ENVIRONMENTAL ASSESSMENT OF THE KASSENA-NANKANA IRRIGATION SCHEME VIS A VIS MICROBIAL CONTAMINATION OF TOMATOES PRODUCED FROM IRRIGATED FARMS IN THE KASSENA-NANKANA EAST MUNICIPALITY

BY

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DECLARATION

I testify that this research work was carried out entirely by me in the Environmental Science Programme, Faculty of Science, University of Ghana. This thesis has never been presented, either in parts or in whole, for the award of a degree in this university or any other institution. All cited work and assistance have been fully acknowledged.

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DEDICATION

I dedicate this thesis to the Lord God, who it is, that has enabled me to accomplish this task. I dedicate it also to my family most especially to my late father Mr. Abdulai Nyorka

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ABSTRACT

This aim of the study was to conduct an environmental assessment of three irrigation systems in the Kassena-Nankanna East Municipality and determine microbiological quality of tomato crops grown on farms irrigated from study schemes and water used for irrigation. A structured questionnaire and direct observation was used to gather background information from a total of 120 farmers from the study area in order to identify environmental conditions that may be contributing to the contamination of the irrigation water source and tomatoes. A total of 192 samples (96 samples each of water and tomatoes) from the three study sites were collected. Standard methods (Hach Company) were used for the determination of physico-chemical parameters of water samples. The bacteria load/burden (heterotrophic bacteria and coliform count) were determined by the pour plate method whiles identification of specific pathogens was done using biochemical assay. The study showed that organic fertilizer (poultry manure and cow dung) and pesticides are used by farmers for the cultivation of tomatoes in the study area. High illiteracy rate, lack of training in irrigation, open defecation among the inhabitants, free range system of animal husbandry and poor agronomic practices in the study area were factors for contamination of the irrigation water and tomatoes in the study area.

The measured values of pH for canal water samples ranged from 6.70 - 7.9, while that of the Dam and river water samples ranged from 6.50 - 7.0 and 6.5 - 7.3 respectively. Temperature of the water samples ranges from 26.5^{0}C – 29^{0}C for canal, 26.7^{0}C - 27.9^{0}C and 27.13^{0}C - 27.7 ^{0}C for river water. The mean nitrate levels in the dam water sources were highest with a mean value of (23.35mg/l) and a ranged from 21mg/l - 24.9mg/l. The mean value of nitrate levels in the river water source was 11.77 mg/l with a range of 9.4mg/l-14.3mg/l. Canal water had the least mean nitrate level of 1.62mg/l and a

range of 1.10mg/l - 2.8mg/l. The mean fecal coliform count in water samples from Yigwania (River) was highest (1.28 x 10^7cfu/100ml) followed by water samples from Doba (dam) 6.14 x 10^6cfu/100ml whilst samples from canal were having the least mean faecal coliform levels (3.3 x 10^5cfu/100ml). The mean faecal coliform count (cfu/100ml) in irrigation water sampled from the study area was higher than the world health organization (WHO, 2006) recommended level (1 x 10^3 cfu/100 ml) for unrestricted irrigation of crops. The highest mean fecal coliform count in external tomatoes parts was in samples from Yigwania (4.48 x 10^5cfu/g) followed by samples from Doba (3.535 x 10^5cfu/g). Samples from Bonia (canal irrigation) had the least mean fecal coliform count (2.91 x 10^3cfu/g). Tomatoes samples from the study area were faecally contaminated with mean faecal coliform levels exceeding the international commission on microbiological specifications for foods (ICSMF, 1974) recommended level of 10^3 fecal coliform per gram fresh weight.

The dominant bacterial species isolated from the water and tomato samples were *Klebsiella pneumonia*, *Staphylococcus aureus*, *Xantomnas maltophilia*, *Escherichia coli* and *Pseudomonas aeruginosa.*

Contaminated irrigation water and insanitary practices in and around irrigation schemes in the Kassena-Nankana East is a major source of microbial contamination of tomatoes with pathogenic bacteria. Public health authorities and other regulatory agencies should intensify their efforts in educating farmers on proper agronomic and sanitation practices as well as monitoring the conditions of sanitation and hygiene round these farms.

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LIST OF ABREVIATIONS

API -	Analytical Profile Index
BOD -	Biochemical Oxygen Demand
CDC-	Centre for Disease Control
CFU -	Colony Forming Unit
DO-	Dissolved oxygen
EPA-	Environmental Protection Agency FDA -Food and Drugs Authority
EC-	Electrical conductivity
FDA -	Food and Drugs Administration
FAO -	Food and Agricultural Organization
GIDA-	Ghana Irrigation Development Authority
GSS-	Ghana Statistical Service
ICSMF -	International Commission on Microbiological Specifications for Food
ICOUR-	Irrigation Company of Upper Region
IWMI -	International Water Management Institute
K.N.E.M-	Kassena-Nankana East Municipality
PCA-	Plate count agar
NPK-	Nitrogen, phosphorus and potassium
TDS-	Total dissolved solid
TSS-	Total suspended solid
TWN-	Third World Network
UNICEF-	United Nations International Children Fund
UNESCO-	United Nations Educational, Scientific and Cultural Organization
UK-	United Kingdom
US-EPA -	United States Environmental Protection Agency
WHO -	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Irrigation plays an essential role in agricultural productivity by providing favourable conditions particularly for dry season farming through the artificial supply of water to crops. It has the capability to control water supply to crops and provides drainage facilities for the disposal of excess water, which is impossible with rain-fed agriculture (Mutsvangwa *et al.*, 2006; Snyder, 2005).

Increased crop cultivation in recent years has resulted in increased diversion of freshwater, with 70% of water now being used for irrigation in the world and reaching as high as 87% in in some parts of Africa (FAO, 2005). About 17% of the world's cropland is irrigated to produce one third of the world's food supply (FAO, 2011). Moreover, about 90 % of vegetables consumed in the cities are grown within and this provides a major source of income for many urban households (Drechsel *et al.*, 2006). In Ghana, irrigated agriculture has become common in peri-urban communities and about 66% of fresh water is drawn for irrigation (WHO, 2005).

In Northern Ghana, climate change has led to significant reduction of rainfall with an annual average of 859.9mm (Rahaman *et al.*, 2002). The total mean value of rainfall for 2001 rainy season was 859.9 mm which was much lower compared to the 1033 mm mean value for 1961 - 1990 (Friesen, 2002; Rahman *et al.*, 2002). Farmers in the North therefore depend heavily on rivers, streams, dams, canals and wells to supplement inadequate rainfall in order to provide enough water to agricultural crops (Rahman *et al*., 2002).

Although irrigated agriculture is beneficial in its contribution to food production and livelihood improvement in the world, many studies have associated irrigated food crops to food borne diseases outbreaks due to the use of contaminated water for irrigation (Amoah, 2008; Hamilton *et al*., 2006; Abdul-Ghaniyu *et al*., 2002).

Various studies conducted over the last decade in Ghana on water used for irrigating farms revealed the presence of various bacteria and chemical pollutant (Monney *et al.,* 2013; Obuobie *et al*., 2006; Amoah *et al*. 2005; EPA, 2002). Ghana's environmental protection agency (EPA) which is one of the water resources regulatory body in the country carried out water quality analysis on surface water between 1999 and 2001 and reported that the quality of most of surface water bodies had been compromised by various forms of bio-pysico-chemical pollutants such as pathogenic bacteria, nitrates, phosphates and sulphates (EPA, 2002). Amoah *et al.,* (2006) also found irrigation water from urban farming sites in Accra and Kumasi to be contaminated with faecal coliform up to10^7/cfu/ ml.

Various agricultural practices have been associated with irrigation water contamination. Practices such as the use of animal waste for manure, pesticide application and open defecation contaminate food crops directly or indirectly through the contamination of irrigation water. Such practices have also been recognized as the leading cause of pre-harvest and post-harvest contamination of food produce (Duffy *et al.,* 2005).

There is evidence that irrigation of food crops with contaminated water accounts for at least 4% of the food borne disease burden in low-income countries and more than 90% of food borne illness is caused by biological pathogens (Blumenthal *et al.,* 2000; Jones, 2010; McDermott & Delia, 2011). Notable among these pathogens in contaminated food are; *Shigella* spp, *Salmonella* spp, Enterotoxigenic and Enterohemorrhagic *Escherichia coli, Campylobacter* spp, *Listeria monocytogenes*, *Yersinia enterocolitica*, *Bacillus cereus*, *Staphylococcus aureus, Clostridium botulinum*, viruses and parasites such as *Giardia lamblia*, *Cyclospora cayetanensis*, and *Cryptosporidium parvum* (Fan *et al.*, 2009; linch *et al.*, 2009; WHO, 2008)

Diarrhoea diseases are among the top infectious diseases and globally kill 2.1 million people annually, most of whom are children (1.4 million) in developing countries (WHO, 2011). Thirty three (33) to ninety percent (90) of these diarrheoa cases are attributed to food contamination (McDermott & Delia, 2011; WHO, 2001). The high prevalence of diarrhoea diseases in many developing countries shows that there are major food hygiene and water safety problems (WHO, 2011). In Ghana, diarrhoea is the leading most common health problem that accounts for 84 000 deaths annually, with 25 per cent being children under 5 years (UNICEF, 2006; WHO, 2011).

Tomatoes are the world`s second largest vegetable crop, with more than 70 million tons grown each year (FAO, 2008). In Ghana, tomato is probably the most important vegetable grown. This is because many of Ghana’s ecological zones are suitable for its cultivation (Kolavalli *et al.*, 2011). The land area for its production was seen to have increased from 28,400ha in 1996 to 37,000ha in 2000 (GIPC, 2001).

Consumption of tomatoes has increased because of its use in many Ghanaian dishes (Beuchat, 2002; Kolavalli *et al.,* 2011). However it is one common vegetable that has been implicated in a number of food borne disease outbreaks (Valadez *et al.,* 2012). According to Valadez *et al* (2012), pathogenic bacteria that have been found in or on tomatoes and cause foodborne diseases to humans include; *Salmonella enterica, Listeria monocytogenes, Baccilus cereaus, E.coli, Campylobacter spp* and *Shigella spp.*

1.2 Statement of the Problem

The rainfall pattern in the Northern part of Ghana results in shortage of water for cultivation of vegetables and other food crops in most part of the year. Most farmers cannot depend on rain fed agriculture and therefore resort to alternative surface water sources such as dams, canals, rivers and wells for irrigation of their vegetables (Rahman *et al*., 2002).

Underground water is generally of good microbial quality than surface water (Steele and Odumeru, 2004). However, the practice of open defecation among the inhabitants, runoff from croplands, use of organic manure from humans and livestock and leachate from refuse and recreational activities has led to poor physico-chemical and bacteriological characteristics of underground water in the Kassena-Nankanna East Municipality (Oyelude *et al*., 2013) where this study was conducted. It is therefore evident that if underground water in the municipality is polluted, then surface water is of significant concern for investigation since it is more susceptible to pollution than underground water.

The unhygienic and insanitary condition has led to an outbreak of cholera leading to the death of two people with more than 17 admitted at the war memorial hospital in the Municipality. This outbreak was linked to consumption of contaminated food and water (KNDA, 2012).

It is also known that many farmers in the municipality use surface water for irrigating their farms. The issue of contaminated food crops have become a public concern with increasing environmental awareness and electronic media activity in Ghana. While many studies report on unacceptable levels of microbial and chemical contaminants in food crops and water used in irrigating crops, not many environmental assessment studies to identify the sources of irrigation water contamination have been conducted. It is also well known, that the Northern Region supplies a substantial amount of tomatoes produced in Ghana.

This study was therefore carried out to assess the bacteriological quality of tomatoes and irrigation water as well as the environmental conditions that may influence these contaminations

1.3 Aim

The aim of this study was to conduct an environmental assessment of three irrigation systems in the Kassena-Nankanna East Municipality and determine microbiological quality of tomato crops grown on farms irrigated from study schemes and water used for irrigation

The specific objectives are to;

1. Identify environmental factors that may affect irrigation water quality and cultivated tomatoes from irrigation schemes in the Kassena-Nankana East Municipality.
2. determine the physicochemical characteristics of the irrigation water from different irrigation schemes (canal, river and dam) in the Kassena- Nankana East Municipality.
3. determine the bacteriological quality of water from different irrigation schemes
4. assess the bacteriological quality of tomatoes (external and internal tissues) grown on farms irrigated in study area

1.4 Justification

Consumption of fresh fruits and vegetables is integral to healthy diets that supply essential vitamins, minerals and fibre. Worldwide, the consumer is encouraged to include five to nine daily servings of fresh fruits and vegetables in their diet (Matthew, 2006).

Kassena-Nankanna East Municipality in the Upper East Region of Ghana is a major vegetable growing area not only for the Municipality but for the whole country. Unfortunately, water sources used in irrigation of vegetables receive a lot of runoff of agrochemicals from farms, organic manure from humans and livestock and leachate from refuse and recreational activities (Ataogye, 2012).

Increase in population has led to a significant level of encroachment along the periphery of irrigation of water bodies within the Municipality. This has resulted in an increase in farming, animal rearing and domestic sewage disposal within the vicinity (KNDA, 2006). There is therefore the fear that water sources used for crop irrigation could contribute to contamination of vegetables that are produced from irrigated farms. For instance, the World Health Organization (WHO) recommended level of faecal coliform in irrigation water for unrestricted irrigation of crops likely to be eaten raw is 1×10^3cfu /100 ml (WHO, 2006b). Earlier research carried within the municipality found that, the microbial levels in irrigation water and cultivated roselle leaves produced from the irrigated farms were higher than that of WHO and International Commission on Microbiological Safety of Foods (ICMSF) standards (Ataogye, 2012).

Meanwhile, the consumption of vegetables is being promoted as a preventive measure for many health conditions such as cancer; cardiovascular and other related health problems which are increasingly becoming important public health concern in developing countries (Bhowmik *et al.*, 2012; WHO, 2003b).

This study therefore addresses the gap in literature by delving into environmental factors that promote irrigation water and food crop contamination in the study area.

1.5 Research questions

1. What are the prevailing environmental conditions that predispose irrigation water and tomatoes to contamination?

2. What is the physicochemical characteristic of the irrigation water from irrigation schemes in the Kassena-Nankanna East Municipality?

3. What is the level of bacterial contamination of water from irrigation schemes (canal, dam and river) in the Kassena-Nankanna municipality?

4. What is the level of contamination of tomatoes produced from irrigation schemes (canal, dam and river) in the Kassena-Nankanna East Municipality?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Irrigation schemes and health in Sub-Saharan Africa

Historically, irrigation development in Sub-Saharan Africa (SSA) started around the mid-1960s with governments playing a central role after receiving significant donor support from the World Bank (Inocencio *et al.*, 2005). However, only four percent (4%) representing 6 million hectares of the region's total cultivated land is irrigated. In Asia and Latin America, irrigated lands constitute 37 percent and 14 percent of arable lands respectively (You *et al*, 2010).

Approximately 90% of irrigation schemes are developed from surface water in SSA with groundwater exploitation still less used in most countries in the region (FAO, 2005). Majority of these irrigation schemes are small scale with limited impact on food production when compared to large-scale irrigation developments which tend to be more beneficial (You, 2008). Climate change also impacts negatively on food production in the region (Agbola, 2011). It affects all aspects of human activities, bringing about droughts, floods, forest fires and heat or cold waves (Zoellick, 2009). Its impact on agriculture is significant (UNFCCC, 2007).

While irrigation is being promoted to boost food production, it comes with some challenges. For instance, the use of contaminated water has been implicated in food borne outbreaks. The WHO has identified pathogens (bacteria, viruses, protozoa, cysts and helminthes eggs), organic and inorganic toxic substances as the cause of many health problems in the world (WHO, 2006a). These pathogens can be easily transmitted especially if contaminated crops are not properly sanitized and are eaten fresh (Blumenthal *et al.*, 2000). Pathogen contamination of food crops can be from several sources such as wash water, infected irrigation system operator and use of organic fertilizers (Han *et al.*, 2000).

Irrigation practices that expose the edible portion of plants to direct contact with contaminated water may increase microbial load on the food crops (Bourquin & Thiagarajan, 2009).

The contamination of the environment and exposure of the public to pathogens and inorganic pollutants in food could lead to high health risk. Foodborne illness outbreaks traced to a variety of different foods can be found worldwide (Todd, 1998). According to WHO (2002) illness due to contaminated food is the most widespread health problem in the world. Research conducted by Mead *et al.* (1999) reported that the number of cases of foodborne illness vary yearly.

In order to protect consumers and the general public, the WHO made a call on its member states to recognize food safety as an essential public health function, with respect to point of production, processing and distribution (WHO, 2002). The World Health Organization suggested that food safety issues must be addressed along the entire food chain by using strategies that rely on appropriate scientific information at both national and international level (WHO, 2003a).

2.2 Irrigation in Ghana

The development of formal irrigation schemes in Ghana is recent compared to other countries in the region. The first of such schemes was initiated in 1960 (Smith, 1978). Even though, the records traced irrigation in the country to about a century ago, intensive use of irrigation is a more recent phenomenon resulting from population growth and increase demand for food.

The Ghana Irrigation Development Authority (GIDA) has 22 irrigation schemes covering about 14,700 ha of land. Sixty percent (60%) of these schemes are cultivated and put under irrigation whilst the remaining 40% is not being cultivated (GIDA/JICA, 2004). Ghana is endowed with sufficient water resources that have the potential to be used for irrigation. Unfortunately, productivity of existing irrigation schemes, particularly those that were publicly developed, are generally low (GIDA/JICA, 2004). The Kassena-Nankana East Municipality has one of the largest formal irrigation schemes in Ghana. The scheme consists of a 5 km long dam created on an artificial lake with a surface area of 1860 ha. It had a water storage capacity of 93 million m^3 of water of which 37 million m^3 could be used for irrigation (Asare, 2002; Salifu, 1998).

2.3 Food production and the role of irrigation

The world population is predicted to grow from 6.9 billion in 2010 to 8.3 billion in 2030 and to 9.1 billion in 2050 (UNDESA, 2009a). With expected increase in population, food demand is likely to increase by 50% by the year 2030 (Bruinsma, 2009). About 800 million people in developing countries today are suffering from malnutrition and 199 million children under the age of five are facing acute or chronic food deficiencies (WHO, 2011). Currently, as many as 70 nations fall into the class of low-income food-deficit countries (FAO, 2011). Increased agricultural productivity has become an important system for a nation to move out of poverty (Faurès *et al.*, 2007).

Irrigation farming helps to increase agricultural productivity and hence alleviates hunger, preserves life and increase the material wealth of a country (Shah, 2008). In Northern Ghana for instance, where there is erratic rainfall distribution pattern, irrigation farming has been considered more useful to rain-fed agriculture (Dinye and Ayitio, 2013)

The yield per acre of irrigated land far outweighs that obtained through rain-fed agriculture on the same size of land (Shah, 2008). In 2005, the yield per hectare of rice cultivated on irrigated land on the Tono and Vea irrigation schemes in the Upper East of Ghana was reported to be more than four times that produced using rain-fed agriculture (Yilma *et al.*, 2005). According to Ali and Pernia (2003) rural household income is 77 per cent higher with irrigated agriculture than those who resort to rain fed agriculture.

2.4 Environmental consideration of irrigation schemes

Throughout the entire globe there is strong pressure on agriculture to produce more food. These are as a result of rapid population growth and increasing levels of urbanization (Merker, 2004). Even though irrigation has increased food security in the world and raised millions out of poverty, poor management of irrigation schemes has caused one-third of irrigated lands in the world to reduce productivity due to water logging and high salinity levels (Ahmad *et al*., 2008; Faurès *et al.*, 2007).

Poor management of irrigation schemes has the potential for causing serious environmental problems (Table 1). Notable among these problems are increased erosion, pollution of surface water and groundwater from agricultural pesticides, deterioration of water quality, increased nutrient levels in the irrigation and drainage water resulting in algal blooms, proliferation of aquatic weeds and eutrophication in irrigation canals and downstream waterways (FAO, 2011)

Table 1: Main environmental problems resulting from irrigation schemes and appropriate mitigation measures

Environmental problem	Mitigation measures
Salinization	Provide drainage systems.
Alkalization	Maintain channels to prevent seepage
Waterlogging	Provide water for leaching as a specific operation.
Soil acidification	Maintain both the irrigation and drainage systems
Increased incidence of water related diseases	Educate about causes of disease
Reduction in irrigation water quality	Control industrial development

Source: FAO, 2011

Water may carry causative agents (pathogens) of communicable diseases of man or provide the right environment for the breeding and propagation of their vectors. Irrigation and drainage projects create a number of ecological conditions for disease vectors to emerge in areas where they did not occur before, or to a rapid increase of their original densities (WHO, 1996).

Most of the reported impacts of irrigation development on health consist of water related diseases (Table 2). Generally, four groups of diseases are distinguished based on their way of transmission (Cairncross and Feachem, 1993; WHO, 1988).

I. water-related insect-borne parasitic diseases: diseases transmitted by insects that depend on water for their propagation such as river blindness, filariasis and malaria

II. water-washed diseases: diseases due to the lack of proper sanitation and hygiene such as louse-borne infections and infectious eye and skin diseases.

III. water-based diseases: infections transmitted through an aquatic invertebrate organism with an intermediate host living in water, such as guinea worm and schistosomiasis

IV. water-borne or faecal- orally transmitted diseases: infections spread through contaminated drinking water, such as cholera, typhoid and diarrhea related diseases.

