60 years

   iv .Above 60 years

3. What is your level of Education?

   i. No formal Education

   ii. Primary Education

   iii. Secondary Education

   iv. Other (Specify)...........................

B. General information on risk factors associated with consuming unsafe vegetables.

1. Are you eating vegetables in your household? Yes/No

2. If yes, what types of vegetables are common in your home?

   1..................., 2..............................., 3.......................... 4..................................

3. Where are you getting the vegetables?

   a. At the market

   b. To the vendors roaming along the street

c. To the nearby farmers.

d. Others (specify)..

4. Why are you eating vegetables?

a. Cheap and easy to get

b. For body health

c. Others (Specify)..

5. Do you thing vegetables are safe for eat? Yes/No

If No, give reason...

6. Are you aware with source of water used for vegetables irrigation? Yes/No

7. If yes mention the place where vegetables are grown and water source used

(1) ....

(2)..

(3)..

8. Do you think the water are safe? Yes/No

9. If No, give reasons..

10. What are challenges you face as a vegetable consumers?

a. Seasonal crop

b. Unsafe

c. High cost

d. Others (Specify)..

11. Do you think there are health problems related to vegetables consumption? Yes/No

12. If yes, mention..

13. Do you get those problems in your household? Yes/No

14. If yes what do you do?

a. Go to hospitals

b. Buy medicine from pharmacy

c. Taking natural herbs

d. Others (specify)..

15. How many times per month do people in your household attend the hospital?

a. Once per month

b. Twice per month

c. More than twice per month

16. As a vegetable consumer what do you suggest about availability and quality of vegetables and water in general..

THANK YOU