Water-based and water-related diseases transmitted through vectors or intermediate hosts sometimes increase with irrigation development. Canals, dams and drains may create ideal breeding sites for anopheles mosquitoes or for snails, bringing both the vectors and the disease closer to people. Many field studies have described the influence of irrigation on the spread of these water-based and water-related diseases (Hunter *et al*., 1993; Steele *et al*., 1997; Harmancioğlu *et al*., 2001). Various studies have associated schistosomiasis with water-contact activities like recreational (swimming) or specific agricultural activities, washing of clothes and cooking utensils, fishing and with the proximity of homes or communities to sites harbouring cercariae shedding *Bulinus* and *Biomphalaria* snail species (El-Ayyat *et al.*, 2003; Matthys *et al.*, 2007)

Water borne diseases are transmitted through water contaminated by human, animal, chemical waste eg. Cholera and typhoid fever. Poor hygiene and lack of sanitation facilities in and around irrigation schemes could lead to the contamination of irrigation water. Outbreak of faecal-orally transmitted diseases has been linked to infected farmers. Water-washed diseases are also caused by lack of proper sanitation and hygiene around irrigation schemes eg. Trachoma (WHO, 1988). More than 80 million people are infected with water related diseases every year (Table 2)

Table 2 : Some water-related diseases and their importance

Disease group	Disease	Estimated infection rate (1000/year)	Estimated morbidity (1000/year)	estimated mortality (1000/year)
Water-borne diseases	Diarrhea	not available	1,000000[1]	5000[1]
	Typhoid Fever	1,000	500	25
Water-wash diseases	Ascariasis	80,000000	1,000	20
	Ancylostomiasis	700000	1,500	50-60
Water-based diseases	Schistosomiasis	200,0000	?	500-1,000
Water-related vector borne diseases	Malaria	240'000	100'000	not available
	Onchocerciasis	17800	340	20-50
	Lymphatic filariasis	90'200	2'000-3'000	low

Based on WHO, 1988

Environmental factors should be considered at the planning, construction and operation stages of irrigation schemes so as to eliminate or reduce health and environmental effects resulting from these projects. This can be achieved through physical transformation of land, water and vegetation, aimed at preventing, eliminating or reducing the habitats of vectors without causing undue adverse effects on the quality of the human environment (WHO, 1996) (Table 3).

Table 2: Environmental management measures for vector control in irrigation schemes

COMPONENT	MEASURE
Lay-out of irrigation Scheme	design scheme to allow for field drainage and to eliminate stagnant water
	siting human settlements away from irrigated fields to reduce human-vector contact
	constructing latrines in the fields, layed out in a grid pattern, to provide farm workers with sanitary facilities while at work
Settlement design	Provision of water supply and sanitation (piped water supplies, washing and communal laundry facilities, safe children's swimming pools, latrines
	screening of houses and better house design
	domestic animal pens at strategic sites to avert mosquito vectors away from humans
	(insecticide-impregnated) mosquito nets, particularly for use by high-risk groups
Reservoir design and operation	avoid construction of night water storage reservoirs which may serve as vector breeding and disease transmission sites
	periodic drawdown to achieve water level fluctuation
	vegetation clearance to reduce vector breeding
	fishing facilities that prevent unnecessary water contact

Table 3 continued

Irrigation canal design and operation	straight canals to eliminate standing pools suitable for vector breeding
	canal lining of major or designated water contact points to inhibit vector breeding
	other design measures to increase water velocity, aimed at a reduction of vector breeding
	sluicing and flushing of snails
	vegetation clearance against snail or mosquito breeding
	mechanical screening of water intakes against the transport, via water, of snails
	pathways and bridges across canals and drains, particularly in and around villages, to avoid unnecessary water contact
	self-draining hydraulic structures to achieve water level fluctuation early (or late) working hours for canal maintenance crews to avoid schistosomiasis infection at peak transmission periods
Cropping system and other agricultural practices	use of upland crops, at least once per cropping cycle, to prevent the establishment of vector species that need permanent water bodies for survival
	avoid double - or triple cropping to limit the vector breeding to the rainy season
	use of varieties with a short growing season to reduce the period that standing water is available
	Synchronization of cropping cycle in large areas of smallholder irrigated rice production, to ensure interruption of the availability of breeding sites

2.5 Environmental assessment of irrigation schemes

Environmental assessment means an evaluation of the entire irrigation scheme, taking into consideration factors including agricultural water, soil amendments, harvesting, domestic animal and wildlife intrusion, adjacent land use, employee health and hygiene, packing house/equipment, cleaning and sanitation to assess any safety risks that may affect the potential for the crops to be contaminated (FDA, 2013).

These assessment therefore looks at a wider approach to identifying potential sources of contamination of irrigation water, taken into considerations factors both on the farms themselves where the produce originated, as well as in surrounding watersheds. Such an approach can help to identify not only possible sources of contamination, but also the conditions in the environment that facilitated or created that contamination. These conditions are termed environmental antecedents here, and are the circumstances that allow contributing factors that can affect health, such as contaminated irrigation water, to occur (Gelting *et al.*, 2005).

Environmental assessments (EA) may be conducted prior to planting, during production, and immediately prior to harvest in order to prevent outbreaks and contamination events before they occur (FDA, 2013).

2.6 Aspects of environmental assessment consideration

2.6.1 Irrigation water pollution indicators

There are several physico-chemical parameters that indicates pollution in water and these may include; total suspended solids, nitrates, nitrite, total dissolved solids, dissolved oxygen, biological oxygen demand, turbidity and electrical conductivity.These comes from ploughed fields, construction and logging sites, urban areas, and eroded stream banks when it rains. These sediments are carried into rivers, lakes coastal waters, and wetlands. This results in impairment of respiration of fishes, reduction in plant productivity and reduction in water depth. Aquatic organisms and their habitats are affected and also aesthetic property of the water is reduced (WHO, 1993).

Nitrates are present in water particularly in places where agriculture fertilization is high. Other important pathways of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feedlot discharges from car exhausts. Earlier works carried out to assess the quality of underground water in the study area recorded high concentration of nitrate ions (12.40mg/l) in some selected wells above the recommended standard of 10mg/l for drinking water. They attributed this high concentration of nitrates to the use of inorganic fertilizer and manure in agricultural activities, and indiscriminate disposal of human and animal excreta (Oyelude *et al.*, 2013). Nitrogen and phosphorus in water used for irrigation of crops do not usually cause problems for humans. However, high concentrations of nitrate nitrogen (NO_3^--N) can cause problems for human health in drinking waters as NO_3^- is converted to NO_2^- in the digestive tract and this combines with haemoglobin in the blood, reducing O_2 carrying capacity which can lead to brain damage. Nitrate is not normally accumulated in high enough concentrations in food crops, considering their daily intake to be a problem for human health (Broadbent and Reisenauer 1985). Leaf crops typically accumulate the highest levels of NO_3^- (Bergman, 1992) if it is available in the soil. However, consumers do not often eat sufficient amounts for problems to occur. High NO_3^- concentrations in plants are much more likely to be a problem for grazing ruminants than humans (Harris and Rhodes, 1969).

The presence of large amounts of soluble organic matter conotes the amount of nitrates and nitrites in water which can result in the microorganisms persisting for longer amounts of time. As heterotrophic organisms, coliform bacteria rely on organic matter as a nutrient source. Soluble organic matter in water provides a rich nutrient source for the bacteria to make use of (Fan *et al.*, 2009; Sylvia *et al.*, 2005).

Dissolved oxygen (DO) content is one of the most important factors that determine the health of surface waters. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. Oxygen is the single most important gas for most aquatic organisms; free oxygen (O_2) or is needed for respiration. DO levels below 1 ppm will not support fish; levels of 5 to 6 ppm are usually required for most of the fish population. The average value of DO levels (6.5mg/l) indicates the average quality of surface water (APHA, 1985). Dissolved oxygen concentrations in unpolluted water normally range between 8 and 10mg/L and concentrations below 5 mg/L adversely affect aquatic life (Arimoro *et al*., 2008; DFID, 1999; Rao, 2005).

Biological oxygen demand is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand (Abida & Harikrishna 2008) . Unpolluted, natural waters will have a BOD of 5 mg/l or less. BOD directly affects the amount of dissolved oxygen in surface water. The negative effect of high BOD is the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff (USEPA , 1997).

Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. These particles suspended in water absorb or reflect light and cause the water to appear "cloudy. This problem is more common in the water from surface supplies. The major problem with turbidity is aesthetic, but in some cases suspended matter can carry pathogens with it. Large amounts of organic matter can also produce stains on sinks, fixtures, and laundry (Pescod, 1992).

Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility, and valence; and on the temperature of measurement. Increasing levels of conductivity and cations are the products of decomposition and mineralization of organic materials (Abida, 2008). Sunitha *et al.*, (2005) identified that the electrical conductivity finds higher level correlation significance with many of water quality parameters, like TDS, total alkalinity, sulphates, total hardness and magnesium. Kalyanaraman (2005) identified that the water quality of ground and surface water can be predicted with sufficient accuracy just by the measurement of EC alone. This provides a means for easier and faster monitoring of water quality in a location.

PH is a measure of the acidity or basic (alkaline) nature of a solution. Is an important parameter that determines the suitability of water for various purposes, including toxicity to animals and plants. A pH range of 6.0 to 9.0 helps provide protection for the life of freshwater fish and bottom dwelling invertebrates.

Low pH increases the release of metals, some toxic, from soils and sediments. That is, the pH value of the water may influence levels at which certain chemical substances become toxic. The normal pH range for irrigation water is from 6.5 to 8.4; pH values outside this range are a good warning that the water is abnormal in quality. Normally, pH is a routine measurement in irrigation water quality assessment (Pescod, 1992).

Temperature of water especially in polluted water can have serious effects on dissolved oxygen (DO) and biological oxygen demand (BOD). The decrease and increase in surface water temperature usually depends on the season, geographic location, sampling time and temperature of effluents entering the stream (Ahipathy, 2006). Pathogens survive for longer periods of time at lower temperatures. Studies of surface water contaminated with manure containing *E. coli* 0157:H7 showed that the pathogen survived for 92 days at ambient temperature (Fan *et al.*, 2009).

2.6.2 Bacteria indicator contaminants in irrigation water

The faecal indicator organisms that are used to monitor water quality in irrigation water study are Enterobacteriaceae which include the total coliforms, faecal coliforms and *E. coli* (Fan *et al.*, 2009). Total coliforms are Gram negative, oxidase negative and catalase positive organisms that have the ability to ferment lactose at 35ºC with the formation of acid and gas as its end products. These organisms are rod-shaped and do not possess the ability to form endospores (Schraft &Watterworth, 2005). They are a subset of Enterobacteriaceae, and include bacteria from the genus *Escherichia, Citrobacter, Enterobacter, Klebsiella,* and *Salmonella SPP* (Fan *et al.*, 2009). The use of total coliforms as an indicator of contamination is unreliable because they are capable of growing both in the environment and in water systems (Paulsen *et al.*, 2007). Their presence in water may not necessary indicate faecal pollution. However, a water source that contains large concentrations of organic matter is likely to habour large numbers of total coliforms (Fan *et al.*, 2009).

Faecal coliforms are considered a sub-group of the total coliforms. Many of them are mesophiles and capable of growing and producing acid from lactose at 44.5°C. These are generally considered to be the thermotolerant. Faecal coliforms are adapted to survive within the intestine of a warm-blooded organism. Notable indicators are; *E. coli*, *Klebsiella spp, Enterobacter spp, Citrobacter spp, Hafnia spp, Pantoea spp, Raoultella spp* and *Serratia spp* (Leclerc *et al.*, 2001). The presence of faecal coliforms in water is an indication of faecal pollution. This has resulted in the development of more specific tests to detect which coliforms are present.

E. coli is considered to be the most reliable indicator for faecal contamination of irrigation water because they are part of the normal flora of the intestinal system of warm blooded animals and cannot grow in water without the presence of faecal material (Tallon *et al.*, 2005; Alonso *et al.*, 1999; Francis *et al.*, 1999).
Not all strains are harmful but the pathogenic strain, *E. coli O157:H7* have been identified and reported in several related food borne diseases outbreaks.

Pathogenic *E. coli* is the most common cause of infantile diarrhea in many countries, specifically in the developing world. According to Francis *et al* (1999), if *E. coli* 0157:*H7* strain is ingested, it can result in significant health effects including haemorrhagic colitis, gastroenteritis kidney failure, thrombocytopenic purpura and haemolytic uremic syndrome (Gil and Selma, 2006). It is important to monitor faecal matter in rivers and other surface water bodies especially those that are used for drinking and irrigation purposes because there is very little control over animal faeces entering the these water bodies (Francis *et al.*, 1999).

Escherichia coli are known to be able to withstand very highly acidic environments and can survive at pH ranges as low as 3.3 - 4.2 (Maciorowski *et al.*, 2007). The world health organization (WHO) has set specific guidelines for a variety of uses of water including water used for irrigation purposes. The Environmental Protection Agency (EPA) has also set up guidelines for the quality of irrigation water. They both recommend that water used for the irrigation of fresh agricultural produce especially those that are to be eaten raw such as fruits and vegetables should have a faecal coliform load not exceeding 1000 cfu per 100 ml (WHO, 2006b). The World Health Organization recommends that *E. coli* in irrigation water should not be more than 1000 organisms per 100 ml (WHO, 2006b ; WHO, 1989). However, the permissible load of *E. coli* on raw fruits and vegetables is zero per g product. It will be of a significant concern for further investigation in order to identify specific pathogens in vegetables because the presence of *E.coli* indicates the presence and the likelihood of other disease causing pathogens.

2.7 Sustainability of agricultural production under irrigation

Due to ecological and environmental reasons sustainable management of surface water is crucial in order to provide continuous and reliable operation so that the demand for safe water for irrigation can be met. This demands efficient allocation of water resources, embracing water conservation strategies, as well as protecting the environment (Nouri *et al.*, 2008; 2009; Ch ang, 2005; Loucks *et al.*, 2000). According to Zarghaami (2006) effiecient water management needs comprehensive consideration of all areas such as technical, social, environmental, institutional, political and financial. Water resources management is essential in order to sustain agricultural production under irrigation in the presence of changing climate (Ashraf *et al.,* 2007; Khalkheili and Zomani, 2009). Interaction of both human and physical aspects of irrigation is very important in supporting its sustainability (Chang, 2005). Monitoring environmental impacts of irrigation schemes plays an important role to ensuring its sustainability (Schoups *et al.*, 2006)

2.8 Tomatoes as an important irrigated crop in Ghana

2.8.1 Nutritional and health benefits of tomatoes

Tomato (*Lycopersiconesculentum*) is a member of the Solanaceae family which also includes other well-known species, such as potato, tobacco, peppers and eggplant (Olson *et al.,* 2004). The edible part represents about 94% of the total weight of the fruit (De Lannoy, 2001). A 100g tomato contains 93.8g water, 1.2g protein, 4.8g carbohydrate, 7mg calcium, 0.6mg iron, 0.5mg carotene, 0.06mg thiamine, 0.04mg riboflavin, 0.6mg niacin and 23mg vitamin C (De Lannoy, 2001). Tomatoes are also very rich in all three important vitamins A, B and C (Norman, 1992) while most vegetables are deficient in one or more. It is a rich source of many important nutrients and contains as much vitamin C as many citrus fruits, with a normal sized tomato providing up to 20% of the of vitamin A, 40% of the of vitamin C (ascorbic acid), vitamin E, trace elements, flavonoids, phytosterols, and several water-soluble vitamins. The fruit has high magnesium, potassium and phosphorus content, good source of lycopene, foliates and a reasonable amounts of potassium, dietary fiber, calcium, with as few as 35 calories (USDA, 2010; Collins, 2007; Sargent 1998).

In addition to the diverse nutrients that tomatoes contain, it also plays an important role in the prevention of many common health problems (Collins, 2007). A medium sized tomato can make people healthier and decrease the risk of conditions such as cancer, osteoporosis and cardiovascular disease. People who eat tomatoes regularly have a reduced risk of contracting cancer diseases such as lung, prostate, stomach, cervical, breast, oral, colorectal, esophageal, pancreatic, and many other types of cancer. Tomato is also good for liver health, good energy drink and for rejuvenating the health of patients on dialysis, prevent hardening of the arteries and reduce high blood pressure, a powerful antioxidant, prevents oxidation effectively, rapid skin cell replacement, healing sunburn because of its unique vitamin C, good sports drink to restore yourself from fatigue and sleepiness (Bhowmik *et al.*, 2012; Wener, 2000).

Considering the nutritional health benefit that are derived from consumption of these vegetable, it is therefore important to ensure that this vegetable is produced under safe environmental conditions to prevent their contamination with pathogens that could lead to serious health effects rather than which could overplay the reason for its consumption.

2.8.2 Irrigation and tomato production in Ghana

Tomato has a good adaptation to a wide range of climatic conditions, and so is found throughout tropical Africa (De Lannoy, 2001). According to FAO (2005), tomato is the most important vegetable grown in Ghana and a wide range of areas are suitable for its production.

Production of the crop in Ghana is done by small-scale farmers who grow it basically for its fresh use. However, with the introduction of irrigation projects, large scale monoculture has become wide spread, especially in the Northern and Upper Regions, and around southern Volta region. Tomato production is also vibrant in Akumadan and the Wenchi Districts. The varieties cultivated in Ghana have evolved from varieties introduced by the Portuguese. The fruits are of irregular shape and multisided. These cultivars are Poma, Pectomec, Roma, Royal and Mongal(Third world network (TWN), 2007).

Tomato cultivation has been a significant economic activity in the Upper East region, especially in Navrongo. Tomatoes have long been the most important crop in the Upper East region and it is seen to be more profitable than rice, maize, groundnuts, yam, pepper and dairy. Close to 90% of the two million people living in the area cultivates them (Third world network (TWN), 2007).

2.8.3 Sources of microbial contamination of tomatoes

Microbiological contamination refers to the presence of one or several bacteria, yeasts, mould, fungi, protozoa or their toxins and by-products, on vegetables that can affect the health of consumers (Levitt, 2000). Tomatoes and other vegetables can become contaminated whilst growing in the field or during harvest, handling, processing, distribution and use (Beuchat, 1998).

Microbial contamination depends on different factors of which include the soil characteristics that could serve as the reservoir of foodborne pathogens such as *Bacillus cereus* (Jorgensen and Lund 1985) or water used for irrigation.

Wild birds are probably the second most common source of natural contamination to surface waters used for irrigation purposes. Pathogenic bacteria may contaminate vegetables as a result of birds feeding on garbage, sewage, fish, or lands that have been grazed by cattle's or have had applications of fresh manure. This may contribute to the disseminating of microbiological organisms such as *Campylobacter spp, Salmonella spp, Vibrio cholerae*, *Listeria spp* and *E. coli* O157:H7 (Lary *et al.*, 1997). Several studies have come out with findings that animals can cause contamination of irrigation water and vegetables through their faeces. They suggested that farmers should stop animals from entering their farms in order to reduce the risk of contamination (Amoah *et al.*, 2005; Davis and Kendall, 2005; Johnston *et al.*, 2006).

In the production of seeds intended for sprout production, the practice of animal grazing to initiate flowering of alfalfa may result in the introduction of enteric bacteria. Similar consequences may result from allowing wild animal's access to seed fields. Non-composted or improperly composted manure can contaminate fruits and vegetables through uses such as a fertilizer or soil amendment, or in irrigation water (Buck *et al.,* 2003). Poultry manure, which represents 75% of the organic fertilizer used, generally contains faecal coliforms (1.30 x 106/g) and enterococci (3.4 x 106/g) (Westcot, 1997). This even occurs in areas where pipe-borne water was used for irrigation which indicate that the contamination was from the poultry manure. Research conducted by Amoah *et al., (*2005) of some selected vegetables with irrigation water revealed that most of the vegetables analysed were contaminated with faecal matter. Drechsel *et al*. (2000) reported that fresh poultry litter samples sometimes used without sufficient drying for vegetable production in Kumasi had high fecal coliform counts. Other studies have also attributed microbial contamination of irrigation water and food crops to the use of cow dung as a fertilizer (Lau and Ingham, 2001; Zschock*et al*., 2000).

Irrigation method also has an effect on the microbial load on tomatoes. Amoah *et al*. (2005) showed that on farms where overhead irrigation techniques are used, larger leaf surface areas are exposed to the contamination from irrigation water and possibly from soil particles splashing unto the plant. According to Sadovski *et al* (1978), spray irrigation could increase the risk of contamination because it exposes large portion of the edible part of vegetables to irrigation water causing the attachment of microorganism. This practice enhances direct contact of irrigation water with the edible parts of the tomatoes.

Therefore, to minimize the risk of infection associated with raw fruits and vegetables, potential sources of contamination from the environment should be identified and specific measures and interventions to prevent and/or minimize the risk of contamination should be considered and correctly implemented.

2.8.4 Contamination risk of tomato

Tomato fruits have a thin epidermis which makes them easily compromised by mechanical pressure, which can result in punctures, cracks, abrasions, and insect wounds that render the fruit susceptible to pre harvest and postharvest microbial invasion. The stem scar tissue is also capable of absorbing water and any microorganisms that may be present (Bartz and Showalter, 1981).

The majority of bacteria found on the surface of plants is usually Gram-negative and belong either to the *Pseudomonas* group or to the Enterobacteriaceae (Lund, 1992). However, the number of these bacteria on vegetables usually varies depending on seasonal and climatic variation and may range from 104 to 108 per gram.

The inner tissues of tomatoes are usually regarded as sterile (Lund, 1992). However, bacteria can be present in low numbers as a result of the uptake of water through certain irrigation or washing procedures. The survival or growth of contaminating microorganisms is affected by intrinsic, extrinsic and processing factors. Factors of importance are nutrient composition, pH, presence of scales and fibres, redox potential, temperature and gaseous atmosphere. Mechanical shredding, cutting and slicing of the produce open the plant surfaces to microbial attack. In some developing counties, farming activities are found almost everywhere: behind houses, along roadsides, on roofs, along and between railway lines, in parks, along rivers, under power lines, and in high, medium and low density areas. At least 20 million West Africans currently live in urban households with some kind of urban agriculture (Drechsel *et al*., 2006).

Any microbial contamination present is likely to reflect the environment through which the product is obtained. Consumption of contaminated vegetables could pave the way for ingestion of considerable number of human pathogenic bacteria. This eventually could result in establishment and manifestation of diseases on humans (Taura and

Habibu, 2009; Francis *et al*., 1999;). Identifying the environmental conditions that may influence the proliferation and subsequent growth of microorganisms would help prevent them from becoming contaminated and this would protect the health of the consumer.

The tomato plant can also be contaminated with pathogens due to internalization of pathogens both through the root system and flesh or stem scars (Burnett *et al.,* 2000). Previous research showed that pathogens can enter lettuce plants through its roots and end up in the edible leaves. Also, pathogens such as *E. coli* may enter may enter and infect plant tissues through Small gaps in growing roots (Solomon *et al,* 2002; Warriner *et al.,* 2003).

In a study by Guo *et al* (2001), the possibility of internalization of *Salmonella spp* in tomato fruits developed from inoculated flowers and stems was observed. *Salmonella spp* was detected in stem scar tissue and pulp of tomatoes from inoculated plants. It was also detected on tomatoes from plants receiving stem inoculation before or after flower set, and on or in tomatoes that developed from inoculated flowers. The highest percentage of *Salmonella spp* was found on the surface of the tomato and around stem scar tissue (Guo *et al*. 2001). Eliminating pathogens from the external parts of tomatoes may not still make it safe for consumption since pathogens can become internalized at various developmental stages of the plant.

2.8.5 Tomatoes in food borne outbreak

Foodborne illness outbreaks, traced to a variety of different foods, can be found worldwide (Todd, 1998). A research conducted by Mead *et al.,* (1999) has shown that the number of reported cases of foodborne illness vary from year to year and have estimated that for every 1 case reported up to 350 are unreported.

Food-borne illnesses on tomatoes are of particular concern to scientists because the amount of tomato consumption is increasing. From 1996 to 2008, eighty-two foodborne illness outbreaks were associated with the consumption of fresh tomatoes produce. Of these produce related outbreaks 14 representing 17.1% were linked to tomatoes. Fresh –cut tomatoes were associated with 5 of the 14 tomatoes outbreaks (FDA, 2008). One of the contributing factors to the increase in food borne disease associated with tomatoes is that it is frequently eaten without being cooked, so there is no heating to eliminate pathogens before consumption (Matthews, 2006).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

The research was conducted in the Kassena-Nankana East Municipality(Figure 1a). The Municipality is about 40 km away from Bolgatanga, the regional capital of Upper East Region of Ghana(Figure 1b). It is located between latitude 10°30' and 11° 00' North and 1°00' and 1° 30' West longitude of the Sahelian Savannah. The municipality covers a land area of 1,674 square kilometers with a population of about 149,680 (Ghana Statistical Service, 2010). The annual average rainfall is 850mm which occurs between July and September, with the rest of the year being relatively dry (Donkoh *et al.*, 2008). The average annual temperature range is between 20^0C and 40^0C. Rearing of livestock, domestic animals, and the growing of vegetables such as tomatoes, cabbage and carrots are the main activities (Donkoh *et al.*, 2008,).

Three vegetable growing communities which uses different water sources (canals, dams and rivers) for irrigation were purposively selected for the study. These were Bonia, Doba and Yigwania(Figure 2). Farmers in these communities use buckets, watering cans and pumping machines to draw the water for irrigation of the crops. Those who use watering cans and buckets splashed the water on the whole plants whiles the others use pumping machines with a long tube to splash the water on the soil around the plant.

Bonia is located within the Kassena-Nankana East Municipalty. The irrigated land area here is about 7 hectares with about 50 vegetable farmers. Water for irrigation is from canals from the Tono irrigation scheme. Farmers in this community grow vegetables such as tomatoes, cabbage and carrot.

Doba is located along the main Navrongo-Bolgatanga road with a total land area of about 4 hectares cultivated by over 45 vegetable farmers. Most of the farmers use water from the Doba dam for irrigation.. The vegetables that are grown by the farmers are tomatoes, okra, pepper, garden eggs and leafy vegetables.

Yigwania, located within the municipality with a total land area of about 5 hectares cultivated by over 38 vegetable farmers. Vegetables that are grown by farmers are mainly tomatoes, lettuce, cabbage, carrots, garden eggs, spring onions and other leafy vegetable (NHRC, 2002)

Fig 1a Fig 1b

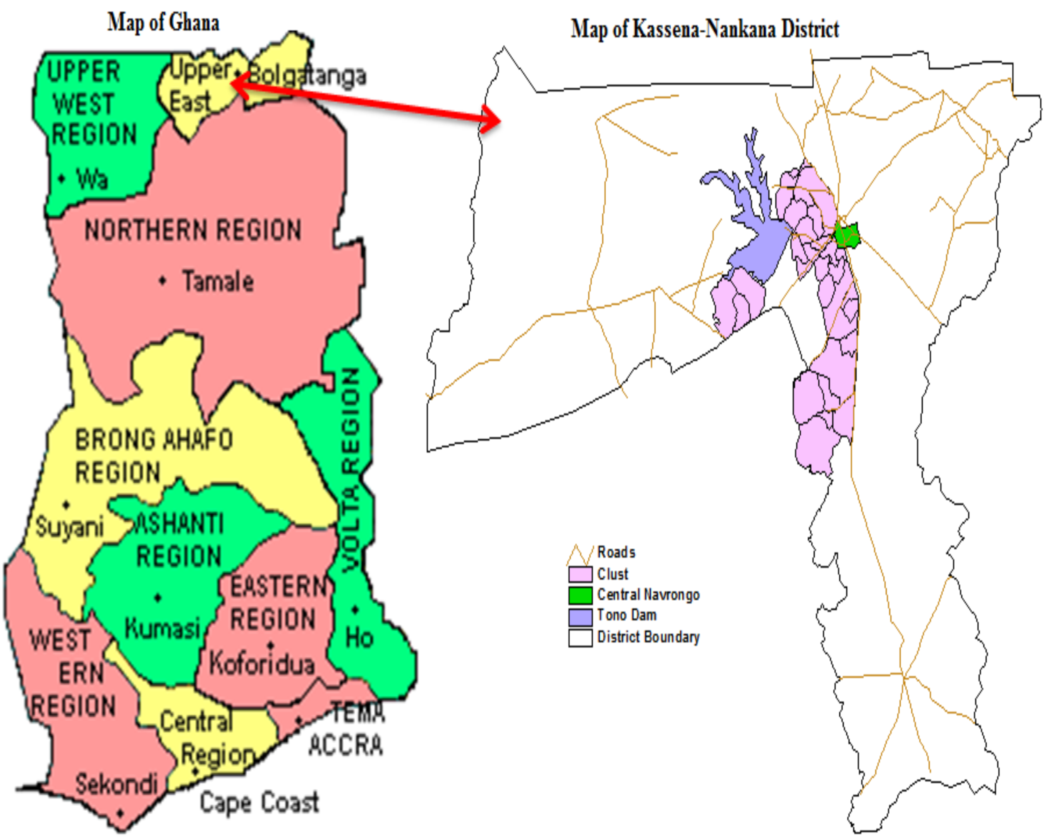

Figure 1 : A) Map of Ghana showing Upper East Region, B) map of Kassena - Nankana East Municipality

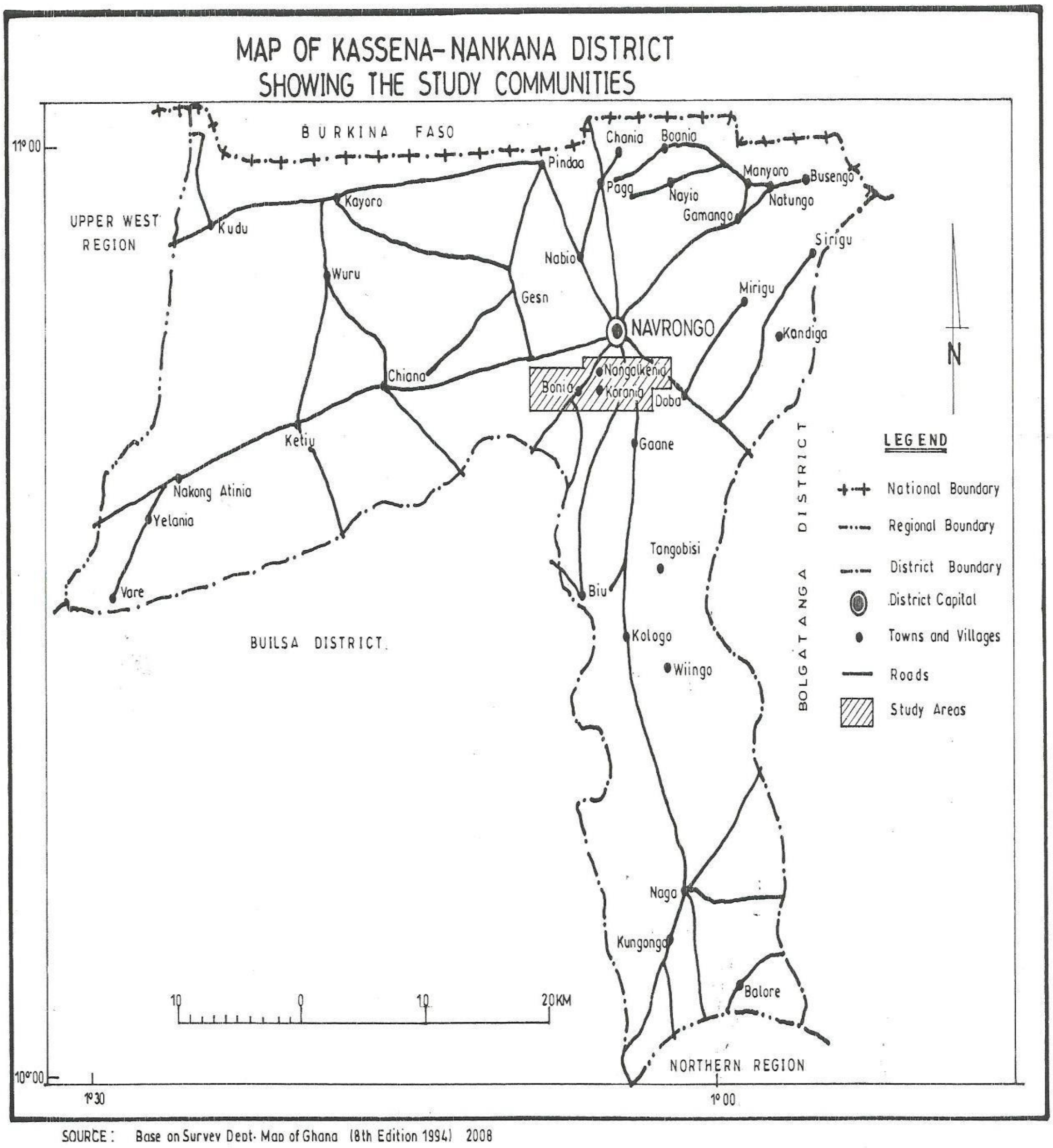

Figure 2 : Map of Kassena-Nankana East municipality showing study communites

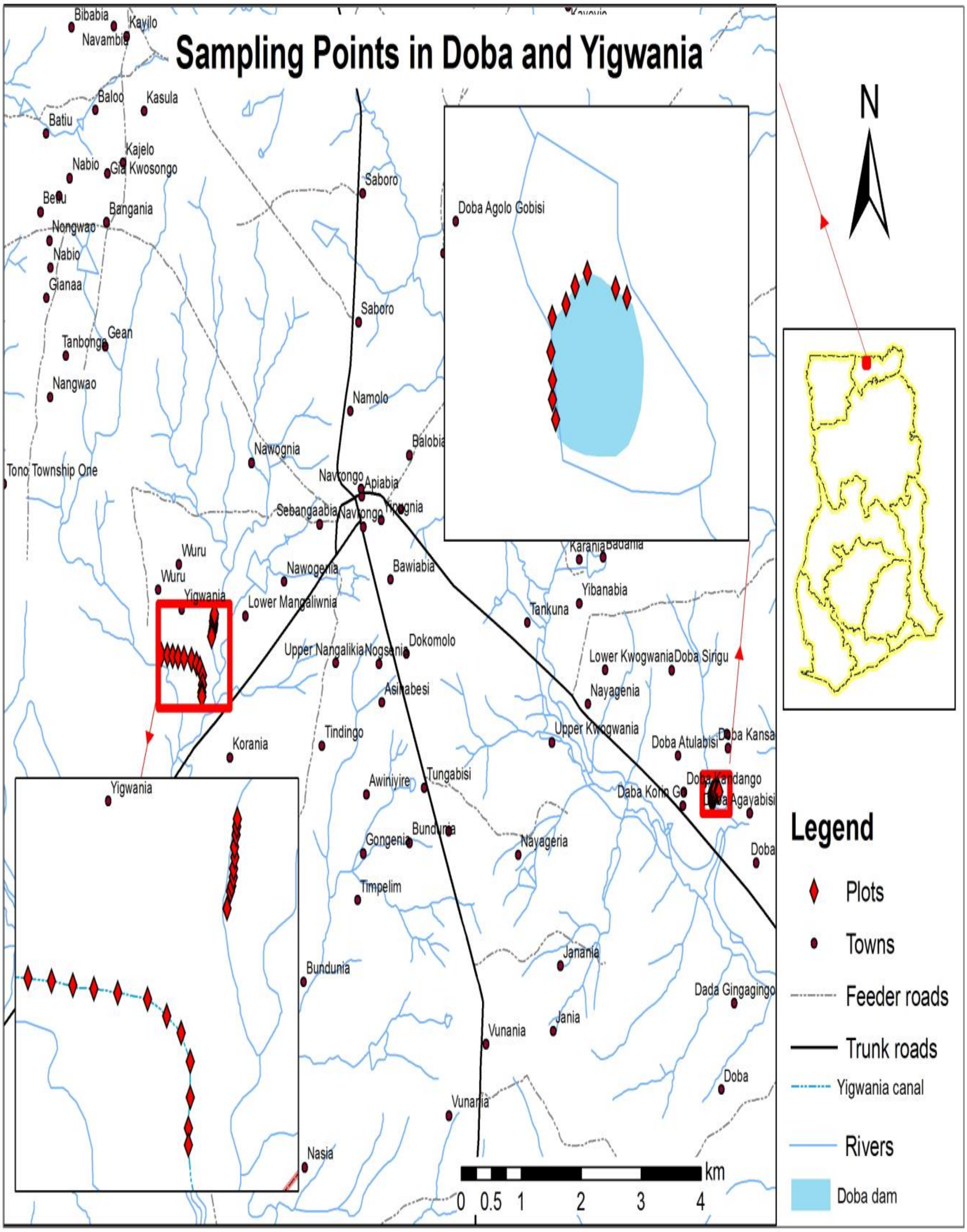

Figure 3 :Map showing the sampling points within the study area in the Kassena-Nankanna East Municipality

3.2 Study design

3.2.1 Environmental assessment

Environmental assessment was done by using structured questionnaire and observation. Questionnaires were administered to farmers to gather information which included demographic characteristics of farmers, source of irrigation water, method of irrigation and cropping system, harvesting, animal intrusion, adjacent land use activities, employee health & hygiene, packing house/equipment and cleaning and sanitation.

The questionnaire was administered through face to face interview of farmers. Informed consent was sought from participant before they were interviewed. Farmers were randomly selected to respond to questionnaire. Sample size of respondents to questionnaire was determined using the conventional statistical model,

$n = (N \div 1)/N(\alpha)^2$ Where; n=sample size; N=sample frame; and α=margin of error, was used to derive the sample size for the administration of questionnaire. Thus the selected number of respondents to questionnaire was determined on a 5% margin of error and total population of farmers at Bonia, Doba and Yigwana (which were 55, 48 and 40 farmers respectively). In all, 120 farmers out of a total of 143 farmers were selected using simple random sampling and interviewed. This consisted of 45 farmers from Bonia, 40 farmers from Doba and 35 farmers from Yigwania. The number of farmers selected were based on the total number of farmers in the study area.

Observational study was conducted by visiting the study areas at regular intervals (thrice a month) from September to December, 2013 to observe the farming practices such as method of irrigation, fertilizer application and pesticide application and the general environmental situation(Plate 1, 2 and 3).

Plate 1: Picture of cattle grazing closed to irrigated farms in the study area.

Plate 2 : Picture of a pumping machine used for withdrawing water from Doba dam for irrigation of vegetables

Plate 3: Picture of pesticide container left closed to Doba dam in the study area

3.2.2 Data collection for bacteriological and physicochemical analysis

Water and tomatoes samples were taken from all the three study sites on a monthly basis starting from January to April, 2014 using simple random sampling. Sampling of irrigation water and tomatoes was carried out in the morning between 8 to 9:00am at the time when farmers irrigate their tomato farms.

3.2.2.1 Sampling of irrigation water

Two hundred milliliters sterile bottles were used to collect water from ten different points at the dam site, and at 20 m intervals along the river and the canal(Plate 4, 5 and 6). The bottle was dipped into the water without opening until about 30cm below the water surface. The bottle was then opened and filled; the cap was then replaced under the water .The samples were stored in ice chest at 4^{0}C and then transported to the Noguchi Memorial Institute for Medical research and ecological laboratory of University of Ghana for the bacteriological and physico-chemical analysis respectively.

Plate 3 : A picture of Bonia canal used by farmers for irrigation of vegetables

Plate 4: A picture of Doba dam used by farmers for irrigation of vegetables

Plate 5 : A picture of Yigwania river used by farmers for irrigation of vegetables

3.2.2.2 Sampling of tomatoes

Once a month, 32 tomatoes samples (each containing four whole tomatoes) were randomly collected using sterile scissors. These were put into separate sterile zip-lock bags and transported on ice chest to the Noguchi Memorial Institute for Medical Research where they were analyzed immediately or stored at 4^0C until analysis.

3.3 Physico-chemical analysis

All laboratory analyses for physicochemical parameters of sampled water were done at the Ecological Laboratory of the Institute of Environment and Sanitation Studies. All protocols and procedures were strictly followed. Parameters analyzed included temperature, pH, electrical conductivity, Total Dissolved Solids, Nitrogen-nitrate, phosphate ions, nitrogen- nitrite, alkalinity, total suspended solids, sodium ions, potassium ions and BOD. All the Laboratory measurements were done under an established standard method (APHA, 2001; WHO, 1994).

Suspended Solids

The level of suspended solids was assessed using spectrophotometer. The Spectrophotometer cell was calibrated to zero reading using 25ml of demineralized water (blank). The water sample was then poured into a 1 litre beaker and 25ml aliquots immediately poured into a sample cell. The prepared water sample was swirled to remove any bubbles to uniformly suspend any residue. Next the sample was placed into the cell holder of the calibrated spectrophotometer set at 810 nm and the reading taken in mg/L suspended solids.

Turbidity

The turbidity of the samples was determined using a Portable Turbidimeter meter (Model 2100P). A sample cell was filled with 15 ml of the water sample and the cell was capped. The cell was wiped with a soft, line-free cloth to remove water spots and fingerprints. A thin film of silicone oil was applied and wiped with the soft cloth to obtain an even film over the entire surface. This was placed in the cell holder and the reading taken in Nephelometric turbidity units (Hach Company, 2001).

Nitrate (NO_3^- -N) Analysis.

The nitrate level in each sample was measured using Nitrate powder Pillows in a direct reading HACH spectrophotometer (Model DR. 2000). A sample cell was filled with 10ml of only the sample (blank). The blank sample was placed in the spectrophotometer for calibration. Ten (10) ml of the sample was measured into sample cell of the spectrophotometer. One Nitraver 5 Nitrate Reagent powder pillows was added to the sample. The mixture was then shaken vigorously for 1 minute. Five minutes was allowed for the solution to react. An orange colour of the mixture indicates the presence of nitrate. After five minutes, the prepared sample was then placed into the cell holder of the calibrated spectrophotometer to determine the Nitrate-nitrogen concentration at 500 nm in mg/l (Hach Company, 2001).

Nitrogen Nitrite (NO_2^-) Analysis

The nitrite level in each sample was measured using nitrite reagent powder pillows in a direct reading HACH spectrophotometer (Model DR.2000). A sample cell was filled with 10ml of only the sample (blank). The blank sample was placed in the spectrophotometer for calibration (zeroing). Ten (10) ml of the sample was measured into sample cell of the spectrophotometer. One Nitraver 3 Nitrate Reagent powder pillows was added to the sample. The mixture was then shaken vigorously to dissolve the powder. A 20-minute was allowed for the solution to react. A pink colour of the mixture indicates the presence of nitrite. After the 20-minutes, the prepared sample was placed into the cell holder to determine the nitrite concentration at 507nm in mg/l (Hach Company, 2001).

Phosphate Phosphorus (PO_4^{3-})

A sample cell (the blank) was filled with 10ml of the sample and placed into the cell holder to calibrate it. Ten milliliters of the water sample (prepared sample) was placed in the sample cell. Phosphover 3 phosphate powder pillow was added to the sample content and swirled immediately to mix. A two minute reaction period was allowed and a blue coloration of the mixture indicates the presence of phosphate. After reaction period, the prepared sample was placed into the cell holder and the level of phosphate-phosphorus was determined at 890nm. The spectrophotometer displayed the results in mg/l PO_4^{3-} (HACH, 2001).

Dissolved Oxygen

The Azide modification of the Winkler method was used for the determination of dissolved oxygen test. Two milliliters of concentrated tetraoxosulphate (VI) acid (H_2S0_4) was added to the samples which had already been fixed on the field with 2ml each of Winkler 1 (Manganous chloride) and Winkler 2 (alkaline- Iodide- azide reagents. Hundred militres of the sample was titrated with 0.025 M sodium thiosulphate ($Na_2S_20_3$) to a pale straw colour. Two milliliters of starch solution was added as indicator and titrated till first disappearance of blue colour (APHA, 2001).

The calculation is as below;

For titration of a 100ml sample, mg/l 02 = vol. of M/80 thiosulphate used × 101.6

Biological Oxygen Demand (BOD)

The BOD test involved filling a hermetically sealed BOD bottle with the sample of water and incubating it at the specified temperature for five days. The Dissolved oxygen was measured initially and after incubation, the BOD was found by the difference between the initial and the final DO. The dilution water was prepared by 1 ml each of phosphate buffer, Magnesium sulphate, calcium chloride and iron (III) chloride solution per litre of water (APHA, 2001).

Mathematically the BOD was computed as below;

BOD_5 mg/l = D1– D2. D1 and D2 were the dissolved oxygen content before and after incubation respectively.

3.4 Bacteriological Analysis

3.4.1 Enumeration of bacteria load in irrigation water

The bacteria load/burden (heterotrophic bacteria and coliform count) in the irrigation water were determined by the pour plate method. One milliliters (ml) of a thoroughly mixed water sample was transferred into a sterile bottle containing 9ml of Phosphate buffered saline(PBS) to make a 10^{-1} dilution. Serial dilutions from 10^{-2} to 10^{-7} were made by transferring 1ml volume of 10^{-1} dilution into a test tube containing sterile 9ml PBS to make the 10^{-2} dilution and until a 10^{-7} dilution was obtained. With the aid of a pipette, hundred microliters of each dilution was transferred into respective labeled petri-dish.

Total heterotrophic bacterial count and total coliform count were determined by culturing each dilution in the labeled petri dishes with plate count agar (PCA) and *E. coli* coliform selective (ECS) media respectively. The ECS media for enumeration of total coliform and faecal coliform was incubated at 37^{0}C and 44^{0}C for 24 to 48 hours respectively whiles that of heterotrophic bacteria count was incubated at 37^{o}C for 18 - 24 hours. Bacterial counts were made using a colony counting chamber (Gallen Kamp, UK). Plates showing counts between 30 - 300 colonies were selected and their total colony forming unit per gramme (cfu /g) calculated by multiplying the count by the dilution factor (plate 7).

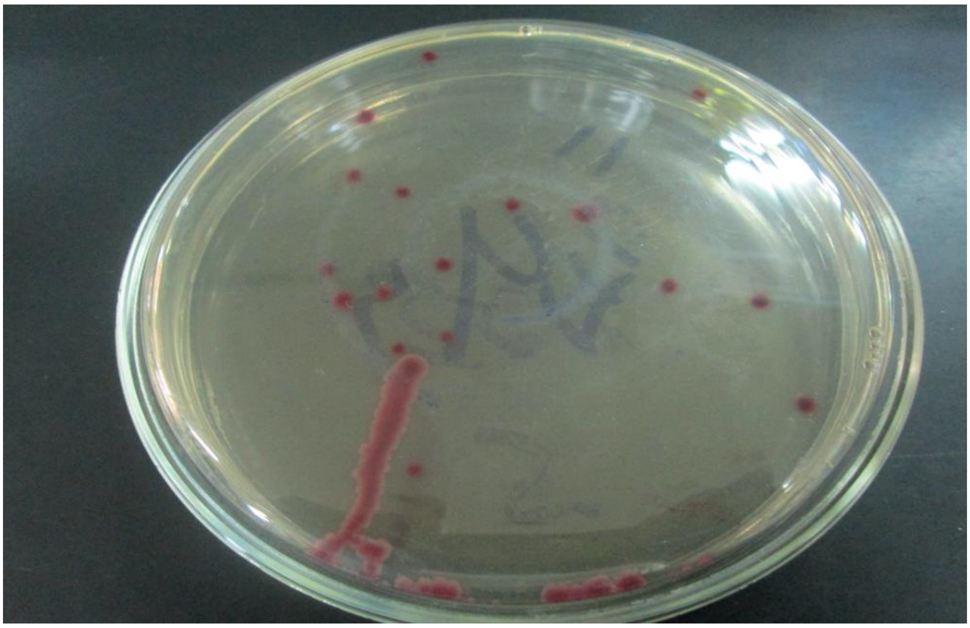

Plate 6: Picture of faecal coliform growing on *E.coli* coliform selective media

3.4.2 Enumeration of bacteria load on tomatoes

The bacteriological quality of the samples was determined by the pour plate method. Bacteriological examination was carried out on both internal and external parts of the tomato. For the examination of the external tomato parts, about ten grammes (10g) of whole tomatoes sample were weighed and transferred into a small stomacher bag.

Ninety ml of Phosphate buffered saline (PBS) was added and after thoroughly washing, the resultant PBS solution was transferred into a sterile bottle to make a 10^{-1} dilution. Serial dilutions from 10^{-2} to 10^{-7} was made by transferring 1ml volume of 10^{-1} dilution into a test tube containing sterile 9ml PBS to make the 10^{-2} dilution until a 10^{-7} dilution is obtained.

For examination of the internal tomato parts, whole tomato samples were opened aseptically after sanitizing with chlorine (100ppm) and 1 g of the inner tissues were weighed and transferred into sterile bottles containing 9ml PBS solution. The mixture was macerated and 1ml used to prepare tenfold serial dilution to obtain a range of 10^{1} to 10^{7}.

With the aid of a pipette, hundred microliters of each dilution was transferred into respective labeled petri-dish. Heterotrophic bacterial, total coliform and faecal coliform counts were determined by culturing with PCA and *E. coli* coliform selective media respectively. The culture media for enumeration of total coliform and faecal coliform were incubated at 37^{0}C and 44^{0}C for 24 to 48 hours respectively whiles that of heterotrophic bacteria count was incubated at 37^{o}C for 18-24 hours.

Bacterial counts were made using a colony counting chamber (Gallen Kamp, UK). Plates showing counts between 30 - 300 colonies were selected and their total colony forming unit per gramme (cfu/g) calculated by multiplying the count by the dilution factor.

3.5 Identification of bacteria pathogens in irrigation water and tomato samples

3.5.1 Bacteriological media inoculation and incubation

Four milliliters of each of the 10^{-1} dilution of the tomatoes and irrigation water samples were transferred into centrifuge tubes and centrifuged at 3,800 rpm for 15 minutes. The supernatant were discarded and pellets streaked on Blood Agar and also inoculated into 10ml selenite broth for the selective enrichment of *Salmonella* and *Shigella spp* and incubated at 37^{o}C for 18 - 24 hours.

3.5.2 Gram staining

Procedure; A sterile loop was used to transfer a portion of the colony on a cultured plate and emulsified using a drop of distilled water on a clean microscopic slide, and smeared evenly. This was fixed by passing three times on a gentle flame. The smear was flooded for one minute with crystal violet stain. The crystal violet stain was washed thoroughly in a gentle jet of water (tap water). After that, the smear was flooded for one minute with lugol´s iodine solution. This was also washed under running tap water and the excess water blotted. Stained smears were decolorized by adding drops of 95% acetone over the slide until streaks of colour stopped coming from the smear. The slide was then washed immediately in water and the excess water drained off from the slide. This was followed by the addition of safranin, to counterstain, for 10 - 30 seconds. This was again washed under slow running tap water, blotted with filter paper, dried and examined by microscope using the oil immersion objective.

3.5.3 Biochemical identification assay

Gram positive bacteria

Catalase test

This assay tests the presence of the catalase enzyme which catalyzes the decomposition of hydrogen peroxide to free oxygen gas and water.

$2H_2O \rightarrow H_20 + O_2$

It is used to differentiate between *Staphylococci spp* and *Streptococci spp.*

Procedure: an 18-24hr old colony was purified by sub culturing the isolates. A small amount of the colony was carefully collected without the agar to prevent false positive reaction and placed on a clean glass slide. Using a Pasteur pipette, a drop of 3% hydrogen peroxide was put onto the colony. immediate effervescence (evolution of gas bubbles or white foam) indicated positive reacton.

Staphylase test

Further identification of the catalase positive staphylococci was done using the staphyase kit prolix TM latex agglutination system (pro-Lab Diagnostics) to differentiate between *Staphylococcus aureus* and other *staphylococci species*. *S. aureus* produces coagulase and cell wall protein called protein A that binds with the carrier portion of the IgG molecule. If *S. aureus* is present, the coagulase reacts with the fibrinogen and the IgG reacts with the protein A to cause clumping. **Pocedure:** A loop full of catalase positive cocci was emulsified into the latex agglutination test reagent. Coagulation was a positive reaction for *Staphylococcus aureus*

Identification of Gram negative bacteria

Oxidase test

The oxidase test is a biochemical reaction that assays for the presence of cytochrome oxidase, an enzyme sometimes called indophenol oxidase. In the presence of an organism that contains the cytochrome oxidase enzyme, the reduced colorless reagent becomes oxidized to a dark blue.

Procedure: A piece of filter paper was soaked in freshly prepared oxidase reagent (N, N, *N', N'* - tetramethyl - *p* - phenylenediamine dihydrochloride in distilled water). Fresh and discrete bacterial colonies culture on solid medium for between 18 - 24hrs were then scraped with a sterile inoculating loop and rubbed onto the filter paper. The filter paper was examined after 10 seconds for blue colour which signifies positive oxidase reaction.

Sulphide, indole production and motility assay (SIM)

SIM assay is used to differentiate enteric bacilli on the basis of sulfide production, indole formation and motility.

Procedure: A short inoculating wire with a straight nichrome needle was used to inoculate the SIM medium by stabbing and incubated for 18hrs. Blackening of the tube indicate sulphide production; formation of a deep pink colour over the medium indicate an indole positive reaction and cloudiness throughout the medium, or a brush-like growth around the line of inoculation indicate the test organism is motile.

Confirming bacterial species using analytical profile index (API 20 E biomerieux) test kit

Proceedure: Using a sterile cotton swab, a single well isolated colony was removed from an isolation plate and carefully emulsified in about 5 ml of sterile distilled water to achieve a homogenous bacterial suspension. Using the same pipette, both the tube and the cupule in the API test kit were filled with bacterial suspension. For the other tests only the tubes (and not the cupule) were filled. Anaerobic conditions were created in the tests arginine dihydrolase (ADH), lysine decarboxylase (LDC), ornithine decarboxylase (ODC), hydrogen sulphide production (H_2S) and urease (URE) by overlaying the bacterial suspension with mineral oil. The incubation box was then closed and incubated at 37^{o}C for 18 – 24 hours.

DATA ANALYSIS

3.6 Data handling and analysis

The results were analyzed by Analysis of Variance (ANOVA) using SPSS Statistix 9 software (SPSS Inc., Chicago. IL, USA). All data were double-keyed and cross tabulated to ensure the accuracy of the entries made.

The responses in the questionnaires were coded and subsequently analyzed using statistical test. Descriptive statistics such as geometric mean, frequencies, prevalent rates and ranges was used for the study variables. ANOVA was used to compare faecal coliform levels on tomatoes from different farms.

Total bacterial counts were computed and compared to World Health Organization and the International Commission on Microbiological Specifications for Food standards to determine whether the obtained levels were within acceptable limits. Levels were interpreted as no contamination, within acceptable limits and above acceptable limits.

Levels of contamination and isolated organisms were classified as having no risk, low risk and high risk.

The t-test (one sample) was used to test significance of difference between mean faecal coliform levels on tomatoes and in irrigation water from the different sites. Significant difference of the physicochemical parameters of the water from the various irrigation schemes was also computed. Significant levels were based on a p value less than 0.05.

CHAPTER FOUR

4.0 RESULTS

4.1 Demographic Characteristics of respondents

A total of 120 farmers responded to questionnaire (Appendix A). The analysis showed that different age groups of people are directly involved in tomatoes and other vegetable cultivation in the study area (table 4). Most of the 120 respondents were within the ages of 20 and 40 years represented by 35 farmers (77.8%) from Bonia, 31 farmers (77.5) from Doba and 22(62.9%) from Yigwania. Only 8 (17.7%), 9 (22.5%) and 9 (28.6%) farmers in Bonia, Doba and Yigwania respectively were above 40 years of age (Table 4.1).

Of the 120 farmers, 42 (93.3%) farmers from Bonia, 38(95%) from Doba and 34(97.1%) farmers from Yigwania were males. Only 3 (6.7%), 2 (5%) and 6 (5%) respondents from Bonia, Doba and Yigwania respectively were females.

Majority of the farmers in the three areas were Christians. Thirty one (68.9%), 36 (90%) and 32 (91%) of the farmers interviewed at Bonia, Doba and Yigwania respectively were Christians. However, Moslems represented12 (26.7%) of farmers in Bonia, 1 (2.5%) in Doba and 1 (2.9%) in Yigwania.

Thirty three (73.3%), 33 (82.5) and 32 (91.4) of the farmers interviewed in Bonia, Doba and Yigwania respectively have not had more than six years of formal education. Farmers with secondary and tertiary education represented 12 (26.7%) of the farmers in Bonia, 7 (17.5%) of the farmers in Doba and 3 (8.6%) of the farmers in Yigwania (Table 4.1).

The study also found only 20 (44.4%) respondents in Bonia, 7 (17.5%) respondents in Doba and 9 (25.8%) respondents in Yigwania have had formal training in irrigation and

15(28.9%) respondents in Bonia, 26 (65%) in Doba and 29 (82.9%) in Yigwania have been cultivating tomatoes for more than ten years (Table 4) .Thirty three percent of the farmers in Bonia have been in vegetable cultivation business for more than 10 years while whiles Doba and Yigwania registered 65% and 86% respectively. Vegetable farming seems to be a common occupation among the inhabitants in the three areas.

TABLE 4 : Demographic characteristics of respondents.

Parameter	Frequency of responses		
	Bonia (N=45) (n, %)	Doba (N=40) (n, %)	Yigwania (N=30) (n, %)
Age(years)			
< 20	2(4.5)	0	3(8.5)
20-30	20(44.5)	21(52.5)	15(42.9)
31-40	15(33.3)	10(25)	7(20)
> 40	8(17.7)	9(22.5)	10(28.6)
Sex			
Male	42(93.3)	38(95)	34(97.1)
Female	3(6.7)	2(5)	1(2.9)
Literacy status			
No formal education	19(42.2)	20(50)	26(74.3)
Primary	14(31.1)	13(32.5)	6(17.1)
Secondary	10(22.2)	5(12.5)	3(8.6)
Tertiary	2(4.5)	2(5)	0
Religion			
Christian	31(68.9)	36(90)	32(91.4)
Moslem	12(26.7)	1(2.5)	1(2.9)
Formal training in irrigation			
Offered agriculture at senior high school	3(6.7)	1(2.5)	1(2.9)
Through agricultural extension officers	22(48.9)	5(12.5)	8(22.9)
Through agricultural training institute	2(4.4)	1(2.5)	0
No formal training	18(40)	33(82.5)	26(74.2)
Years spent in irrigated vegetable farming			
1-10	30(66.7)	14(35)	6(17.1)
11-20	9(20)	22(55)	17(48.6)
>20	6(8.9)	4(10)	12(34.3)

No statistically significant relationship between years spent in irrigation and the level of water and tomatoes contamination was detected by using a one-way analysis of variance

(ANOVA: P > 0.05). There was however significant difference between level of education and contamination level of irrigation water and tomatoes (ANOVA: P<0.05). Respondents with higher education level were more likely to avoid contamination of irrigation water and tomatoes crops (ANOVA: *P*<0.05). There was also significant difference (ANOVA: P<0.05) in formal irrigation training and level of contamination of irrigation water and tomatoes crops. Farmers who had formal training in irrigation were more likely to avoid contamination of irrigation water and food crops.

4.2 Environmental Assessment

4.2.1 Source of Water and Mode of Irrigation

The main sources of water for irrigation of vegetables in the study area are irrigation canals, dams, rivers/streams and hand dug wells. Regarding the mode of irrigation, 42 (35.0%) out of the 120 respondents, used rubber hose connected to a pumping machine to withdraw water from any of the identified sources. Of these, 12 (26.7%) of them were from Bonia, 21 (52.5%) from Doba and 9(25.7%) from Yigwania. The study revealed only a few respondents (16.7%) used watering cans for irrigation. Of these, only 1 (2.2%) respondent from Bonia, 8 (20%) respondents from Doba and 11 (31.4) respondents from Yigwania used watering cansfor irrigation (Figure 4).

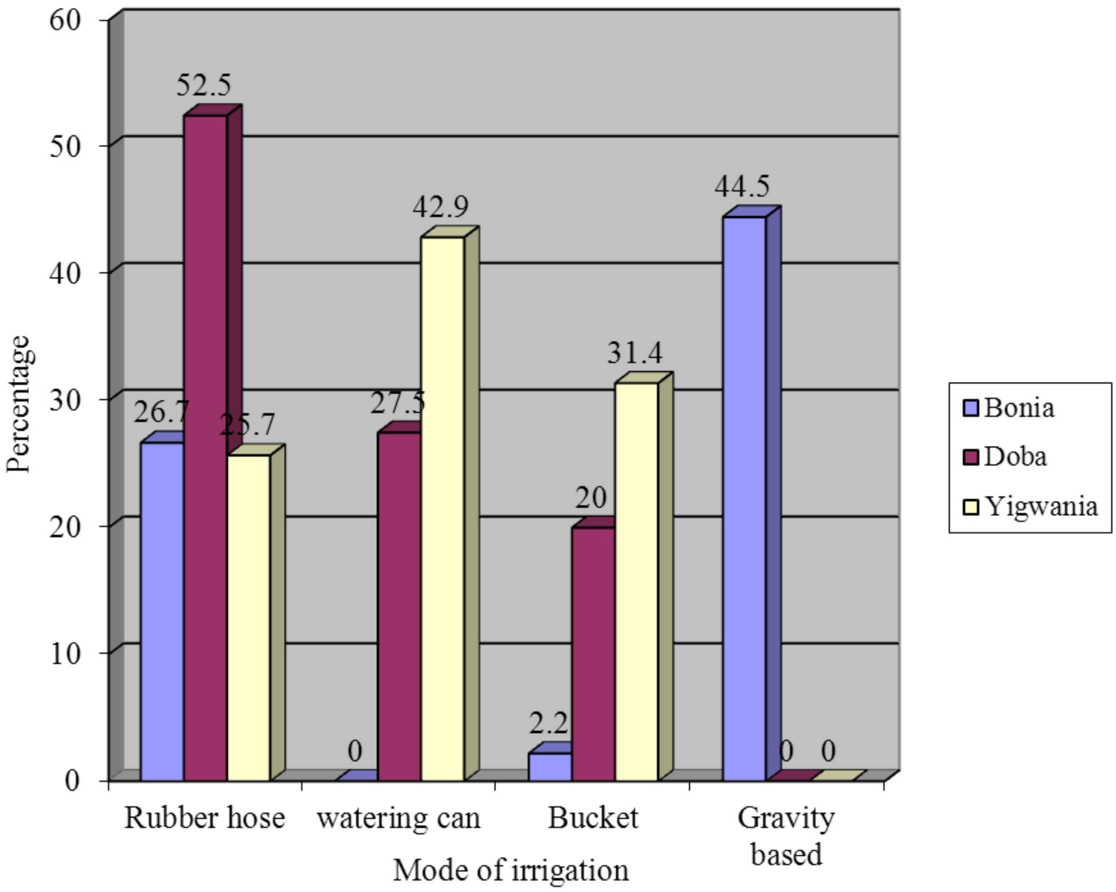

Figure 4: Percentage of respondents that use different mode of irrigation in tomato production

4.2.2 Fertilizer and Pesticides Use

The main types of fertilizers used by the farmers in the study area were inorganic fertilizers and organic fertilizers. Organic fertilizer use was found to be generally low compared to the use of inorganic fertilizers. The results showed that 1 (2.2%) of the respondents from Bonia, 2 (5%) from Doba and 5 (14.3%) from Yigwania use poultry manure as fertilizer whiles 8 (20%) and 7 (20%) of the respondents in Doba and Bonia respectively used cow dung (Table 5). There were signicant difference (ANOVA:

P<0.05) between level of education and avoidance of the use of fresh manure. Respondents with higher education level were more likely to avoid applying fresh manure to growing crops (p = .038)

Pesticide use in the study area was found to be common. The most frequently used pesticide is karate (60%) followed by roundup (24.2%) and furadan (18.3%) (Table 5).

It was also observed that, farmers mixed the pesticides into a sprayer (knapsack) and used it to spray directly on the crops. Furthermore, farmers in the area used the water source for irrigation to mix the pesticide. Findings from the study also showed that only 5 (12%) respondents from Doba and 6 (17.1%) from Yigwania wear goggles, gloves, coat, boots, and nose mask when applying pesticides (Table 5).

TABLE 5 : Type of pesticides and fertilizers used by farmers for vegetables cultivation in the study area

		Respondents		
Type of pesticide		Bonia	Doba	Yigwania
Brand name	Active ingredient	n(%)	n(%)	n(%)
Cymethoate	Cypermethrin	7(15.6)	0	2(5.7)
Karate	Lamda cyhalothrin	35(77.8)	29(72.5)	9(25.7)
Dursban	Chlorpyrifos	8(17.8)	7(17.5)	6(17.1)
Furadan	Carbofuran	9(20)	8(20)	5(14.3)
Diathane	Mancozeb	12(26.7)	3(7.5)	5(14.3)
Kocide	Copper-hydroxide	7(15.6)	0	1(2.9)
Perfekthion	Dimethoate	3(6.7)	0	0
Topsin	Methylthiophanate.	0	0	2(5.7)
Roundup	Glyphosate	18(40)	5(12.5)	6(17.1)
Thiodan	Endolsufan	5(11.1)	2(5)	0
DDT	Dichloro-Diphenyl-Trichloro-Ethane	3(6.7)	3(7.5)	2(5.7)
Protective measure used for pesticides application				
Goggles+gloves+coat+ boots +nose mask		8(17.8)	5(12.5)	6(17.1)
Goggles+ gloves+coat + boot		5(11.1)	2(5)	0
Gloves+coat+boot + nose mask		2(4.4)	0	0
Gloves+ boot + nose mask		5(11.1)	0	1(2.9)
Goggles + nose mask		6(13.3)	2(5)	2(5.7)
Boot + nose mask		3(6.7)	5(12.5)	3(8.6)
Gloves and boot		8(17.8)	3(7.5)	4(11.4)
None		8(17.8)	23(57.5)	19(54.3)
Type of fertilizer				
Inorganic fertilizer		41(91.1)	12(30%)	9(25.7%)
Inorganic fertilizer+poultry droppings		0	4(10%)	3(8.6%)
Inorganic fertilizer+cow dung		0	5(12.5%)	6(17.1%)
Poultry droppings		4(8.9%)	2(5%)	5(14.3)
Poultry droppings +cow dung		0	5(12.5%)	2(5.7%)
Cow dung		0	8(20%)	7(20%)

4.2.3 Animal Intrusion on Farm

Field observation showed that cattle and other domestic animals are reared by the free range system in the study area. Of the 120 farmers, 25 (55.6) from Bonia, 23 (57.5) from Doba and 18 (51.42) from Yigwania did not prevent wild animals from entering to their farms (Figure 5).

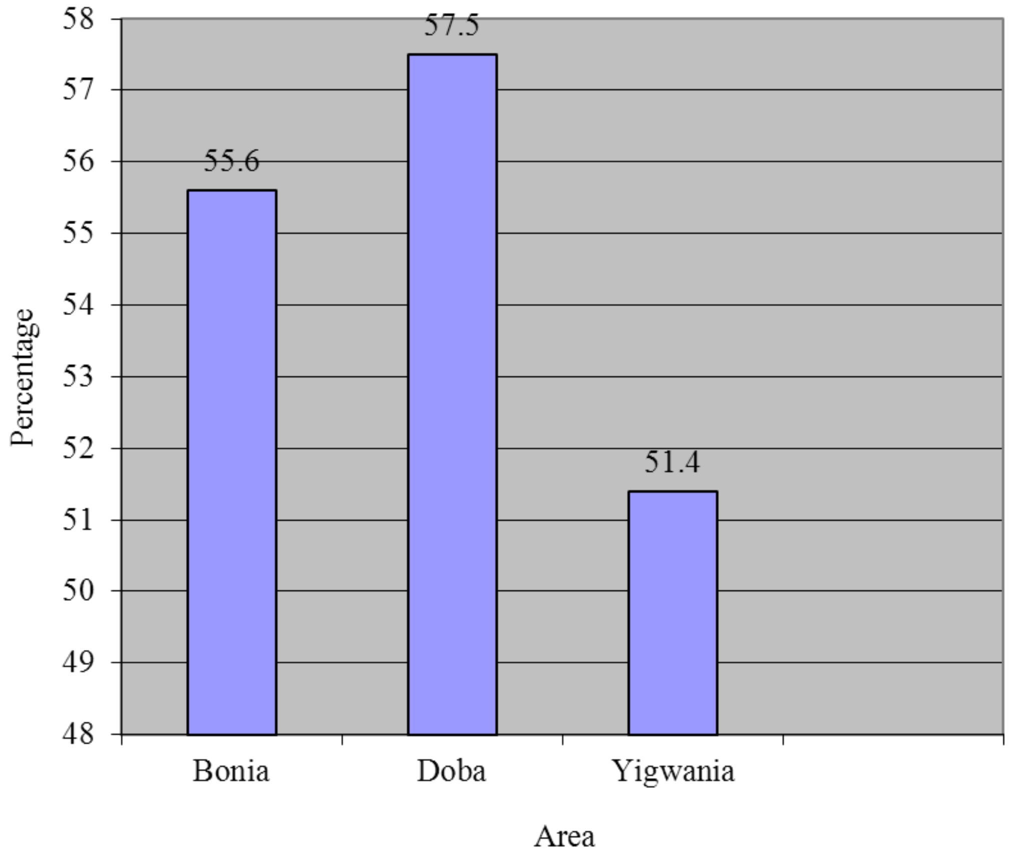

Figure 5: Percentage of respondents that did not prevent wild animals from entering their farms

4.2.4 Environmental Sanitation and Health Situation

None of the irrigation scheme had a toilet facility; farmers therefore practice open defecation close to the water bodies and the farms. The three main health problems in the study area as indicated by the farmers were malaria, schistosomiasis and diarrhea (Figure 6)

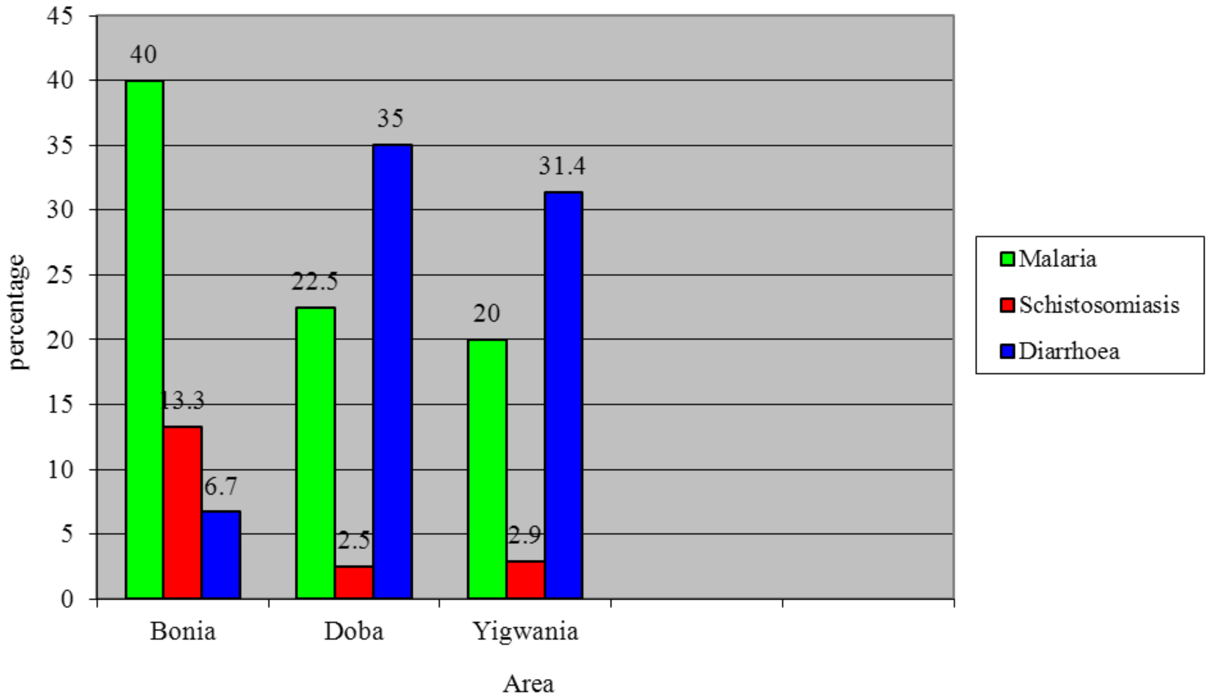

Figure 6 : The main health complains given by respondents

4.2.5 Physicochemical and Bacteriological Characteristics of Irrigation Water Samples

Irrigation water samples were collected from canal, dam and river water bodies in the study area. Twelve irrigation water samples per month were collected from the canal water source at Bonia whiles 10 samples each was collected from dam and river water sources at Doba and Yigwania for three months from February to April 2014.

Findings of the physicochemical analysis of the respective irrigation water are shown in Table 6. The measured values of pH for canal water samples ranged from 6.70 to 7.90, while that of the dam and river water samples ranged from 6.50 to 7.0 and 6.5 to 7.3 respectively. Even though the multiple comparison showed significant difference (ANOVA: $P < 0.05$) in mean values of pH levels between canal and dam as wells as dam and river, there was no significant difference between the canal and river water (ANOVA: $P > 0.05$) as shown in appendix B. However, the mean values of pH were within the food and agricultural organization (FAO) recommended levels for water used for irrigating agricultural crops.

The temperature level between the three water sources showed no significant difference (ANOVA: $P > 0.05$). Temperature of the water samples ranged from 26.5^{0}C to 29^{0}C for canal, 26.7^{0}C -27.9^{0}C for dam and 27.13^{0}C - 27.7 ^{0}C for river water (Table 6)

Electrical conductivity (EC) of different water sources in the study area ranged from 98.0 µs/cm to 564µs/cm in canal water, 142µs/cm to 564 µs/cm in dam water and 312 µs/cm to 400 µs/cm in river water. There was significant difference (ANOVA: $P < 0.05$) in the mean values of the EC between the various water sources (Appendix B). However, the mean values of EC in the water sources were within the food and agricultural organization (FAO) recommended levels of water used for irrigating crops of EC ≤ 3000 µs/cm.

The mean nitrate levels in the water samples differed significantly (ANOVA: $P < 0.05$). The dam had the highest mean value of 23.35mg/l and ranged from 21mg/l - 24.9mg/l. The mean value of nitrate levels in the river water source was 11.77 mg/l with a range of 9.4mg/l - 14.3mg/l. Canal water had the least mean nitrate level of 1.62mg/l and a range of 1.10mg/l-2.8mg/l (Table 6).

Nitrite levels in the water sampled from the various sources also differed significantly (ANOVA: $P < 0.05$) (Appendix B). Nitrite levels in irrigation water ranged from 0.80mg/l - 2.01mg/l with a mean value of 1.05mg/l for canal; 9.40mg/l - 14.3mg/l with a mean value of 11.82mg/l for dam and 4.21mg/l-10mg/l with a mean a mean value of 7.56mg/l for river water (Table 6).

The concentration of phosphate ions in the water sources differed significantly (ANOVA: $p < 0.05$). The concentration of phosphate ions in canal water samples ranged from 1.2mg/l - 1.8mg/l, whilst the concentration of phosphate ions in dam water samples varied from 20.1mg/l to 24.7mg/l and river water samples ranged from 1.4mg/l to 2.8mg/l.

The dissolved oxygen content between the water sources was not significantly different.

The dissolved oxygen content in water sources ranged from 0.8 to 7.5mg/l for canal, 1.4 to 6.9 mg/l for dam and 1.4 to 6.8mg/l for river water samples (Table 6).

TABLE 6 : Physico-chemical characteristics of irrigation water samples from the study area

	Source							
	Bonia(canal)		Doba(dam)		Yigwania(river)			
Parameter	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Sig.	WHO standard
Ph	6.94	0.25	6.76	0.14	6.92	0.22	0.001	6.5-8.5
EC/µs/cm	122.47	13.91	301.27	123.5	357.2	24.53	0	<3000
Turbidity/ mg/L	14.5	1.56	210.13	94.29	288.2	180.76	0	-
Nitrate ions /mg/L	1.62	0.49	23.31	1.22	11.77	0.21	0	
Nitrite ions/mg/L	1.05	0.24	11.82	1.19	7.56	1.83	0	5-20
Phosphate ions /mg/L	1.54	0.17	23.35	1.1	2.15	0.39	0	200
Dissolved oxygen/mg/L	5.3	2.34	5.05	2.13	4.65	2.17	0.498	5
BOD/mg/L	4.62	2.76	6.09	1.02	5.92	1.52	0.005	10
Temperature	27.02	0.46	27.1	0.34	26.99	0.36	0.55	-

*** BOD-Biological Oxygen Demand** ***EC-Electrical conductivity**

To investigate the association, of the Physico-chemical parameters of the irrigation water in the study area, Pearson's Product moment correlation coefficient was used. During the study period, considerable numbers of significant positive correlation were observed in the various water sources. The significant positive correlation observed for the physicochemical parameters for canal water are: pH and BOD (Correlation test: $P < 0.01$), pH and Temperature (Correlation test: $P < 0.01$), EC and Turbidity (Correlation test: $P < 0.01$), EC and DO (Correlation test: $P < 0.01$), Turbidity and EC (Correlation test: $P < 0.05$), turbidity and TDS (Correlation test: $P < 0.01$), Turbidity and DO (Correlation test: $p < 0.01$) (Table 7)

The significant positive correlation observed for the physicochemical parameters for Dam water are: pH and EC (Correlation test: $P<0.01$), pH and Salinity (Correlation test: $P < 0.01$), pH and nitrate (Correlation test: $P < 0.01$), pH and Phosphate (Correlation test: $P < 0.01$), pH and DO (Correlation test: $P < 0.01$), EC and Nitrate ($P < 0.01$), EC and Phosphate ($P<0.01$), EC and DO Correlation test: ($P < 0.01$), Turbidity and Potassium (Correlation test: $p < 0.05$), Turbidity and Temperature (Correlation test: $P < 0.01$), Nitrate and DO (Correlation test: $P<0.01$), Nitrate and BOD (Correlation test: $P < 0.01$), Nitrate and Temperature (Correlation test: $p<0.01$), Nitrite and Phosphate ($p < 0.01$), Nitrite and DO (Correlation test: $P < 0.01$) BOD and Temperature (Correlation test: $P < 0.01$) (Table 8).

The significant positive correlation observed for the physicochemical parameters for River water are: pH and EC (Correlation test: $P < 0.01$), pH and turbidity (Correlation test: $P < 0.01$), pH and Nitrite (Correlation test: $P < 0.01$), pH and TDS (Correlation test: $P < 0.01$), EC and Turbidity (Correlation test: $P < 0.01$), EC and Nitrite (Correlation test: $P < 0.01$), EC and DO (Correlation test: $P < 0.01$), Turbidity and DO (Correlation test: $P < 0.01$), Nitrate and DO (Correlation test: $P < 0.01$), Nitrite and DO (Correlation test: $P < 0.01$), BOD and Temperature (Correlation test: $P < 0.01$) (Table 9)

TABLE 7 Pearson Product-moment correlation coefficient between the studied physic-chemical parameters in canal water samples

	PH	EC	Turb	NO_3^-	NO_2^-	PO_4^{3-}	DO	BOD	Temp
PH	1	-.464**	-0.268	-0.036	-0.26	0.031	-.557**	.562**	.862**
EC	-.464**	1	.480**	-0.018	0.166	0.007	.961**	-.842**	-.422*
Turb	-0.268	.480**	1	-0.22	0.211	-0.023	.513**	-.331*	-0.28
NO_3^-	-0.036	-0.018	-0.22	1	-0.253	-.352*	-0.078	-0.307	-0.152
NO_2^-	-0.26	0.166	0.211	-0.253	1	-0.078	0.247	-0.095	-0.11
PO_4^{3-}	0.031	0.007	-0.023	-.352*	-0.078	1	0.008	0.057	0.104
DO	-.557**	.961**	.513**	-0.078	0.247	0.008	1	-.849**	-.484**
BOD	.562**	-.842**	-.331*	-0.307	-0.095	0.057	-.849**	1	.528**
Temp.	.862**	-.422*	-0.28	-0.152	-0.11	0.104	-.484**	.528**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

*EC-Electrical conductivity

*Turb.-Turbidity

*BOD-Biological oxygen demand

*Temp.-Temperature

TABLE 8: Pearson Product-moment correlation coefficient between the studied physico-chemical parameters in dam water samples

	pH	EC	Turb	NO_3^-	NO_2^-	PO_4^{3-}	DO	BOD	Temp
pH	1	.673**	-0.104	-.776**	.659**	.607**	.749**	-.784**	-.606**
EC	.673**	1	-.369*	-.836**	.797**	.530**	.879**	-.889**	-.854**
Turb	-0.104	-.369*	1	0.235	-.379*	0.103	-.420*	0.356	.469**
NO_3^-	-.776**	-.836**	0.235	1	-.855**	-.637**	-.930**	.929**	.859**
NO_2^-	.659**	.797**	-.379*	-.855**	1	.479**	.879**	-.884**	-.770**
PO_4^{3-}	.607**	.530**	0.103	-.637**	.479**	1	.558**	-.463**	-.451*
DO	.749**	.879**	-.420*	-.930**	.879**	.558**	1	-.953**	-.919**
BOD	-.784**	-.889**	0.356	.929**	-.884**	-.463**	-.953**	1	.909**
Temp	-.606**	-.854**	.469**	.859**	-.770**	-.451*	-.919**	.909**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

*EC-Electrical conductivity

*Turb.-Turbidity

*BOD-Biological oxygen demand

*Temp.-Temperature

TABLE 9 : Pearson Product-moment correlation coefficient between the studied physico-chemical parameters in river water samples

	pH	EC	Turb.	NO_3^-	NO_2^-	PO_4^{3-}	DO	BOD	Temp.
pH	1	.786**	.774**	-.380*	.636**	0.133	.801**	-.792**	-.730**
EC	.786**	1	.885**	-0.314	.683**	0.207	.920**	-.763**	-.760**
Turb.	.774**	.885**	1	-.372*	.565**	0.188	.979**	-.799**	-.785**
NO_3^-	-.380*	-0.314	-.372*	1	-0.193	-0.15	-.363*	0.163	0.062
NO_2^-	.636**	.683**	.565**	-0.193	1	0.187	.651**	-.537**	-.562**
PO_4^{3-}	0.133	0.207	0.188	-0.15	0.187	1	0.182	-0.014	-0.232
DO	.801**	.920**	.979**	-.363*	.651**	0.182	1	-.810**	-.786**
BOD	-.792**	-.763**	-.799**	0.163	-.537**	-0.014	-.810**	1	.671**
Temp.	-.730**	-.760**	-.785**	0.062	-.562**	-0.232	-.786**	.671**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

*EC-Electrical conductivity

*Turb.-Turbidity

*BOD-Biological oxygen demand

*Temp.-Temperature

4.2.6 Bacteriological Quality of Irrigation Water and Tomatoes Samples

4.2.6.1 Bacteriological quality of irrigation water

Table 10 shows the heterotrophic bacteria, total coliform and faecal coliform counts in irrigation water sources from Bonia (canal), Doba (dam) and Yigwania (river).

The mean heterotrophic bacteria count between the three water sources showed no significant difference (ANOVA: $P > 0.05$) as shown in appendix C. The mean heterotrophic bacteria count of the water samples ranged from 3.0 x 10^4 cfu/100ml to 6.7 x 10^7cfu/100ml with an average count of 2.77 x 10^6cfu/100ml for canal, 3.20 x 10^5cfu/100ml to 8.0 x 10^9cfu/100ml with an average count of 5.0 x 10^8cfu/100ml for dam and 1.22 x 10^5cfu/100ml to 8.0 x 10^9cfu/100ml with a mean counts of 4.0 x 10^8cfu/100ml for river water (table 10).

The multi comparison (LSD) showed significant difference (ANOVA: $P < 0.05$) in the mean total coliform counts between river water and canal water (ANOVA: $P < 0.05$), and dam water and river water sources (ANOVA: $P < 0.05$) (Appendix C). However, there was no significant difference in total coliform counts between canal samples and dam samples (ANOVA: $P < 0.05$) as shown in appendix C. Total coliform counts of the samples ranged from 3.20 x 10^5cfu/100ml to 6.50 x 10^7cfu/100ml for the canal samples with a mean count of 1.10 x 10^7cfu/100ml; 3.0 x 10^6cfu/100ml to 9.0 x 109cfu/100ml for the dam samples with a mean count of 4.27 x 10^8cfu/100ml and 1.90 x 10^7cfu/100ml to 1.39 x10^{10}cfu/100ml for the river samples with a mean count of 1.44 x 10^9cfu/100ml.

The mean faecal coliform counts of irrigation water samples from the river were significantly higher than samples from canal (ANOVA: $P < 0.05$) (Appendix C). There was no significant difference in faecal coliform counts between river and dam water samples. Faecal coliform count of the water samples ranged from 3.10 x 10^4cfu/100ml to 8.0 x 10^7cfu/100ml with a mean count of (1.28 x 10^7cfu/100ml) for river, 2.41 x 10^5cfu/100ml to 6.0 x 10^7cfu/100ml with a mean value of 6.14 x 10^6cfu/100ml for dam and 7.9 x 10^3cfu/100ml to9.20 x 10^5cfu/100ml with a mean value of 3.30 x 10^5cfu/100ml for canal (Table 10).

The mean faecal coliform counts of the water sources were compared with the World health organization (WHO) recommended levels (1 x 10^3cfu/100ml) for unrestricted irrigation of crops likely to be eaten raw using one sample t-test. The results shows that the faecal coliform levels of each of the water sources were significantly higher than the world Health Organization (WHO, 2006b) standard for unrestricted irrigation since their P values were all less than 0.05 as shown in table 11.

TABLE 10: Mean bacteria load of irrigation water samples and respective irrigation schemes.

	Area/ Source		
	Bonia (Canal)	Doba (Dam)	Yigwania (River)
Parameter	N=36	N=30	N=30
Heterotrophic bacterial count(cfu/100ml)	2.70 x 10^6	4.0 x 10^8	5.0 x10^8
Total coliform(cfu/100ml)	1.10 x 10^7	4.27 x 10^8	1.44 x 10^9
Faecal coliform(cfu/100ml)	3.30 x 10^5	6.14x10^6	1.28 x 10^7

TABLE 11: Mean faecal coliform counts (cfu/100ml) of irrigation water from the various irrigation schemes and the world health organization (WHO) standard for unrestricted irrigation

Source	Mean	Std dev.	Diff. fromWHO standard	p-value
Canal	3.28 x 10^5	2.70 x 10^5	3.28 x 10^5	0
Dam	6.15 x 10^6	1.04 x 10^6	6.15 x 10^6	0.0015
River	1.28 x 10^7	2.35 x 10^7	1.28 x 10^7	0.0028
WHO standard	1 x 10^3			

* Diff. from WHO means differences between the faecal coliform counts in the tomatoes samples from the various sources and ICMSF standard

4.2.6.2 Bacteriological Quality of Tomatoes Samples from the Study Area

Table 12 shows the results of the bacteriological quality of tomatoes sampled from the different irrigation schemes in the Kassena–Nankanna East Municipality. There were significant differences in heterotrophic bacteria, total and fecal coliform counts among the tomatoes samples from Bonia (canal), Doba (dam) and Yigwania (river) at $P < 0.05$.

The mean heterotrophic bacteria count of the external parts of tomato samples from Yigwania were significantly different (ANOVA: $P < 0.05$) from samples from Bonia. There were significant differences(ANOVA: $P<0.05$) between heterotrophic bacteria counts of the external parts of tomatoes sampled from Doba and Yigwania (Appendix C). However, there was no significant difference (ANOVA: $P>0.05$) between the mean heterotrophic bacteria count of the external parts of tomatoes sampled from Bonia and Doba. The mean heterotrophic bacteria count of the external parts of tomatoes samples from Bonia was 1.56×10^6cfu/g with a range of 3.10×10^3cfu/g to 5.0×10^7cfu/g whiles samples from Doba ranged from 1.70×10^6cfu/g to 9.0×10^7cfu/g with a mean count of 3.30×10^7cfu/g. The highest mean heterotrophic count of external parts of tomatoes (8.11×10^7cfu/g) was recorded from Yigwania samples (Table 12).

The mean heterotrophic bacteria counts of the internal parts of tomato sampled from Yigwania was significantly different from the mean heterotrophic bacteria count of the internal parts of tomato samples from Bonia (ANOVA: $P < 0.05$). The mean heterotrophic bacteria counts of the internal parts of tomatoes sampled from Bonia ranged from 3.30×10^3cfu/g to 9.0×10^5cfu/g with a mean counts of 9.39×10^4cfu/g; 3.90×10^4cfu/g to1.22×10^7cfu/g for Doba with a mean count of 1.81×10^6cfu/g and 4.10×10^4cfu/g to 7.10×10^7cfu/g for Yigwania with a mean count of 2.52×10^6cfu/g(Table 4.9)

No significant difference (ANOVA: $P > 0.05$) was observed in the mean total coliforms of the external parts tomatoes samples from the three areas. The mean total coliform count of the external parts of tomatoes sampled from Yigwania was 1.86 x 10^7cfu/g with a range of 1.28 x 10^5cfu/g to 4.0 x 10^8cfu/g. The mean total coliform counts of the external parts of tomato samples from Doba ranged from 3.40 x 10^5cfu/100ml to 4.8 x 10^7cfu/g with a mean value of 7.59 x 10^6cfu/g whilst samples from Bonia ranged from 3.0 x 10^3cfu/g to 5.60 x 10^6cfu/g with a mean value of 3.08 x 10^5cfu/g (Table 12)

The mean total coliform count of the internal parts of tomato samples from Yigwania and Bonia were significantly different (ANOVA: $P < 0.05$) as shown in appendix C. The mean total coliform count of the internal parts of tomatoes sampled from Bonia ranged from 3x10^3cfu/g to 6.20 x 10^5cfu/g with a mean count of 1.11 x 10^5cfu/g; 3.4 x 10^4cfu/g to 6.40 x 10^6cfu/g for Doba with a mean count of 6.70 x 10^5cfu/g and 3.0 x 10^3cfu/g to 9.0 x 10^6cfu/g for samples from Yigwania with an average count of 9.0 x 10^6cfu/g (Table 12)

Faecal coliform count of the external parts of tomato sampled from Yigwania were significantly different from the faecal coliform count of the external parts of tomato sampled from Bonia (ANOVA: $P < 0.05$). Similarly, fecal coliform count of the external parts of tomato sampled from Doba was significantly different from fecal coliform count of the external parts of tomatoes samples from Bonia (ANOVA: $P < 0.05$). The highest mean fecal coliform count of the external parts of tomatoes samples was in samples from Yigwania (4.48 x10^5cfu/g) followed by samples from Doba (3.535 x 10^5cfu/g). Samples from Bonia (canal irrigation) had the least mean fecal coliform count (2.91 x 10^3cfu/g) of the external parts of tomatoes (Table 12).

Faecal coliform counts of the internal parts of tomato samples from Yigwania were significantly different (ANOVA: $P < 0.05$) from mean fecal coliform counts of the internal parts of tomatoes samples from Bonia whiles fecal coliform counts of the internal parts of tomato samples from Doba were significantly different from mean faecal count of the internal pars of tomatoes samples from Bonia (ANOVA: $P < 0.05$) (Appendix C). The mean fecal coliform counts of the internal parts of tomatoes sampled from Bonia, Doba and Yigwania were 1.85×10^2cfu/g, 1.69×10^3cfu/g and 2.66×10^3cfu/g respectively (Table 12)

The mean faecal coliform counts of the external and internal parts of tomatoes samples were compared with the international commission on microbiological specifications for foods (ICSMF, 1974) recommended level of 10^3 fecal coliform per gram fresh weight using a one sample t- test. The results shows that the faecal coliform counts of the external parts of tomatoes sampled from the three different sites were significantly higher than the ICSMF standard since their p -values were less than 0.05 as shown in table 13.

TABLE 12 Mean bacteria load of the external and internal partsof tomatoes samples

Area	Tomatoes part	Parameter		
		Heterotrophic bacteria count (cfu/g	Total coliform Count (cfu/g)	Faecal coliform count (cfu/g)
Bonia	External	1.56×10^6	3.078×10^5	2.91×10^3
	Internal	9.39×10^4	1.11×10^5	1.85×10^2
Doba	External	3.3×10^7	7.59×10^6	3.535×10^5
	Internal	1.81×10^6	6.7×10^5	1.69×10^3
Yigwania	External	8.1×10^7	1.86×10^7	4.48×10^5
	Internal	6.2×10^6	1.08×10^6	2.66×10^3

TABLE 13 Faecal coliform counts (cfu/100ml) in tomatoes samples from the various irrigation schemes and the international commission on microbiological specifications for foods (ICSMF, 1974) standard.

Faecal coliform count (cfu/g) on tomatoes samples compared with ICMSF standard					
Source	Part	Mean	Std dev.	Diff. from ICMSF standard	p-value
Bonia	external	2.91×10^3	2.68×10^3	9.10×10^2	0.0001
	internal	1.85×10^2	2.83×10^2	-8.15×10^2	1
Doba	internal	3.54×10^5	3.48×10^5	3.55×10^5	0
	external	1.69×10^3	2.65×10^3	6.9×10^2	0.083
Yigwania	external	4.48×10^5	6.44×10^5	4.47×10^5	0.0003
	internal	2.66×10^3	2.78×10^3	1.66×10^3	0.0014
ICMSF standard		1×10^3			

Diff. from ICMSF means differences between the faecal coliform counts in the tomatoes samples from the various sources and ICMSF standard.

Twenty seven (60%), 30 (75%) and 27 (77.1%) tomatoes sampled from Bonia, Doba and Yigwania respectively were contaminated externally with faecal coliform. Also, 19 (42.2%), 24 (60%) and 22 (62.9%) of tomatoes samples from Bonia, Doba and Yigwania respectively had their internal parts contaminated with faecal coliform as shown in figure 7

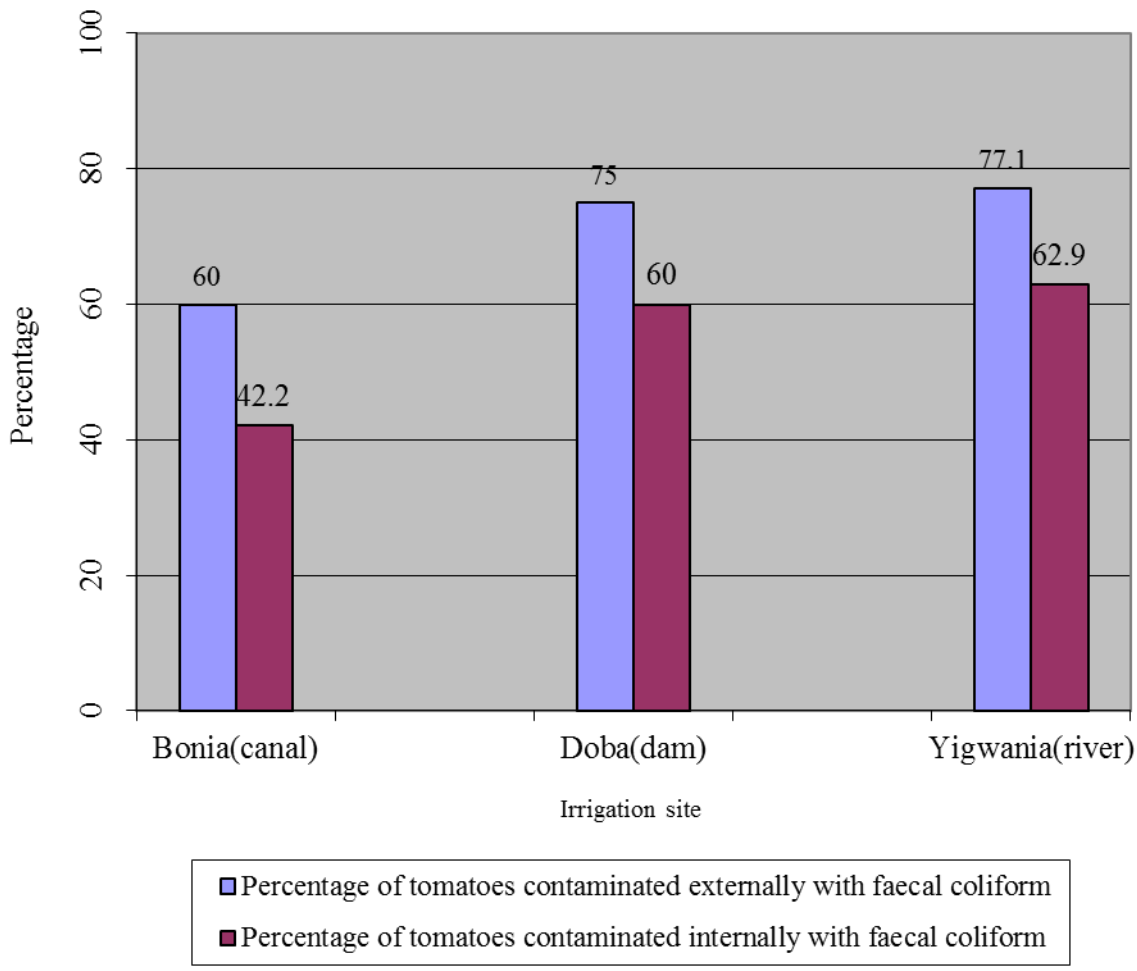

Figure 7: Percentage of tomatoes samples showing external and internal faecal contamination at the various irrigation schemes within the Kassena- Nankana East Municipality

4.2.6.3 Bacterial Species Isolated from the Irrigation Water and Tomatoes Samples

Different bacterial species were identified from different water sources sampled from Bonia, Doba and Yigwania. The dominant bacterial species were *Klebsiella pneumonia*, *Staphylococcus aureus*, *Xantomnas maltophilia*, *Escherichia coli* and *Pseudomonas aeruginosa*. Thirteen (36.1%) of the Bonia samples, 14 (46.6%) from Doba and 12 (40%) from Yigwania were contaminated with *E. coli* whiles 4 (11.1%), 6

(20%) and 5 (15.7%) samples from Bonia, Doba and Yigwania respectively were contaminated with *Staphylococcus aureus* (Table 14).

Similar bacteria species were also isolated from the external and internal parts of the tomatoes samples. Four (11%) of the samples from Bonia, 6 (20%) from Doba and 8 (26.7%) from Yigwania were externally contaminated with *E. coli* whiles 2 (2.8%), 4 (13.3) and 3 (10%) samples from Bonia, Doba and Yigwania respectively were externally contaminated with *Staphylococcus aureus* (Table 5.2). One (2.8%), 3 (10%) and 4 (13.3%) samples from Bonia , Doba and Yigwania respectively were internally contaminated with *Staphylococcus aureus* (Table 15).

TABLE 14: Bacteria species isolated from irrigation water samples from the different irrigation schemes.

water source	Bacteria species	Frequency	Percentage
Bonia (N=36)	*Escherichia coli*	13	36.1
	Staphylococcus aureus	4	11.1
	Klebsiella species	12	33.3
	Staphylococcus spp	8	22.2
	Faecal enterococci	9	25
Doba (N=30)	*Staphylococcus spp*	8	22.2
	Faecal enterococci	14	38.9
	Escherichia coli	14	46.6
	Staphylococcus aureus	6	20
	Klebsiella species	17	56.7
	Staphylococcus spp	12	40
	Faecal enterococci	13	43.3
	Klebsiella pneumoniae	3	10
	Enterobacter spp	8	26.7
	Xantomonas maltophilia	3	10
	Pseudomonas spp	8	26.7
Yigwania (N=30)	*Escherichia coli*	12	40
	Staphylococcus aureus	5	16.7
	Klebsiella species	20	66.7
	Staphylococcus spp	11	36.7
	Fecal enterococci	16	53.3
	Klebsiella pneumoniae	5	16.7
	Enterobacter spp	8	26.7
	Xantomonas maltophilia	4	13.3
	Pseudomonas spp	10	33.3

TABLE 15: Bacteria species isolated from the external parts of tomatoes samples from the different irrigation schemes

Source of tomatoes sample	Bacteria species	Frequency	Percentage
Bonia (N=36)	*Escherichia coli*	4	11
	Staphylococcus aureus	2	2.8
	Klebsiella species	8	22.2
	Staphylococcus spp	3	8.3
	Faecal enterococci	5	13.9
Doba (N=30)	*Escherichia coli*	6	20
	Staphylococcus aureus	4	13.3
	Klebsiella species	14	46.7
	Staphylococcus spp	7	23.3
	Faecal enterococci	4	13.3
	Klebsiella pneumoniae	2	6.7
	Enterobacter spp	4	13.3
	Xantomonas maltophilia	3	10
	Pseudomonas spp	4	13.3
Yigwania (N=30)	*Escherichia coli*	8	26.7
	Staphylococcus aureus	3	10
	Klebsiella species	7	23.3
	Staphylococcus spp	9	30
	Faecal enterococci	7	23.3
	Klebsiella pneumoniae	2	6.7
	Enterobacter spp	3	10
	Xantomonas maltophilia	2	6.7
	Pseudomonas spp	4	13.3

N is the number of samples taken from the irrigated farms

TABLE 16: Bacteria species isolated from the internal parts of tomatoes samples from the different irrigation schemes

Source of tomatoes sample	Bacteria species	Frequency	Percentagee
Bonia (N=36)	*Escherichia coli*	1	2.8
	Staphylococcus spp	2	5.6
Doba (N=30)	*Escherichia coli*	3	10
	Staphylococcus spp	1	3.3
	Klebsiella species	4	13.3
Yigwania (N=30)	*Escherichia coli*	4	13.3
	Staphylococcus spp	2	5.6
	Klebsiella species	2	5.6

N is the number of samples taken from the irrigated farms

CHAPTER FIVE

5.0 DISCUSSION

5.1 Demographic Characteristics of Respondents

Gender plays an essential role in agricultural development in the Kassena-Nankana East Municipality. Agriculture is a male dominated occupation within the Municipality. According to tradition, males are the heads of the family and are responsible for providing food for the family. Women on the other hand are responsible for processing, preserving and marketing of farm produce.

The descriptive statistics from this research revealed that 95% of those involved in tomatoes and other vegetables production were males whiles 5% were females. This is in line with Drechsel *et al* (2006) who reported that, in 16 out of 20 cities in West Africa, men are mostly involved in open-space urban vegetable farming while women dominated the vegetable retail sector. This assertion is however contrary to studies conducted in some in East Africa indicated that women form the majority of vegetable farmers (Sawio, 1994; Mvena *et al*., 1991; Rakodi, 1988). The contradictions might be the result of different traditions that exist among African countries.

Age plays a vital role in determining the productivity of agriculture; both the youth and elderly are the front line of farming in Ghana and sub Saharan Africa. The findings established that those who were within the age group of 20-50 years dominated with a percentage of (96%) whiles those who were less than 20 years were few with a percentage of (4%). The observe low participation in irrigation amoung the teenagers could be that they were people who were attending school and could not combine the farming with education.

The study showed that people of all literacy levels are involved in irrigated urban and peri urban vegetable production and thus confirming other reports that people of all educational backgrounds are involved in urban and peri-urban agriculture (Amoah et al., 2008). This practice is however dominated by illiterates and people with very low level of education. Descriptive analysis revealed that farmers who did not have any form of formal education and those who had only primary education were the majority (82.4%). This is typical in Africa where Agriculture is considered to be for those who are not educated. This could be a contribution factor to contamination of the tomatoes since most of these illiterates farmers may not be aware of some of the agricultural practices that can bring about safer production of vegetables without contamination.

5.2 Environmental assessment

The main sources of water for irrigation are dams, hand dug wells, rivers and canals. Majority of tomatoes producers (54%) at Doba in the study area use rubber hose connected to a pumping machine for irrigation. This method could either be overhead or flood depending on the user. The rubber hose could be held up as the water flows making it an overhead or the hose could be laid down as the water flows making it flood irrigation.

Forty three percent and 28 percent of farmers at Yigwania and Doba respectively use watering cans of 15liters to fetch and manually carry water from a river and dam water to the fields, followed by watering of crops through the spout or shower head of the can simulating an overhead irrigation method.

The high levels of bacterial contamination are of major public health concern. Apart from the irrigation scheme at Bonia (canal) where gravity based irrigation is mostly practiced which minimizes direct contact of irrigation water with the tomatoes, farmers at the other sites use buckets, watering cans and rubber hose to introduce (spray) the water directly on the crops. This practice enhances direct contact of irrigation water with the edible parts of the tomatoes. This explains why most of the tomatoes were found to be contaminated with the coliforms. This is in agreement with the statement made by Sadovski *et al*., (1978) that spray irrigation could be expected to increase the risk of contamination in comparison to drip irrigation or flooding because vegetables provide large contact surfaces for water and for the attachment of microorganism. .

The descriptive statistics revealed that 82.7% of the farmers in the municipality use pesticides and this confirm work done by Dinham (1993) who estimated that 87% of farmers in Ghana use chemical pesticides to control pests and diseases on vegetables and fruits. Ntow *et al*. (2006) also gave the proportions of pesticides used particularly on vegetable farms as herbicides (44%), fungicides (23%) and insecticides (33%). These pesticides can bio concentrate in the tomatoes produce which can affect the health of consumers.

Some of the pesticides are however banned while others are only for restricted use but farmers still used both of them for vegetable production. For example, DDT is banned but some farmers in the study area, though few (10%) mentioned the use of the chemical for vegetable production.

Majority (82.4%) of the respondents were illiterates and did not know the health and environmental effects of improper disposal of pesticides containers. They, thus throw the used pesticides containers into water bodies and the surrounding environment. this study also found that respondents with higher education levels were more likely to practices that will contaminate irrigation water and tomato crops.

These results positively supported the previous study conducted by Bruening, Radhakrislma, and Rollins (1992) which stated low significant positive relationships existed between educational level of farmers and their perceptions about good agricultural mismanagement practices. It is therefore important to educate farmers on proper methods of handling and using these pesticides and disposal of the containers.

Earlier research has shown that, there is an overuse, misuse and abuse of pesticides in farming mainly due to illiteracy and ignorance of the health effects of these chemicals (Ntow *et al.*, 2006). Yeboah *et al.*, (2004) reported that majority (82.4%) of tomato farmers are illiterates and do not adhere to safe agronomic practices. Many of the agrochemicals are toxic to human health and the environment and as a result their use should be strictly regulated internationally, nationally and regionally with regulations and conventions (WHO, 2008; PAR, 2000). It is important for Environmental Protection Agency and Agricultural Extension Officers to educate farmers on the proper handling and usage of these pesticides. The reliance on organic fertilizers (poultry manure and cow dung) in the study area could lead to the contamination of the irrigation water and the tomatoes produce especially farmers at Doba and Yigwania where organic manure is applied on the farms by broadcasting method.

None of the irrigation schemes had a toilet facility; farmers therefore practice open defecation close to the water bodies and the farms. These practices can lead to the contamination of irrigation water and tomatoes produced.

Majority of the respondents at Bonia complained about malaria and schistosomiasis as their major health problems. The Canal that is used for irrigation may have created an ideal breeding site for mosquitoes or for snails, bringing both the vectors and the disease closer to the farmers (Boelee, 2006). The irrigation water bodies serve as a source of water for bathing and other recreational activities by the farmers and their families. These activities can easily lead to the transmission of the schistosomiasis to the farmers. Various studies have associated this disease with water-contact activities like recreational (swimming) or specific agricultural activities, washing of clothes and cooking utensils, fishing and with the proximity of homes or communities to sites harbouring cercariae shedding *Bulinus* and *Biomphalaria* snail species (Matthys *et al.*, 2007; El-Ayyat *et al.*, 2003).

Farmers at Doba and Yigwania ranked diarrhea first to malaria and schistosomiasis as their major health concern. This may be as a result of poor sanitary conditions arising from lack of toilet facilities and free range system of animal husbandary in these two areas.

Farmers within the study community rear animals by the free range system and the rich grazing fields along the water bodies attract grazing animals. Twenty-nine (72.5%) of the farmers at Doba and 28 (80%) of farmers at Yigwania do not have fences to keep these animals out of their tomato farms. Field observation also showed that 25 (55.6) farmers from Bonia, 23 (57.5) from Doba and 18 (51.42) from Yigwania did not prevent wild animals from entering to their farms (Figure 5). A possible reason why respondents tried to prohibit wild animals from accessing their gardens may be they were more concerned about preventing crops from being eaten or destroyed rather than being concerned about food safety issues. Therefore, they may not consider keeping other animals, such as domestic bird animals and pets, out of their gardens because these animals would not damage their crops.

The high nitrate levels in the Dam and canal water samples could have been as a result of the presence of these animals that have defecated or urinated into the water bodies directly or indirectly through runoffs. Earlier works carried out to assess the quality of underground water in the study area recorded high concentration of nitrate ions (12.40mg/l) in some selected wells above the recommended standard of 10mg/l. They attributed this high concentration of nitrates to the presence of animals (Oyelude *et al.*, 2013). These water bodies serve as source drinking water for both domestic and wild animals in the area.

The sloppy and low lying nature of irrigated lands in the study area especially the farms at Yigwania could have facillitated the transport of faeces of wild birds, domestic animals, human excreta and household waste into water sources which might have lead to contamination of irrigation water. Earliear findings revealed that farm run-offs could be a major source of contamination because it often carries faeces of wild birds, domestic animals, human excreta and household waste into water sources (Amponsah-Doku *et al*., 2010; Drechsel *et al*., 2000).

It implies that fecal matter from domestic and wild animals could be a source of contamination of irrigation water and tomatoes produce. Farmers should prevent animals from entering their irrigation farms, especially during the growing and harvesting seasons. Several studies have come out with findings that animals can cause contamination of irrigation water and vegetables through their faeces. They suggested that farmers should stop animals from entering their farms in order to reduce the risk of contamination (Davis and Kendall, 2005; Bihn, *et al.*, 2000).

5.3 Physico-chemical characteristic of irrigation water samples

The results showed that average pH values obtained from water samples collected from the irrigation water sources (river, dam and canal) were close to neutral and optimum for the growth and development of most mesophillic bacteria and must have supported the proliferation of heterotrophic bacterial count, total coliform and faecal coliforms in these water sources. According to Pautshwa *et al.* (2009), temperature and pH have an effect on the level of faecal coliform and enterococci in water bodies.

Electrical conductivity (EC) is also an important parameter for water quality. Higher conductivity indicates high amount of ions that exceed the recommended limit (Ayers and Westcot, 1985). None of the three different sources showed levels of EC above the limit recommended for irrigation. However, EC was significantly correlated with most of the physico-chemical parameters. Sunitha *et al.*, (2005) identified that the EC finds higher level correlation significance with many of water quality parameters, like TDS, total alkalinity, sulphates, total hardness and magnesium. Mahajan *et al.*, (2005) identified that all the parameters are more or less correlated with others in the correlation and regression study of the physico-chemical parameters of ground water. Kalyanaraman (2005) identified that the water quality of ground and surface water can be predicted with sufficient accuracy just by the measurement of EC alone. This provides a means for easier and faster monitoring of water quality in a location.

Dissolved oxygen (DO) is a very important indicator for the survival of aquatic organisms and is thought to be a better measure of water quality than feacal coliform counts. The main factor contributing to reduced dissolved oxygen levels is the build-up of organic wastes. Findings from this study indicated the practice of free range system of animal husbandry and open defecation as well as the discharge of sewage into the water bodies which could account for the observed lower levels. Dissolved oxygen concentrations in unpolluted water normally range between 8 and 10mg/L and concentrations below 5 mg/L adversely affect aquatic life (Rao, 2005; DFID, 1999).

The mean values of nitrate and nitrite obtained for dam water and river water sources where high. Nitrate and nitrite levels for dam were 23.3mg/l and 11.8mg/l respectively whiles that of the river was 11.7mg/l and 7.6mg/l respectively. Free range system of animal rearing as well as open defecation and the use of organic and inorganic fertilizers could account for the high levels. Earlier works carried out to assess the quality of underground water in the study area recorded high concentration of nitrate ions (12.40mg/l) in some selected wells above the recommended standard of 10mg/l for drinking water. They attributed this high concentration of nitrates to the use of inorganic fertilizers and manure in agricultural activities, and indiscriminate disposal of human and animal excreta (Oyelude *et al.*, 2013). The significant higher levels of nitrates observed in the dam water sources could have been as a result of increased human and animal activities in and around the water body. Because the canal is a built infrastructure unlike the dam and the river, the people do not defecate close to it. The canals are also design in such a way that animals cannot get direct access to the water. This might have been the reason for the low levels of nitrate in such water bodies.

The low levels of DO and the high nitrogen levels correlates very well with the high levels of total coliform, heterotrophic bacteria and faecal coliforms in these water bodies since nitrates levels in water bodies can stimulate the growth of microorganisms.

The levels of phosphate were within World Health Organization guidelines for irrigation water. Canal water recorded the lowest because there is less activity along such water body. Doba dam recorded the highest and is due to human and animal activities from around the vicinity of the dam water body.

5.4 Bacteriological quality of irrigation water and tomatoes produce

The results showed that the water samples from the canal, dam and river did not meet the International Commission and the World Health Organization (WHO, 2006b) guide lines for faecal coliform bacteria limit ($1x10^3$cfu/100ml) in unrestricted irrigation of crops likely to be eaten raw. This is in agreement with previous investigations in Tamale and and Kassena-Nankana East municipality which indicated that most of the water sources for irrigation are polluted (Ataogye, 2012; Abdul-Ghaniyu *et al*., 2002).

The observed high levels of faecal coliform are an indication of faecal contamination and hence poor bacteriological quality of the irrigation water being used in the study area. Fecal coliforms normally live in the intestinal tract of warm-blooded animals. Their presence in water and tomatoes produce is an indication of fecal contamination and of the potential presence of enteric pathogens which originate in the digestive system of these animals. Hence these waters are not suitable for human consumption and irrigation of tomatoes and other vegetables without prior treatment.

There is therefore the need to improve education of farmers and residents to desist from defecating along the banks of irrigation water sources as they can serve as a source of contamination of vegetables. Furthermore, consumers' needs to be aware and impressed upon to wash vegetable properly before consumption. Moreover, the municipal authority needs to enforce by-laws preventing open defecation and other insanitary practices along water sources. Furthermore, the local administration needs to provide toilet and waste disposal facilities.

On the contrary, the canal water was less polluted than the dam and river. The canal irrigation system at Bonia is part of the Tono irrigation facility which is managed by the Irrigation Company of Upper Region (ICOUR). The management and regulation of the activities of farmers in canal irrigation system could be the reason for the low level of contamination of irrigation water in the canal compared to the dam and the river water bodies. Also the flowing nature of the canal may cause pollutants to be distributed thereby reducing their concentration (Fei-Baffoe, 2008).

The environmental assessment revealed that water from major gutters and drains within the heart of the municipality flow directly into the river water body and this could be a contributing factor to the high microbial load in such water body compared to the dam and the canal water bodies.

Tomatoes samples analyzed showed heterotrophic bacteria count, total coliform count and faecal coliform counts more than the 1×10^3 per 100 g wet weight hence can be classified as undesirable for consumption according to the International Commission on Microbiological Specifications for Food (ICMSF, 1974) and the World Health Organization guidelines (WHO, 2006b). The possible sources of contamination of the tomatoes in the study area are; irrigation water, manure, wild and domestic animals, human excreta and human handling. The use of contaminated irrigation water and produce handling practices could result in increases in the bacterial load on the tomatoes (Keraita *et al*. 2007; Amoah *et al*., 2005; Obiri-Danso *et al.*, 2005; Keraita *et al*., 2003; Francis *et al*., 1999;).

Both external and internal tissues of the tomatoes sampled were contaminated with bacteria and this corroborates the findings of previous studies that pathogens may colonize both internal and external plant parts and can survive for long periods depending on environmental factors and nutrients (Olaimat and Holley, 2012; Brandl, 2006). Solomon *et al* (2002) have shown that pathogenic *E. coli* 0157:H7 can become internalize in the inner parts of vegetables and become protected from the action of sanitizing agents.

The presence of *E. coli* and other pathogens in the internal parts are of particular concern because it would be difficult to remove such pathogens by washing the external parts. Washing of vegetables may not eliminate pathogens in the internal parts in order to make them safe for consumption once they are contaminated. This emphasizes the need to ensure good agricultural practices to protect the health of consumers. Suslow, *et al*., (2000) suggested that since it is difficult to remove or kill harmful bacteria that exist in produce, minimizing microbial contamination from production to consumption is the best option than cleaning the produce after it has been contaminated.

The findings from this study also revealed that contamination of the external parts of tomatoes was higher than the internal tomatoes parts for all pathogens tested. This is because the external parts come into direct contact with plausible contaminants such as the irrigation water, organic manures and human excreta.

Most of the isolated pathogens were enterobacteria that could be transmitted by both animals and humans. Isolation of pathogens such as *Xanthomonas maltophilia, Klebsiella pneumonia and Staphylococcus aureus* from the tomatoes produce as well as the water sources indicates the potential risk of infections. Outbreak of water and food borne diseases such as bacillary dysentery, urinary tract infections, pneumonia, typhoid, respiratory infections, gastroenteritis, and food poisoning could occur if hygiene, water and sanitation facilities and practices are not up to standard in these areas.

Finally, Isolation of *E. coli* from the tomatoes produce is of significant concern because strains of these bacteria are pathogenic and are the most common cause of infantile diarrhea in many countries, specifically in the developing world. Many studies in different parts of the world have linked pathogenic *E. coli* as one of the most common pathogens associated with the endemic life-threatening diarrhea in many countries (Black *et al.*, 1981; Guerrant *et al.*, 1983 and Feachem *et al.*, 1983). There is the need to develop risk reduction strategies at the farm level to help safeguard the health of consumers.

CHAPTER SIX

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

6.1 Conclusion

The study was conducted to assess three irrigation systems in the Kassena-Nankanna East Municipality with respect to microbiological quality of irrigation water and tomato crops grown.

The study showed that more than 80 percent of farmers involved in tomatoes cultivation in the study area are males. Majority of the farmers were illiterates males and were within the ages of 20 to 40 years.

Farmers with low level of education and no training in irrigation were more likely to carry out improper agricultural management practices that could lead to the contamination of irrigation water and tomato crops. Findings from the study indicate the need to educate farmers on good irrigation practices in order to reduce the level of contamination of irrigation water and tomato crops.

The study has confirmed that water from major gutters and drains within the heart of the Municipality flow directly into the river water source and this could be a contributing factor to the high microbial load and nitrate levels in such water body compared to the dam and the canal water sources.

Other negative practices by farmers include; disposal of used pesticides containers into water bodies and the surrounding vegetation, applying pesticides on tomato crops without wearing protective gear, the practice of open defecation close to the water bodies and the farms, rearing of animals by the free range system and overhead or splash irrigation method using buckets and watering cans. This further emphasizes the need to educate tomatoes farmers on good agricultural practices .

Bacteriological analysis of both irrigation water and tomatoes indicated that though with varying loads, the level of bacterial contamination of the irrigation water sources as well as the tomatoes is above the acceptable limits. Comparing the results to WHO standard for irrigation water indicated they are not suitable for irrigation especially to grow tomatoes and other vegetables, which can be eaten raw. Microbial contamination of tomatoes in the study area is not limited to the external surface, but the internal parts could also pose risk to consumers.

A variety of important pathogens were identified from the tomatoes as well as the water sources and indicate the potential risk of transmitting diarrheagenic bacteria and causative agents of other important diseases.

Limitations of the Study

The laboratory analysis for the microbiological quality of irrigation water and tomatoes crops did not include down streaming analysis and as a result certain specicific pathogens were not confirmed.

The researcher did not include some farms which were part of the study due to inaccessible nature of roads leading to these farms.

Since most of the farmers were illitrates, it was difficult for the researcher and field assistants to ask questions based on the questionnaire design which had no leading questions but which had to be asked in this case.

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6.2 Recommendations

Agriculture extension officers and other regulatory agencies should adopt innovative measures to educate farmers on proper agronomic practices in order to improve upon the microbial quality of vegetables produced in the area.

Agricultural extension officers of the Ministry of Food and Agriculture should educate farmers on best methods of pesticides and fertilizer application in order to avoid possible contamination of surface waters used in irrigation.

A detailed yearly environmental assessment programme should be included in the Kassena-Nankana East Municipality development planning programme in order to help identify environmental antecedents that might be contributing to the contamination of irrigation water and vegetables and also help educate farmers on ways and means of preventing these contamination.

Irrigation companies or management should ensure periodic monitoring of water quality and practices that could predispose irrigation water to contamination.

The municipal authority needs to enforce by-laws preventing open defecation and other insanitary practices along water sources.

The local administration needs to provide toilet and waste disposal facilities in the study area. Farmers should stop irrigation for some days before harvesting. this will help reduce the contamination level on the tomatoes fruits before they are harvested.

Safety practices associated with tomatoes should not be limited to external washing only since the internal parts also pose risk to consumers. There is the additional need of heating tomatoes where possible to eliminate microbes both externally and internally before consumption.

The researcher recommends that the study should be replicated in other regions in the country to assess the level of bacteriological quality of tomatoes and irrigation water. This is important because a greater portion of tomatoes in the Ghanaian market are produced through the irrigation method across the whole country.

Finally, the researcher recommends that studies should be carried out to identify the pesticide residue level in the vegetables that are produced in this area since it was revealed that majority of the farmers use pesticides most of which are hazardous to human health and the environment.

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APPENDICES

Appendix A: Sample of questionnaire

The aim of this study is to obtain background information about environmental sources of contamination of irrigation water and its effect on the quality of tomatoes produce and to discuss matters related to the health of the farmers in the Kassena-Nankana East Municipality .The result will be used to provide useful advice to farmers on ways to reduce vegetable contamination. Thank you very much for your kind cooperation.

PART A: DEMOGRAPHIC DATA

01. Sex: male [ ] female [ ]

02. Age: below 20yrs [ ] 20 -30yrs [ ] 31 – 40yrs [ ] Above 40 [ ]

03. Are you married? A. Yes [ ] B. No [ ] C. divorce [ ] D. Separated [ ] E. others.............

06. Religion: Christian [ ] Moslem [ ] traditional [ ] others [ ]

07. literacy status: Primary [ ] JSS/MSLC [ ] SSS/A' level [ ] Graduate/Certificate [ ] Illiterate [ ].

08a.Do you have any training in farming? Yes [ ] No [ ]

B if yes what level of training? Attended agricultural institutes [ ] Offered agaric at S.S.S [ ] Through extension officers [ ] others. [ ]

09. How long have you worked on irrigated farms?

10. How far is your home away from the farms?

PART B

ENVIRONMENTAL ASSESSMENT

Irrigation water quality assessment

11. What is your source of water for irrigation? A. canal [ ] B. Gutter/stream [ ] C. river [ ] D. Dam [ ] E. others.................................

12. What is the commonest source of water for irrigation in the Municipality? A. canal [ ] B. Gutter [ ] C. river [ ] D. Dam [ ] E. Others……………………………

13. What water source do you consider best for irrigation? A. Well [ ] B. Pipe [ ] C. canal [ ] D. Dam [ ] E. Others………………………

14. Is source of water for irrigation water regular? Yes [ ] No [ ]

Irrigation method

15. a When do you cultivate your crops? All year round [ ] Rainy season [ ] Dry season []

b. Which irrigation method(s) do you use? Watering cans [ ] Water hose [ ]

Sprinkler [ ] Furrow [ ] others (specify)………………………………

c. Are you satisfied with this system? Yes [ ] No [ ]

D.If no, which alternative would you prefer……………………………………

16a. Do you wash your hands after irrigation/farming activity? Yes [ ] No [ ]

b. if yes with which water? Dam [ ] canal [ ] stream/river [ ] borehole [ ] others [ ]

c. Do you wash your hands with soap/disinfectants? Yes [ ] No [ ]

Fertilizers

17. Has animal manure been used for fertilizer on your farm? Yes no

If no, skip question 18a to21

18. What kind of animals is the manure from? A.Cattle [ ] B.Sheep [ ] C.Goat [ ] D.Poultry [ ] E. Unknown [ ]

19. Do you use any protective clothing when applying manure? Yes [ ] No [ ]

20. Do you wash your hands with soap/disinfectants after manure application?

Yes [ ] No [ ]

21a. Are yes chemical fertilizers used? Yes [ ] No [ ]

b. How are they applied?

Pesticides used

22. a.Do you apply pesticides on your farm? Yes [ ] No[ ]

b. If yes, which type(s) of pesticides?……………………………………………

c.How are they applied?

d.What is the water source used for mixing and applying pesticides? A. canal water [ ] B.borehole water[ ] C.dam water [ ] D. others[ ]

e. do you employ any protective measure when applying pesticides? Yes [ ] No [ ]

23.a Where is pesticide equipment stored when not in use? A on the farm B. sent to the house C.others

B.Where do you put the put the pesticides containers after using the pesticides? A. sent to the house [ ] B. leave it on the farm [ ] C. throw it into the water body [ ] D. others [ ]

Tools and Equipment and equipment used in the farm

24a.Are irrigation tools frequently maintained? Yes [ ] No [ ]

b.Is there any broken parts of your irrigation equipment? Yes [ ] No [ ]

25. What do you use to harvest your vegetables? A.Bare hand [ ] bare hand with utensil (e.g.: knife) [ ] c. Gloved hand [ ] d.Gloved hand with utensil[ ] e. Automated/machine (no hand contact) [ ] f.Others [ ]

Animal Management

Are there animals around the field Yes [ ] No [ ]

26a.if yes, then are farm animals or domestic animals housed or grazed anywhere near the field? Yes [ ] No [ ]

b.If yes are there fences to keep them out of crops and away from water sources? Yes [ ] No [ ]

c.Is there evidence of amphibians, reptiles, insects or other birds inside the packing area? Yes [ ] No [ ]

d. if yes, do you derived them away from the farms? Yes [ ] No [ ]

27. Are farm animals (e.g., horses, donkeys) used in the fields? Yes [ ] No [ ]

28. Are there any health problems in some of the farm animals? Yes [ ] No [ ]

Explain:

Health and hygiene

29. What is the prevailing health problems associated with your farming business? A. malaria [ ] B. schistosomiasis [ ] C. cholera [ ] D. others[ ]

30. Do you have access to portable water Yes [ ] No [ ]

31. What water treatment practices do you apply?

32. Do you seek medical attention when you are ill? Yes [ ] No [ ]

33.a Do you have sanitation facilities? Yes [ ] No [ ]

b. If yes then where are they located a. home [ ] b. farm[ ] others [ ]

c. What type sanitation facilities do you have? A.Toilet [ ] B. urinary facilities [ ]

C. othetrs [ ]

34a. Are there toilets facilities near the farm? Yes [ ] No [ ]

b.If no, where do you defecate/urinate? On the farm [ ] closed to the farm [ ] near the water source [ ] very far from the farm [ ]

35. Do you wear disposable gloves when touching tomatoes produce? Yes [ ] No [ ]

36. a. Are there children in the fields? Yes [ ] No [ ]

If no skip 37b to d

b.if yes, do they come in contact with the produce? Yes [ ] No [ ]

c. Do they defecate/urinate in the fields? Yes [ ] No [ ]

d. Do they wash their hands after defecating? Yes [ ] No [ ]

37a. has your source of water for irrigation been used for other purposes? Yes [ ] No [ ]

b.If yes, explain……………………………………………………………………

38.Are there runoffs into your farms and irrigation water source? Yes [ ] No [ ]

Appendix B: Multiple comparisons of the physic-chemical characteristics of the irrigation water. Post hoc

Multiple Comparisons

LSD

Dependent Variable	(I) SOURCE	(J) SOURCE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
PH	canal	Dam	.18500*	.05230	.001	.0811	.2889
		River	.02500	.05230	.634	-.0789	.1289
	Dam	Canal	-.18500*	.05230	.001	-.2889	-.0811
		River	-.16000*	.05463	.004	-.2685	-.0515
	River	Canal	-.02500	.05230	.634	-.1289	.0789
		Dam	.16000*	.05463	.004	.0515	.2685
EC	Canal	Dam	-178.79444*	17.50876	.000	-213.5634	-144.0255
		River	-234.72778*	17.50876	.000	-269.4967	-199.9588
	Dam	Canal	178.79444*	17.50876	.000	144.0255	213.5634
		River	-55.93333*	18.28731	.003	-92.2483	-19.6184
	River	Cana	234.72778*	17.50876	.000	199.9588	269.4967
		Dam	55.93333*	18.28731	.003	19.6184	92.2483
TDS	Canal	Dam	-77.58611*	7.49031	.000	-92.4604	-62.7118
		River	-111.55278*	7.49031	.000	-126.4271	-96.6785
	Dam	canal	77.58611*	7.49031	.000	62.7118	92.4604
		river	-33.96667*	7.82338	.000	-49.5023	-18.4310
	River	cana	111.55278*	7.49031	.000	96.6785	126.4271
		dam	33.96667*	7.82338	.000	18.4310	49.5023
SAL	Canal	Dam	-.00722	.01473	.625	-.0365	.0220
		River	-.02056	.01473	.166	-.0498	.0087
	Dam	Canal	.00722	.01473	.625	-.0220	.0365
		River	-.01333	.01539	.389	-.0439	.0172
	River	Canal	.02056	.01473	.166	-.0087	.0498
		Dam	.01333	.01539	.389	-.0172	.0439
TURB	Canal	Dam	-195.63333*	28.14401	.000	-251.5218	-139.7449
		River	-273.70000*	28.14401	.000	-329.5884	-217.8116
	Dam	Canal	195.63333*	28.14401	.000	139.7449	251.5218
		River	-78.06667*	29.39546	.009	-136.4402	-19.6931
	River	Canal	273.70000*	28.14401	.000	217.8116	329.5884
		Dam	78.06667*	29.39546	.009	19.6931	136.4402

Appendix B continued

NO3_N	Canal	Dam	-21.69000*	.18617	.000	-22.0597	-21.3203
		River	-10.15667*	.18617	.000	-10.5264	-9.7870
	Dam	Canal	21.69000*	.18617	.000	21.3203	22.0597
		River	11.53333*	.19445	.000	11.1472	11.9195
	River	Canal	10.15667*	.18617	.000	9.7870	10.5264
		Dam	-11.53333*	.19445	.000	-11.9195	-11.1472
NO2_N	Canal	Dam	-10.765573*	.303465	.000	-11.36819	-10.16295
		River	-6.506310*	.303465	.000	-7.10893	-5.90369
	Dam	Canal	10.765573*	.303465	.000	10.16295	11.36819
		River	4.259263*	.316958	.000	3.62985	4.88868
	River	Canal	6.506310*	.303465	.000	5.90369	7.10893
		DAM	-4.259263*	.316958	.000	-4.88868	-3.62985
PO4	Canal	Dam	-21.81056*	.16360	.000	-22.1354	-21.4857
		River	-.61389*	.16360	.000	-.9388	-.2890
	Dam	Canal	21.81056*	.16360	.000	21.4857	22.1354
		River	21.19667*	.17088	.000	20.8573	21.5360
	River	Canal	.61389*	.16360	.000	.2890	.9388
		Dam	-21.19667*	.17088	.000	-21.5360	-20.8573
DO	Canal	Dam	.25278	.54965	.647	-.8387	1.3443
		River	.64944	.54965	.240	-.4420	1.7409
	Dam	Canal	-.25278	.54965	.647	-1.3443	.8387
		River	.39667	.57409	.491	-.7434	1.5367
	River	Canal	-.64944	.54965	.240	-1.7409	.4420
		Dam	-.39667	.57409	.491	-1.5367	.7434
BOD	Canal	Dam	-1.47722*	.48834	.003	-2.4470	-.5075
		River	-1.30389*	.48834	.009	-2.2736	-.3341
	Dam	Canal	1.47722*	.48834	.003	.5075	2.4470
		River	.17333	.51006	.735	-.8395	1.1862
	River	Canal	1.30389*	.48834	.009	.3341	2.2736
		Dam	-.17333	.51006	.735	-1.1862	.8395
Na+	Canal	Dam	-2.35500*	.13519	.000	-2.6235	-2.0865
		River	-2.25833*	.13519	.000	-2.5268	-1.9899
	Dam	Canal	2.35500*	.13519	.000	2.0865	2.6235
		River	.09667	.14120	.495	-.1837	.3771
	River	Canal	2.25833*	.13519	.000	1.9899	2.5268
		Dam	-.09667	.14120	.495	-.3771	.1837

Appendix B continued

K+	Canal	Dam	-8.07167*	.26361	.000	-8.5951	-7.5482
		River	-2.85167*	.26361	.000	-3.3751	-2.3282
	Dam	Canal	8.07167*	.26361	.000	7.5482	8.5951
		River	5.22000*	.27533	.000	4.6733	5.7667
	River	Canal	2.85167*	.26361	.000	2.3282	3.3751
		Dam	-5.22000*	.27533	.000	-5.7667	-4.6733
Temp.	Canal	Dam	-.08389	.09800	.394	-.2785	.1107
		River	.02278	.09800	.817	-.1718	.2174
	Dam	Canal	.08389	.09800	.394	-.1107	.2785
		River	.10667	.10236	.300	-.0966	.3099
	River	Canal	-.02278	.09800	.817	-.2174	.1718
		Da	-.10667	.10236	.300	-.3099	.0966

*. The mean difference is significant at the 0.05 level.

Appendix C: Multiple comparison of bacteriological quality of irrigation water and tomatoes produce in the study area

Multiple Comparisons

LSD

Depen-dent Varia- ble	(I) SOU R-CE	(J) SOU R-CE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Hetrotrophic bacteria count in water	Canal	Dam	-402376038.88889	271641372.63164	.142	-941801969.5121	137049891.7343
		River	-497365305.55556	271641372.63164	.070	-1036791236.1787	42060625.0676
	Dam	Cam	402376038.88889	271641372.63164	.142	-137049891.7343	941801969.5121
		River	-94989266.66667	283720160.44982	.739	-658401276.0543	468422742.7210
	River	Canal	497365305.55556	271641372.63164	.070	-42060625.0676	1036791236.1787
		Dam	94989266.66667	283720160.44982	.739	-468422742.7210	658401276.0543

Appendix C continued

Heterotrophic bacteria in external parts of tomatoes	Canal	Dam	-31473941.66667	22673907.78274	.168	-76499828.8799	13551945.5466
		River	-79550941.66667*	22673907.78274	.001	-124576828.8799	-34525054.4534
	Dam	Canal	31473941.66667	22673907.78274	.168	-13551945.5466	76499828.8799
		River	-48077000.00000*	23682124.30905	.045	-95105005.4205	-1048994.5795
	River	Canal	79550941.66667*	22673907.78274	.001	34525054.4534	124576828.8799
		Dam	48077000.00000*	23682124.30905	.045	1048994.5795	95105005.4205
Heterotro-phic bacteria in internal parts of tomatoes	Canal	Dam	-1713277.77778	2185846.12893	.435	-6053934.9865	2627379.4309
		River	-6060111.11111*	2185846.12893	.007	-10400768.3198	-1719453.9024
	Dam	Canal	1713277.77778	2185846.12893	.435	-2627379.4309	6053934.9865
		River	-4346833.33333	2283041.82243	.060	-8880501.9265	186835.2599
	River	Canal	6060111.11111*	2185846.12893	.007	1719453.9024	10400768.3198
		Dam	4346833.33333	2283041.82243	.060	-186835.2599	8880501.9265

Appendix C continued

Total coliform in external parts of tomatoes	Canal	Dam	-7283172.22222	10353914.29876	.484	-27843994.0223	13277649.5778
		River	-18381505.55556	10353914.29876	.079	-38942327.3556	2179316.2445
	Dam	Canal	7283172.22222	10353914.29876	.484	-13277649.5778	27843994.0223
		River	-11098333.33333	10814310.78657	.307	-32573411.3142	10376744.6475
	River	Canal	18381505.55556	10353914.29876	.079	-2179316.2445	38942327.3556
		Dam	11098333.33333	10814310.78657	.307	-10376744.6475	32573411.3142
Total coliform in internal parts of tomatoes	Canal	Dam	-558783.33333	327057.11468	.091	-1208253.9451	90687.2784
		River	-972883.33333*	327057.11468	.004	-1622353.9451	-323412.7216
	Dam	Canal	558783.33333	327057.11468	.091	-90687.2784	1208253.9451
		River	-414100.00000	341600.01532	.228	-1092449.9302	264249.9302
	River	Canal	972883.33333*	327057.11468	.004	323412.7216	1622353.9451
		Dam	414100.00000	341600.01532	.228	-264249.9302	1092449.9302

Appendix C continued

Faecal coliform in water	Canal	Dam	-5820550.00000	3544242.34542	.104	-12858712.8800	1217612.8800
		River	-12511550.00000*	3544242.34542	.001	-19549712.8800	-5473387.1200
	Dam	Canal	5820550.00000	3544242.34542	.104	-1217612.8800	12858712.8800
		River	-6691000.00000	3701840.39778	.074	-14042121.3783	660121.3783
	River	Canal	12511550.00000*	3544242.34542	.001	5473387.1200	19549712.8800
		Dam	6691000.00000	3701840.39778	.074	-660121.3783	14042121.3783
Faecal coliform in external parts of tomatoes	Canal	Dam	-350669.44444*	153206.30972	.024	-654906.8123	-46432.0766
		River	-444982.77778*	153206.30972	.005	-749220.1456	-140745.4100
	Dam	Canal	350669.44444*	153206.30972	.024	46432.0766	654906.8123
		River	-94313.33333	160018.77165	.557	-412078.9004	223452.2337
	River	Canal	444982.77778*	153206.30972	.005	140745.4100	749220.1456
		Dam	94313.33333	160018.77165	.557	-223452.2337	412078.9004

Appendix C continued

Faecal coliform in internal parts of tomatoes	Canal	Dam	-1507.45455*	551.48949	.008	-2603.0847	-411.8244
		River	-2475.12121*	551.48949	.000	-3570.7514	-1379.4911
	Dam	Canal	1507.45455*	551.48949	.008	411.8244	2603.0847
		River	-967.66667	564.46749	.090	-2089.0799	153.7465
	River	Canal	2475.12121*	551.48949	.000	1379.4911	3570.7514
		Dam	967.66667	564.46749	.090	-153.7465	2089.0799
Total coliform count in water	Canal	Dam	-416321944.44444	478879617.46515	.387	-1367281957.6598	534638068.7709
		River	-1435181944.44444*	478879617.46515	.003	-2386141957.6598	-484221931.2291
	Dam	Canal	416321944.44444	478879617.46515	.387	-534638068.7709	1367281957.6598
		River	-1018860000.00000*	500173447.75977	.044	-2012105340.0487	-25614659.9513
	River	Canal	1435181944.44444*	478879617.46515	.003	484221931.2291	2386141957.6598
		Dam	1018860000.00000*	500173447.75977	.044	25614659.9513	2012105340.0487

*. The mean difference is significant at the 0.05 level.

Appendix D: Descriptive statistics of the physic-chemical characterics of the irrigation water in the study area

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
PH	Canal	36	6.9417	.25000	.04167	6.8571	7.0263	6.70	7.90
	Dam	30	6.7567	.13817	.02523	6.7051	6.8083	6.50	7.00
	River	30	6.9167	.22141	.04042	6.8340	6.9993	6.50	7.30
	Total	96	6.8760	.22466	.02293	6.8305	6.9216	6.50	7.90
EC	Canal	36	122.4722	13.90886	2.31814	117.7661	127.1783	98.00	136.00
	Dam	30	301.2667	123.49841	22.54762	255.1516	347.3817	142.00	564.00
	River	30	357.2000	24.52922	4.47840	348.0406	366.3594	312.00	400.00
	Total	96	251.6979	124.61859	12.71883	226.4478	276.9480	98.00	564.00
TDS	Canal	36	66.5139	11.04309	1.84051	62.7774	70.2503	49.00	79.00
	Dam	30	144.1000	51.62855	9.42604	124.8216	163.3784	71.00	185.00
	River	30	178.0667	11.46714	2.09360	173.7848	182.3486	156.00	188.00
	Total	96	125.6198	56.56048	5.77268	114.1596	137.0800	49.00	188.00

Appendix D continued

SAL	Canal	36	.1361	.04871	.00812	.1196	.1526	.10	.20
	Dam	30	.1433	.05683	.01038	.1221	.1646	.10	.30
	River	30	.1567	.07279	.01329	.1295	.1838	.00	.40
	Total	96	.1448	.05959	.00608	.1327	.1569	.00	.40
TURB	Canal	36	14.5000	1.56497	.26083	13.9705	15.0295	12.00	18.00
	Dam	30	210.1333	94.28633	17.21425	174.9262	245.3404	44.00	639.00
	River	30	288.2000	180.75672	33.00151	220.7043	355.6957	34.00	502.00
	Total	96	161.1667	163.38093	16.67500	128.0626	194.2707	12.00	639.00
NO3_N	Canal	36	1.6167	.49425	.08238	1.4494	1.7839	1.10	2.80
	Dam	30	23.3067	1.21625	.22206	22.8525	23.7608	21.00	24.90
	River	30	11.7733	.21162	.03864	11.6943	11.8524	11.40	12.40
	Total	96	11.5687	9.03382	.92201	9.7383	13.3992	1.10	24.90

Appendix D continued

NO2_N	Canal	36	1.05105	.240682	.040114	.96961	1.13249	.801	2.013
	Dam	30	11.81662	1.191173	.217478	11.37183	12.26141	9.400	14.361
	River	30	7.55736	1.828604	.333856	6.87455	8.24017	4.217	10.225
	Total	96	6.44851	4.690757	.478748	5.49808	7.39895	.801	14.361
PO4	Canal	36	1.5361	.16929	.02821	1.4788	1.5934	1.20	1.80
	Dam	30	23.3467	1.10289	.20136	22.9348	23.7585	20.10	24.70
	River	30	2.1500	.39194	.07156	2.0036	2.2964	1.40	2.80
	Total	96	8.5437	10.05709	1.02645	6.5060	10.5815	1.20	24.70
DO	Canal	36	5.3028	2.34002	.39000	4.5110	6.0945	.80	7.50
	Dam	30	5.0500	2.13376	.38957	4.2532	5.8468	1.40	6.90
	River	30	4.6533	2.16616	.39548	3.8445	5.4622	1.40	6.80
	Total	96	5.0208	2.21644	.22621	4.5717	5.4699	.80	7.50
BOD	Canal	36	4.6194	2.75617	.45936	3.6869	5.5520	1.20	8.60
	Dam	30	6.0967	1.02469	.18708	5.7140	6.4793	4.00	8.50
	River	30	5.9233	1.51537	.27667	5.3575	6.4892	3.00	8.80
	Total	96	5.4885	2.06952	.21122	5.0692	5.9079	1.20	8.80
Na+	Canal	36	2.5750	.47472	.07912	2.4144	2.7356	2.20	5.20
	Dam	30	4.9300	.61260	.11184	4.7013	5.1587	4.40	6.20
	River	30	4.8333	.55837	.10194	4.6248	5.0418	4.20	6.20
	Total	96	4.0167	1.24676	.12725	3.7641	4.2693	2.20	6.20
K+	Canal	36	3.8083	1.39045	.23174	3.3379	4.2788	3.20	11.70
	Dam	30	11.8800	1.10216	.20123	11.4684	12.2916	6.80	14.20
	River	30	6.6600	.31360	.05726	6.5429	6.7771	6.20	7.40
	Total	96	7.2219	3.53277	.36056	6.5061	7.9377	3.20	14.20
Temperature	Canal	36	27.0194	.46156	.07693	26.8633	27.1756	26.50	29.00
	Dam	30	27.1033	.33986	.06205	26.9764	27.2302	26.70	27.90
	River	30	26.9967	.36245	.06617	26.8613	27.1320	26.40	27.70
	Total	96	27.0385	.39480	.04029	26.9585	27.1185	26.40	29.00

Appendix E: One way ANOVA of the physico-chemical characteristics of irrigation water in the study area

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Ph	Between Groups	.632	2	.316	7.060	.001
	Within Groups	4.163	93	.045		
	Total	4.795	95			
EC	Between Groups	1008806.601	2	504403.300	100.551	.000
	Within Groups	466523.639	93	5016.383		
	Total	1475330.240	95			
TDS	Between Groups	218532.063	2	109266.031	119.016	.000
	Within Groups	85381.310	93	918.079		
	Total	303913.372	95			
Salinity	Between Groups	.007	2	.004	.986	.377
	Within Groups	.330	93	.004		
	Total	.337	95			
Turbidity	Between Groups	1330456.067	2	665228.033	51.324	.000
	Within Groups	1205409.987	93	12961.398		
	Total	2535866.053	95			
NO3_N	Between Groups	7700.199	2	3850.099	6788.196	.000
	Within Groups	52.747	93	.567		
	Total	7752.946	95			
NO2-N	Between Groups	1950.158	2	975.079	647.059	.000
	Within Groups	140.145	93	1.507		
	Total	2090.304	95			
PO_4^{3-}	Between Groups	9568.044	2	4784.022	10922.767	.000
	Within Groups	40.733	93	.438		
	Total	9608.776	95			
DO	Between Groups	6.939	2	3.469	.702	.498
	Within Groups	459.759	93	4.944		
	Total	466.698	95			

Appendix E continued

BOD	Between Groups	43.958	2	21.979	5.632	.005
	Within Groups	362.920	93	3.902		
	Total	406.877	95			
Na+	Between Groups	119.856	2	59.928	200.391	.000
	Within Groups	27.812	93	.299		
	Total	147.668	95			
K+	Between Groups	1079.897	2	539.948	474.859	.000
	Within Groups	105.747	93	1.137		
	Total	1185.644	95			
Tempe rature	Between Groups	.192	2	.096	.610	.546
	Within Groups	14.616	93	.157		
	Total	14.807	95			

Appendix F: Descriptive statistics of the bacteriological quality of irrigation water and tomatoes produce in the study area

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Heterotrophic bacterial count in irrigation water	Canal	36	2771027.7778	11154684.20629	1859114.03438	-1003174.3629	6545229.9185	30000.00	6.70E+007
	Dam	30	405147066.6667	1291105510.29522	235722537.36930	-76959654.0797	887253787.4131	122000.00	6.50E+009
	River	30	500136333.3333	1484953162.03502	271114114.56174	-54354290.1688	1054626956.8355	320000.00	8.00E+009
	Total	96	283940197.9167	1109682133.13671	113256458.45284	59097700.1197	508782695.7136	30000.00	8.00E+009

Appendix F continued

Heterotrophic bacterial count external part of tomatoes	Canal	36	1559391.6667	8307526.16165	1384587.69361	-1251470.7875	4370254.1208	3100.00	5.00E+007
	Dam	30	33033333.3333	26998356.69754	4929202.99294	22951981.2601	43114685.4066	1.70E+006	9.00E+007
	River	30	81110333.3333	161759938.14768	29533189.00804	20708179.7474	141512486.9193	630000.00	7.80E+008
	Total	96	36254667.7083	96593759.84673	9858559.33173	16682952.9019	55826382.5148	3100.00	7.80E+008
Heterotrophic bacterial count internal part of tomatoes	Canal	36	93988.8889	212967.72093	35494.62016	21930.9791	166046.7987	3300.00	900000.00
	Dam	30	1807266.6667	2748098.63967	501731.87173	781109.7702	2833423.5631	39000.00	1.22E+007
	River	30	6154100.0000	15592365.25896	2846763.39240	331815.1257	11976384.8743	41000.00	7.10E+007
	Total	96	2523172.9167	9115890.58333	930386.68668	676121.8133	4370224.0200	3300.00	7.10E+007
Total coliform count in external parts of tomatoes	Canal	36	307827.7778	933547.95136	155591.32523	-8039.4051	623694.9607	3000.00	5.60E+006
	Dam	30	7591000.0000	11428546.63883	2086557.59786	3323510.5508	11858489.4492	340000.00	4.80E+007
	River	30	18689333.3333	74121535.03739	13532678.91230	-8988102.7156	46366769.3822	128000.00	4.00E+008
	Total	96	8328039.5833	42139735.	4300868.7	-2102	16866343.5	3000.0	4.00E+008

Appendix F continued

				4782	4240	64.40	701	0	
Total coliform count in internal parts of tomatoes	Canal	36	111283.3333	180692.61745	30115.43624	50145.7475	172420.9192	3000.00	620000.00
	Dam	30	670066.6667	1270781.34893	232011.87015	195549.1125	1144584.2208	34000.00	6.40E+006
	River	30	1084166.6667	1989705.66327	363268.89152	341198.3617	1827134.9717	30000.00	9.00E+006
	Total	96	589929.1667	1370945.86472	139921.57640	312149.7167	867708.6166	3000.00	9.00E+006
Faecal coliform count in irrigation water	Canal	36	328483.3333	269502.15106	44917.02518	237296.9244	419669.7423	7900.00	920000.00
	Dam	30	6149033.3333	10428346.07339	1903946.79396	2255024.9133	10043041.7534	241000.00	6.00E+007
	River	30	12840033.3333	23459612.68970	4283119.68683	4080069.9890	21599996.6776	31000.00	8.00E+007
	Total	96	6057264.5833	15106104.02935	1541760.28639	2996483.4276	9118045.7390	7900.00	8.00E+007

Appendix F continued

Faecal coliform count in external parts of tamotoes	Canal	36	2913.8889	2684.78813	447.46469	2005.4873	3822.2905	.00	8300.00
	Dam	30	353583.3333	347755.23406	63491.12873	223729.3948	483437.2718	.00	940000.00
	River	30	447896.6667	1053942.52427	192422.69829	54348.0603	841445.2730	.00	4.30E+006
	Total	96	251555.2083	644121.44619	65740.36981	121044.0732	382066.3435	.00	4.30E+006

Faecal coliform count in internal part of tomatoes	Canal	33	184.5455	282.73321	49.21753	84.2926	284.7983	.00	900.00
	Dam	30	1692.0000	2645.22915	482.95056	704.2552	2679.7448	.00	9500.00
	River	30	2659.6667	2783.34887	508.16765	1620.3471	3698.9862	.00	8900.00
	Total	93	1469.2473	2397.02816	248.56024	975.5852	1962.9094	.00	9500.00

Appendix F continued

Total coliform in irrigation water	Canal	36	11184722.2222	14324431.57408	2387405.26235	6338031.8712	16031412.5733	320000.00	6.50E+007
	Dam	30	427506666.6667	1626669338.82859	296987830.15948	-179901646.9281	1034914980.2614	3.00E+006	9.00E+009
	River	30	1446366666.6667	3063969022.56932	559401649.71942	302261830.8027	2590471502.5307	1.90E+007	1.39E+010
	Total	96	589779687.5000	2010095603.89469	205154523.48973	182496463.8684	997062911.1316	320000.00	1.39E+010

Appendix G: One way analysis of variance (ANOVA) for the bacteriological quality of irrigation water and tomatoes produce in the study area

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Heterotrophic bacterial count in irrigation water	Between Groups	4688975900555734000.000	2	2344487950277867000.000	1.942	.149
	Within Groups	112293495576713500000.000	93	1207456941685091330.000		
	Total	116982471477269230000.000	95			
Heterotrophic bacterial count external part of tomatoes	Between Groups	104007670480389040.000	2	52003835240194520.000	6.182	.003
	Within Groups	782376001445760770.000	93	8412645176836137.000		
	Total	886383671926149760.000	95			
Heterotrophic bacterial count internal part of tomatoes	Between Groups	623318258767361.100	2	311659129383680.560	3.986	.022
	Within Groups	7271130548322223.000	93	78184199444324.980		
	Total	7894448807089584.000	95			
Total coliform count in external parts of tomatoes	Between Groups	5552645772250693.000	2	2776322886125346.500	1.583	.211
	Within Groups	163144298314878880.000	93	1754239766826654.500		
	Total	168696944087129568.000	95			

Appendix G continued

Total coliform count in internal parts of tomatoes	Between Groups	15768447775000.002	2	7884223887500.001	4.504	.014
	Within Groups	162783345803333.300	93	1750358557025.089		
	Total	178551793578333.300	95			
Faecal coliform count in irrigation water	Between Groups	2561912848556250.500	2	1280956424278125.200	6.232	.003
	Within Groups	19116553151263332.000	93	205554334959820.780		
	Total	21678465999819584.000	95			
Faecal coliform count in external parts of tamotoes	Between Groups	3694401403006.945	2	1847200701503.472	4.809	.010
	Within Groups	35720380154388.880	93	384090109186.977		
	Total	39414781557395.830	95			
Feacal coliform count in internal part of tomatoes	Between Groups	98466652.463	2	49233326.232	10.301	.000
	Within Groups	430141794.848	90	4779353.276		
	Total	528608447.312	92			
Total coliform in irrigation water	Between Groups	3485401040346007600.000	2	17427005201730038000.000	4.644	.012
	Within Groups	348992001592230600000.000	93	3752602167658393600.000		
	Total	383846011995690700000.000	95			

Appendix H: A picture of tomatoes samples in a ziplock bag